



# DAM SAFETY GUIDE

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# Dam safety guide

Kainuu Centre for Economic Development,  
Transport and the Environment

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# PREFACE

On 7.8.2007 the Ministry of Agriculture and Forestry appointed a committee with the task of laying the groundwork for revising the dam safety legislation in Finland. The task of the committee was to prepare a draft dam safety guide and to provide comment on a draft dam safety decree. The committee was also charged with presenting suggestions for the organisation of teams of dam safety experts and planners to be attached to the regional Centres for Economic Development, Transport and the Environment and also for maintaining and developing the requisite expertise for maintaining dam safety.

The Ministry of Agriculture and Forestry appointed Ministerial Adviser Leena Westerholm committee chair and Martti Kujanpää of the West Finland Regional Environment Centre vice-chair. The other members were Environment Counsellor Jukka Matinvesi of the Ministry of the Environment, senior legal administrator Elma Solonen of the Ministry of Agriculture and Forestry, design engineer Outi Pyy of the Finnish Environment Institute, development manager Jussi Pyyny of Association of the Finnish Energy Industries and Seppo Voutilainen of the Association of the Finnish Extractive Resources Industry. Juha Laasonen of Fortum Corporation and Risto Kuusiniemi of the Finnish Environment Institute were appointed permanent advisors to the committee. Timo Maijala of the Finnish Environment Institute and Kirsi-Marja Haanpää, coordinator from the Häme centre for Economic Development, Transport and the Environment served as secretaries for the committee.

The committee used, as their point of departure, a draft dam safety law from the final report (mmm 2007:3) of a previously appointed dam safety law review committee, and subsequent expert opinions. The committee also had at their disposal a proposal for updating dam safety guidelines, submitted by the Finnish Environment Institute. This guide has benefited substantially by the advice of hydrologists Bertel Vehviläinen and Noora Veijalainen of the Finnish Environment Institute on hydrological dimensioning, as well as the advice of design engineer Mikko Huokuna, also of the Finnish Environment Institute, on dam break hazard analysis.

The 2012 guide has been updated by Eija Isomäki, Milla Torkkel, Mikko Sulkakoski, Timo Regina and Timo Maijala of the Kainuu Centre for Economic Development, Transport and the Environment (ELY centre). The updated guide has added focus on waste dams and tailings dams in particular.

# 1 INTRODUCTION

The revised Dam Safety Act (494/2009) came into force on 1. October 2009 and the Government Decree on Dam Safety (319/2010) on 5.5.2010. These supersede the 1984 Dam Safety Act (413/1984) and Decree (574/1984). This dam safety guide replaces the Dam Safety Code of Practice (MMM:n julkaisu 7b/1977), removed from circulation on 1.10.2009. The dam safety guide is not binding on the dam owner; the purpose is to complement and elucidate the relevant law and decree through examples and descriptions. The dam owner is legally bound only by the responsibilities and obligations arising from the Act and the Decree.

General supervision, monitoring and development of activities subject to the Dam Safety Act falls within the purview of the Ministry of Agriculture and Forestry. The dam safety authority referred to in the Act is the Kainuu Centre for Economic Development, Transport and the Environment (ELY Centre) responsible for dam safety issues.

The legal reform has brought dam safety regulation up to date with the best working practises, developed in part without the support of legislative work. Former working practises were largely based on the Safety Code of Practice which was not, however, legally binding.

The purpose of the dam safety committee and other interested parties was to confirm the best practises by including the responsibilities and obligations of dam owners in the new Dam Safety Act. Included in the Act are provisions on design, construction, use, maintenance, monitoring, inspections, emergency preparedness and dam safety control.

The Dam Safety Act does not cover permits and building a dam is still subject to other legislation, particularly the Water Act, the Environmental Protection Act and the Land Use and Building Act. These Acts are complemented by the Dam Safety Act and the inclusion therein of dam safety aspects that must be addressed in the permit application process.

The new Act covers a wider area of application than the old Act. The three-metre limit is no longer applied and the obligations of the dam owner are graded according to the hazard posed by the dam, by placing dams in three classes. Classes 1, 2 and 3 correspond to the previous classes P, N and O. Classification is not necessary if the dam safety authority deems the dam safe. In contrast to the old Act, the new Dam Safety Act includes dams in connection with mining operations, and their dam safety monitoring function is transferred from the Finnish Safety and Chemicals Agency (Tukes) to the dam safety authorities. Tailings dams are usually embankments for tailings or dams in waterways in the mine area, used as a water supply. The dam may, according to definition, be permanent or temporary, and thus coffer dams and flood embankments are also covered by the Act. The Act does not apply to canal sluice structures, but may apply to embankment dam structures connected to sluice structures.

The dam owner has an obligation to prepare a dam break hazard analysis outlining the hazards posed by the dam to people, property and the environment. The dam safety authority may decide that a dam break hazard analysis must also be prepared for a dam other than a class 1 dam if this is necessary for the classification of the dam or for the assessment of the need to change the class. The owner of dam must prepare and regularly update a plan of measures in case of accidents and disturbances concerning a class 1 dam (emergency action plan of a dam). The action plan constitutes the dam owner's own emergency preparedness. The emergency authorities will assess the need for an emergency action plan on a case-to-case basis, partly depending on the reports submitted as set out in the Dam Safety Act and partly depending on the statements issued by the dam safety authorities.

The owner of a dam must prepare a programme concerning a classified dam on the monitoring of factors which may impact on dam safety when the dam is brought into operation and during operation (monitoring programme). A specific monitoring programme is, however, not needed if similar factors are being monitored under other law in a way that is approved by the dam safety authority. The owner of the dam shall inspect the condition and safety of a class 1 and 2 dam at least once a year and submit a report in writing on the annual inspection of a class 1 dam to the dam safety authority. The owner of a dam must organise a periodic inspection of class 1, 2 and 3 dams at least every five years and, where necessary, more frequently, where the dam safety authority and rescue authority have the right to take part. The owner of a dam must submit a written report (courtesy copy) on the inspection of a class 1 or 2 dam to the dam safety authority.

The owner of a dam must provide the dam safety authority with the owner's contact information and the contact information of the staff operating the dam, as well as the technical information concerning the dam ordered by Government Decree, for entering into the information system. The dam safety authority and the owner of the dam must keep up-to-date printouts from the data system for each dam as well as other important documents relevant to dam safety, in order to ensure that these are readily available in case of disturbance (dam safety file).



## 2 APPLICATION OF DAM SAFETY LEGISLATION

### 2.1 Acts and decrees

This guide is based on the Dam Safety Act 494/2009 (DSA) and Government Decree on Dam Safety 319/2010 (DDS). Unofficial translations of the Act and the Decree are available on the Internet:

- Dam Safety Act: <http://www.finlex.fi/fi/laki/ajantasa/2009/20090494> (in Finnish) and the unofficial translation: <http://www.finlex.fi/fi/laki/kaannokset/2009/en20090494.pdf>
- Government Decree on Dam Safety: <http://www.finlex.fi/fi/laki/alkup/2010/20100319> (in Finnish) and the unofficial translation: <http://www.finlex.fi/fi/laki/kaannokset/2010/en20100319.pdf>

This guide also contains references to the following acts and decrees:

- Administrative Judicial Procedure Act (586/1996)
- Waste Act (646/2011)
- Mining Act (621/2011)
- Act on the Openness of Government Activities (621/1999), Decree on the Openness of Government Activities and on Good Practice in Information Management (1030/1999)
- Act on Compensation for Environmental Damage (737/1994)
- Land Use and Building Act (132/1999)
- Rescue Act (379/2011), Decree on Rescue Services (407/2011) and the Decree on External Emergency Plans for Sites Posing a Particular Hazard (612/2015)
- Tort Liability Act (412/1974)
- Decree on Waste from the Extractive Industries (190/2013)
- Water Act (587/2011), Decree on Water Resource Management (1560/2011)
- Environment Protection Act (527/2014), Decree on Environment Protection (713/2014).

### 2.2 Scope of application and dam classification



#### DSA Section 2 – *Scope of application*

- (1) This Act applies to dams and the structures and equipment which belong to these independent of the material of which the dam is constructed or how the dam has been constructed or the substance impounded by the dam.
- (2) The provisions concerning a dam laid down in this Act also apply to flood embankments.
- (3) This Act does not apply to sluice gate structures of canals.

#### DSA 4 § – *Definitions*

(1) In this Act:

- 1) *dam* means a structure such as a wall or embankment the purpose of which it is to permanently or temporarily prevent the spread of a liquid or substance that behaves like a liquid impounded by the dam or to regulate the surface level of the impounded substance;
- 2) *watercourse dam* means a dam in a watercourse;
- 3) *waste dam* means a dam for impounding substances that are harmful or hazardous to health or the environment;
- 4) *flood embankment* means a structure the purpose of which is to prevent the spread of water at times when the water level of a watercourse or sea level is unusually high;

Dams are watercourse dams and waste dams for impounding substances that are harmful or hazardous to health or the environment. Tailings dams are waste ponds (dams) or watercourse dams on the surface area of a mine.

The dam safety act also applies to dam structures that impound a liquid only temporarily. These may be, for instance, flood embankments that are permanent, but impound water only when the water level is unusually high or coffer dams that are designed to temporary.

The general term “dam” is used in this guide to denote all the structural parts of the same reservoir as well as operating structures and embankments. The Dam Safety Act does not apply to mines and dam structures in subterranean tunnels, where the provisions of the Mining Act (621/2011) apply.

## 2.3 Authorities and law enforcement



### DSA Section 5 – *Authorities*

- (1) The Ministry of Agriculture and Forestry is responsible for the general steering, follow-up and development of activities under this Act.
- (2) The Centre for Economic Development, Transport and the Environment which is competent in dam safety matters functions as the dam safety authority referred to in this Act.
- (3) The Ministry of Agriculture and Forestry may order that a Centre for Economic Development, Transport and the Environment functions as the dam safety authority within the territory of another Centre for Economic Development, Transport and the Environment.

The Ministry of Agriculture and Forestry has ordered the Kainuu ELY centre to act as dam safety authority for the country as a whole.

Emergency planning for dam accidents and rescue operations in the event of an accident are the responsibility of the rescue authorities (Rescue Act, 379/2011).

## 2.4 Obligations of the dam owner



### DSA Section 4 – *Definitions*

(1) In this Act:

- 5) *owner of a dam* means the owner or manager of the dam or one whose task it is to see to the design, construction, operation and maintenance of the dam.

This chapter is a general overview of some of the dam owner’s obligations – described in greater detail in the Dam Safety Act and Decree as well as in various chapters of this guide.

A dam owner is a person or legal entity registered with the dam safety authority as the party responsible for the dam. When a dam changes owner, the party who gives up ownership must deliver the dam safety file to the new owner and notify the dam safety authority of the change of ownership (DSA Section 33).

A dam owner has a general obligation to design and construct a dam in such a way that its use does not constitute any safety hazard (DSA Section 7). This obligation includes repair work and alterations to the dam (DSA Section 22).

The owner has an obligation to keep the dam in such condition that it functions as intended and is safe (DSA Section 15). A dam shall be operated in such a way that it does not threaten human life or health (DSA Section 16).

The owner must undertake a periodic inspection of the dam at least every 5 years (Section 19) and also to organise the monitoring of the dam according to the monitoring programme (Section 17). The dam owner is liable for damage caused by a dam break as provided in the Tort Liability Act (412/1974), the Water Act (587/2011) and the Act on Compensation for Environmental Damage (737/1994). The dam safety authority’s brief to supervise dam safety does not remove or diminish the obligations of the dam owner. Section 35 of the Dam Safety Act includes provisions for dam safety offences that carry a fine.

The dam owner has an obligation to provide the dam safety authority with copies of the dam safety documents (DSA Section 14) and the contact information of the owner and the operating staff as well as technical information as required by government decree (Section 33).

The dam owner shall keep the aforementioned information up-to-date. Dams are classified according to the danger they cause in the event of an accident (DSA Section 11) and the documentation required depends on the dam class. Chapter 4 of this guide provides a more detailed look at dam classification and documentation.

The owner of a dam must take such action as is necessary to prevent a dam accident and to limit the damage caused by an accident. (DSA Section 24). The Rescue Act (379/2011), section 3, requires anyone who observes or receives information about an emergency that is either occurring or about to occur, to notify those endangered, make an emergency call and take rescue action without delay to the best of their abilities. The dam owner shall immediately inform the dam safety authority of any emergency call concerning a dam (DSA Section 27). The owner of the dam shall also immediately inform the dam safety authority of any exceptional situation as regards dam safety which has occurred at the dam other than those referred to in the DSA, section 27. The dam safety authorities should be informed of the circumstances and development of the situation and given the necessary accounts of dam safety control measures.

If the owner is unable to manage the safety or the monitoring obligations of the dam, or the dam threatens to pose a safety hazard, the dam owner is obliged to notify the dam safety authorities immediately. Such notice does not remove the obligations of the dam owner to manage the safety of the dam.

The owner of a dam shall acquaint himself with the regulations concerning the dam and, on his own initiative, ensure that they are observed. The dam safety authorities provide assistance in matters concerning the interpretation of the provisions and guidelines and inform the owners about relevant provisions, regulations and guidelines, which does not, however, diminish the obligation of the dam owner to keep himself informed about issues pertinent to dam legislation.

## 2.5 Competence requirements



### DSA Section 6 – *Competence requirements*

- (1) A person who prepares the plan concerning the construction of a dam and a person who is responsible for the operation, monitoring and inspections of the dam must possess sufficient expertise in dam safety matters, taking account of the type of the dam and the hazard it may cause. Further provisions on the competence requirements are issued by Government Decree.

### DDS Section 1 – *Competence requirements*

- (1) A person who designs a dam must have appropriate education and possess sufficient expertise and experience in the design of similar structures.
- (2) The staff responsible for the operation of the dam must possess sufficient knowledge and expertise on the circumstances which impact on dam safety, operation of the dam and related safety systems.

The person that designs a dam must have sufficient expertise in matters of dam safety (DSA Section 6) as well as the appropriate training and experience from comparable design projects. Ideally, the person who drafts the monitoring programme shall have the same competence as the dam designer. Appendix 11 gives details on the competence requirements for the designer of an embankment dam and appendix 12 the requirements for a concrete dam designer.

A person who is responsible for the operation, monitoring and inspections of the dam must possess sufficient expertise in dam safety matters (DSA Section 6). The staff responsible for the operation of the dam must possess sufficient knowledge of the circumstances that impact on dam safety, on operating the dam and related safety systems (DDS Section 1 (2)). The required expertise of operating personnel is reached through guidance and training. Monitoring frequency depends on the dam. Monitoring can be continuous, weekly or take place at for example 3-month intervals. A dam is first inspected while under construction and when it is taken into use. When the dam is operational, it is inspected annually and periodically.

A preliminary assessment of the condition of the dam, by an expert who meets the competence requirements set out in section 6 of the Dam Safety Act, shall be submitted to the dam safety authority before the inspection (DSA Section 19 (2)). The same competence requirements apply to those who complete periodic inspections and conditions assessments as set out in DSA section 19(3).

# 3 DAM DESIGN AND CONSTRUCTION

## 3.1 Design requirements

### 3.1.1 General

#### §

##### DSA Section 7 – *General obligation*

- (1) A dam must be designed and constructed so that its use does not cause any danger to safety.
- (2) Further provisions on the hydrological dimensioning and technical safety requirements for the construction of a dam are issued by Government Decree.

##### DSA Section 8 – *Planning and design of a dam*

- (1) The plan and design prepared for constructing a dam must show how the dam safety requirements under this Act have been taken into account.

The dam owner can benefit from calling on the dam safety authority in the early stages of planning and thus make certain that dam safety issues are properly accounted for. The person responsible for designing a dam must have sufficient expertise in matters of dam safety (DSA Section 6 and item 2.5, above). The dam owner shall submit the construction plans for the dam to the dam safety authority.

Tailings dam under construction in Luikonlahti, Kaavi, 2011 (Timo Regina)



Where a project is relatively significant, a responsible chief designer is appointed. The designer of an embankment dam or concrete dam may be also appointed chief designer. The chief designer is responsible for the various sub-areas such as hydrological dimensioning, the design of embankment and concrete dams, the design of regulation and discharge structures, and the compatibility of the designs. In addition to the structures proper, the plan shall contain the dam safety monitoring devices installed in the course of dam construction. The functional assessment of a dam is made to the extent required by conditions. The items to be assessed under different conditions are the function of the dam and channels and the magnitude and duration of a possible over-impoundment. The different conditions are the usual operational conditions in summer and in winter, floods such as design floods and situations arising from operating disruptions and errors.

The Dam Safety Act (sections 2-5) provides for the technical safety requirements concerning hydrological dimensioning and dam structures. The requirements are presented in greater detail in items 3.1.2 and 3.1.3 and in appendices 10-13. Flood embankments are described in item 3.1.4.

### 3.1.2 Hydrological dimensioning



#### DSA Section 7 – *General obligation*

- (2) Further provisions on the hydrological dimensioning --- are issued by Government Decree.

#### DDS Section 2 – *Hydrological dimensioning of a watercourse dam*

- (1) A watercourse dam is designed for a water flow which causes the maximum need for discharge. The dimensioning is presented as the annual probability or frequency of flooding which corresponds to such a water flow (*design flood*).
- (2) The design flood of a watercourse dam is based on a flood which occurs:
- 1) in case of class 1 dam, with a probability of 0.02 – 0.01 per cent, that is, once in 5 000 – 10 000 years on average;
  - 2) in case of class 2 dam, with a probability of 0.2 – 0.1 per cent, that is, once in 500 – 1 000 years on average;
  - 3) in case of class 3 dam with a probability of 1 – 0.2 per cent, that is, once in 100 – 500 years on average.
- (3) A watercourse dam is designed so that during a design flood the water level in the dam basin does not rise above the safe water level when the discharge capacity of the dam excluding the flow through the turbines of the hydropower plant is in operation.

#### DDS Section 3 – *Hydrological dimensioning of other dams*

- (1) The hydrological dimensioning for watercourse dams is used, as applicable, for the hydrological dimensioning of other dams.
- (2) The hydrological dimensioning of a flood embankment is specified according to the need for flood protection.

A watercourse dam is designed for the water flow that causes the maximum need for discharge. The dimensioning is presented as the annual probability or frequency of flooding which corresponds to this water flow (design flood) (DDS Section 2). When the upstream lakes do not constitute a significant reservoir capacity for the dam, the design flood equals the maximum inflow at the dam. The design flood is generally not the maximum inflow, which is usually the spring flood, but where a significant reservoir capacity is available. The greatest discharge requirement and the design flood usually occur in summer or autumn, when the dam reservoir and the regulated lakes upstream of the dam are filled and there is little available reservoir capacity (Veijalainen & Vehviläinen 2008).

The design flood of a watercourse dam is calculated using a frequency analysis on the basis of flow observations or using a hydrological model. Both methods are presented in detail in appendix 10. The DDS, section 2, decrees that a watercourse dam is dimensioned according to the water level in the dam reservoir during a design flood, so that it does not rise above the safe water level when the discharge capacity of the dam, excluding the flow through the turbines of the hydropower plant, is in use. The gate and sill discharge rating curves and coefficients must be calculated.

The maximum safe water level of a dam, which may not be exceeded in a design flood, is the emergency high water (emergency HW). Emergency high water level is the water level which, when exceeded, may cause changes in dam structures. The emergency high water level for an embankment dam, for instance, is usually the elevation of the top of the dam core. The dam safety forms must show the emergency high water level and the methods used to determine that level must be described.

The hydrological parameters are described on the forms in appendices 6 and 6a. When determining the numerical values of the parameters, the instructions of appendix 10 should be followed to the extent they are appropriate. In addition to the time series analysis, dimensioning methods based on model calculation (appendix 10) and estimating the probable maximum flood can be used. Model calculation is often the recommended way of assessing the advance of a design flood for extensive and regulated waterbodies. Even in these cases, however, a design flood value derived from its return period corresponding to the dam class, and the method of calculation, shall always be given.

The hydrological dimensioning of waste dams and tailings ponds is designed as part of the water balance. As a rule, no external run-off water enters the reservoirs, and the design flood therefore equals direct precipitation and meltwater in the pond area, in addition to process fluids. The hydrological dimensioning must therefore take into account a storage capacity that includes emergency requirements. It is particularly important to note this in cases where the environment permit limits the discharge volumes. The design flood frequency applied to dams in a watercourse are also applied to waste dams and tailings ponds, and the discharge dimensioning is based on this.

The design flood and design water level of a flood embankment, i.e. the level the embankment is designed to keep impounded, is chosen according to the desired level of flood protection.

### 3.1.3 Technical safety requirements



#### DSA Section 7 – *General obligation*

- (2) Further provisions on the hydrological dimensioning and technical safety requirements for the construction of a dam are issued by Government Decree.

#### DDS Section 4 – *General technical safety requirements of a dam*

- (1) The stability of the structure of a dam and the functioning and dimensions of the structural components must be sufficient to ensure the safety of the dam in all situations of operation.
- (2) The discharge gates and other operating equipment of a dam must be functionally reliable. An emergency hoisting system or plan must be in place for the operation of the discharge gates of a dam.
- (3) There must be effective transport connections to the dam. The possibility for dam maintenance also in case of flood and dam accidents must be planned and ensured, where necessary. There may be no vegetation or other substances or objects which do not belong to the dam and which may cause damage to the structure of the dam or harm to the maintenance or monitoring of the dam.
- (4) The owner of the dam must provide the dam safety authority with the plans of the dam which show how the technical safety requirements of the dam are implemented and how the raising of the water or other impounded substance takes place when the dam is brought into operation. The owner of the dam must organise the opportunity for the dam safety authority to verify the fulfilment of the technical safety requirements in different stages of the dam construction work.

#### DDS Section 5 – *Specific technical safety requirements for class 1 and 2 dams*

- (1) In addition to the provisions in section 4, the height of a class 1 and 2 dam must be sufficient to ensure the safety of the dam in all situations of operation.
- (2) The crest of an embankment dam of class 1 and 2 must be passable to traffic throughout its length.
- (3) The provisions of this section do not apply to flood embankments.

Appendices 11 and 12 present the structural integrity and the functioning of the structural parts of embankment and concrete dams. Appendices 11-13 concerns technical safety requirements, a summary of which is presented below. Cofferdams are temporary structures and may be regarded as such, without, however, neglecting dam safety. The characteristics of flood embankments are described in item 3.1.4.



Tailings dam raised using tailings sand, 2012 (Timo Regina)

### **Freeboard**

The DDS, section 5 (1), states that the height of a class 1 and 2 dam must be sufficient to ensure the safety of the dam in all situations of operation. The freeboard of an embankment dam is defined as the difference in height between the dam crest and the HW level. At tailings dams the HW level is defined as the highest level of free water. The freeboard is derived from the maximum wave height at HW or the depth of frost penetration, based on design cold content. As a rule, the depth of frost penetration is the deciding factor. The freeboard of a class 1 and 2 dam should equal the frost depth that occurs at least once in ten years. The freeboard may be reduced by insulating the dam structure against frost and by other design solutions. The freeboard should then be at least 1,75 times the height of the maximum wave. For class 3 dams the freeboard is determined by the maximum depth of frost penetration occurring once in five years.

A concrete dam should have a freeboard at least 1,75 times the height of the maximum wave.

### **Safety margin**

The safety margin of class 1 and 2 dams (difference between the top of the core and the HW level) should be no less than 0,4 m, and for class 3 dams 0,3 m.

### **Dam crest**

The dam crest should have sufficient width over its entire length and a structure suitable for maintenance traffic. For a class 1 earth fill dam a crest width of 4 m or more is considered sufficient. The width must be increased by 0,5 m if the height of an earth fill dam exceeds 10 m, and by a further 0,5 m for each successive 10 m. Crest dimensions for a class 2 dam are the same as for a class 1 dam with the exception of earth fill dams under 4 m in height, where the crest width is dimensioned on a case by case basis. The crest of class 3 earth fill dams should be no less than 3 m wide.

### **Access and traffic on the crest of the dam**

Access roads to any dam must be available and unimpeded. The dam design must allow maintenance access, including access in the event of flood or dam accident, in such a way, that the dam can be operated and maintenance work proceed (DDS Section 4 (3)). Earth fill dams should have an access road to the background area or other arrangements ensuring dam maintenance access, including access in the event of flood or dam accident. Recommendations for class 1 and 2 dams include access roads having at least two connections with public roads.

The crest of an embankment dam of class 1 and 2 must be passable to traffic throughout its length (DDS Section 5 (2)). The aforementioned does not apply to flood embankments (DDS Section 5 (3)).

### **Vegetation, substances and objects that are not part of the dam structure**

Vegetation and other substances and objects that are not part of the dam and which may cause damage to the structure of the dam or impede maintenance or monitoring of the dam, are not allowed (DDS Section 4 (3)).

### **Wet slope facing on an earth fill dam**

The size of boulders in wet slope facing and the thickness of the facing of an earth fill dam are determined from the maximum wave height and the effects of ice loads. The facing begins at the foot of the wet slope and extends above the HW-level. If necessary, the wave height is taken into account. Any water body on the downstream side of the dam may require the application of facing.

### **Filtering structures and drainage system of a dam**

The filtering structures and the drainage system should be so dimensioned that they are capable, in all circumstances, of protecting the core against erosion and of discharging the waters seeping through, under or around the dam and to smooth any peaks in flow gradients.

### **Spillway gates**

A spillway gate malfunction, because of a power cut or for another reason, may cause the dammed water level to rise and consequently increase the risk of a dam break. The gates should be equipped with an emergency hoisting system to allow opening within the time margin, i.e. before the situation becomes dangerous. The system must incorporate an alarm signal activated by the rising water level. The emergency hoisting system may be replaced by an emergency hoisting plan (DDS Section 4, (2)), if the plan can be implemented within the time margin (appendix 13).

Imatrankoski regulating dam, 2010 (Milla Torkkel)





### 3.1.4 Characteristics of flood embankments



#### DSA Section 4 – *Definitions*

(1) In this Act:

4) *flood embankment* means a structure the purpose of which is to prevent the spread of water at times when the water level of a watercourse or sea level is unusually high;

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#### DDS Section 3 – *Hydrological dimensioning of other dams*

(2) The hydrological dimensioning of a flood embankment is specified according to the need for flood protection.

Seaside flood embankments are not dealt with separately in this context. Their structure and design are, however, subject to the same principles as flood embankments in waterways. Temporary structures, dismantled after a flood, are also excluded from this guide. They are designed and erected individually, for specific situations.

A permanent flood embankment is designed like a comparable dam, with due consideration for the competence requirements set out in DSA Section 6. A special characteristic is the short duration of the dimensioning impoundment. A time of impoundment cannot be estimated any more accurately than floods in general. The hydrological dimensioning of flood embankments is derived from the desired level of flood protection.

The general technical safety requirements of a dam set out in DDS Section 4 also apply to flood embankments. The dam height and crest traffic load requirements of DDS Section 5 do not, however, apply to flood embankments. The temporary nature of the flood embankment frequently means that the conventional, internal drying system and filtering structures can be dispensed with, and also, that standard dimensioning criteria for wet slope, crest and freeboard are not applied. The technical design of a flood embankment should, however, be specifically considered and justified in each individual case.

Flood embankments are frequently constructed from locally available materials. A flood embankment may be used during the spring thaw, when the structure is usually most loose.

Flood embankment design and use should be planned in keeping with the relevant dam safety aspects. In other words, the embankments must be safe even when the water level exceeds the highest design water level. Plans should be in place for channelling water in situations where the embankment is insufficient to hold a flood. The guiding principle is that the total damage should be minimised. It makes sense, for instance, to channel the water onto local fields, if a built-up area is thereby spared the flood. The controlled discharge is managed using a floodgate, a sill or by opening the embankment in a planned manner.

### 3.2 Accounting of dam safety issues in permit applications



#### DSA Section 9 – *Dam safety studies in the case of permit*

- (1) In a permit application concerning the construction of a dam under another Act the owner of the dam must describe sufficiently the dam hazard and its impact on the dam dimensioning and design criteria.
- (2) When resolving a matter referred to in section 3(6) concerning the construction of a dam the authority shall request a statement from the dam safety authority concerning the fulfilment of the dam safety requirements laid down in this Act.
- (3) In the statement the dam safety authority shall, where necessary, present an estimation of the design criteria from the dam safety perspective.

In this context, a description is a description of the dam hazard; the actual dam break hazard analysis is presented in item 5.1 of this guide.

In the permit application, the dam plan is presented as a general brief. The dam owner shall submit the following information with the permit application

- a description of the dam hazard with a proposal for dam classification
- the main dimensions of the dam and the reservoir area
- hydrological dimensioning or water balance at tailings ponds.

The description of the dam hazard is intended to provide grounds for the dam classification proposal. The description shall account for objects of damage in the risk zone as set out in item 5.1.4. Waste and tailings dams also require a sufficiently detailed description of environmental consequences as set out in item 5.1.5. If the dam hazard description (DSA Section 9, (1)) does not provide sufficient data to classify the dam, the dam safety authority may order the dam owner to add particulars to the description, for instance, to produce a dam break hazard analysis based on a terrain model, including coverage of a flood caused by dam failure (DSA Section 12, (1) and 2, DDS Section 6).

The main dimensions of the dam and the reservoir area shall be presented as set out in the appended sample forms (app. 4a, 4b and 5). Hydrological dimensioning is amplified in item 3.1.2.

### 3.3 Dam construction, alterations and repair work



#### DSA Section 7 – *General obligation*

- (1) A dam must be designed and constructed so that its use does not cause any danger to safety.

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#### DSA Section 22 – *Alteration and repair works*

- (1) In addition to the provisions on the repair and alteration works of a dam laid down in other law, the provisions of Chapter 2 on the planning, design and construction of a dam and Chapter 3 on the classification and dam safety documents apply, as appropriate, to alteration and repair works which significantly impact on the structures of the dam or are otherwise significant as regards dam safety. Such alteration and repair works must be notified to the dam safety authority before they are implemented.

A dam must be built in keeping with good building practise. Construction shall proceed as required by the plan and with experienced and competent personnel. The quality control of construction work shall be independent of the building contractor and the person responsible for supervising the work shall have the right to suspend work if necessary. Construction and quality control of earth fill dams and concrete dams are presented in appendices 11 and 12. The dam safety authorities should be informed of the commencement of dam construction at an early date in order to ensure that all dam safety aspects are considered in time.

Any impact on dam safety arising from modifications or repair work to the dam shall be taken into account when assessing alternatives at the design and construction stages.

Should the changes affect dam safety, the changes shall be reviewed as required when commissioning a new dam 5 (item 3.4). If it is necessary to revise the monitoring programme, the same procedure shall be followed as when drafting a new monitoring programme.

Changes affecting dam safety may include:

- new structures on a dam such as new openings, overflow sills, underpasses or ducts or increased dam height
- renovation or renewal of and modifications to an embankment or concrete dam or a hydroelectric power plant structure acting as a dam
- changes in the use and control of the operating facilities and the structural changes thereby required
- changes in conditions affecting dimensioning such as those affecting high water level and maximum discharge
- changes in conditions upstream or downstream of the dam affecting the classification (e.g. a class 2 dam is reclassified as a class 1 dam)
- at a waste dam, changes in the type of impounded substance or new information concerning its harmfulness affecting the classification.

Repaired flood embankment, Pori, 2010 (Milla Torkkel)



### 3.4. Commissioning the dam and site inspections



#### DSA 7 – *General obligation*

(2) Further provisions on the hydrological dimensioning and technical safety requirements for the construction of a dam are issued by Government Decree.

#### DDS Section 4 – *General technical safety requirements of a dam*

(4) The owner of the dam must provide the dam safety authority with the plans of the dam which show how the technical safety requirements of the dam are implemented and how the raising of the water or other impounded substance takes place when the dam is brought into operation. The owner of the dam must organise the opportunity for the dam safety authority to verify the fulfilment of the technical safety requirements in different stages of the dam construction work.

For the purposes of this guide, the date of commissioning a dam is the day raising the water or other impounded substance has begun. A temporary dam is commissioned when removing the water or other impounded substance is begun from the dammed area. As a rule, several field inspections are undertaken during construction, for instance reviews of structures and foundations conducted during different stages of the work. In every case a field inspection must be made before raising the impounded substance commences (commissioning inspection). A commissioning inspection must be undertaken on an old dam when significant alterations or repair work is scheduled (item 3.3). The dam safety authority takes part in the field inspections as necessary, but is not responsible for inspections or organising them. The responsibility for undertaking inspections lies with the dam owner and the associated experts.

The owner of the dam must provide a commissioning plan which shows the commissioning timetable, the associated monitoring measures and official inspections and how the raising of the water or other impounded substance takes place when the dam is brought into operation.

Waste- and tailings dams can be brought into use in stages during the operational life of the dam, the stages to be defined in the commissioning plan that is submitted to the dam safety authority. The dam owner is obliged to provide the dam safety authority with the opportunity to verify fulfilment of the safety requirements in the various stages of construction, including inspections during the operational life of the dam, when the level of the dam and the impounded substance is raised.

Before the dam is brought into use, the owner must make certain that the technical requirements are met (DDS Section 4-5, item 3.1.3) and that other dam safety factors are taken into account as required. The recommendations presented in appendices 10 to 13 can be used as a basis for the assessment. The field inspection is the responsibility of the chief dam designer (3.1.1) or another competent person. The field inspection is based on the design and quality control reports of the dam.

The decision process for dam classification and documentation is presented in item 4.4.

The commissioning procedure is completed when all the structures are operationally ready, have been brought into full-scale use and their functioning as planned is verified. At the closing of the commissioning inspection the records of the field inspections and the completion documents are collected, whereupon a summary is written and included in the dam safety file.

The procedures for dam construction and repair, including the responsibilities of different parties, is presented in fig. 1.

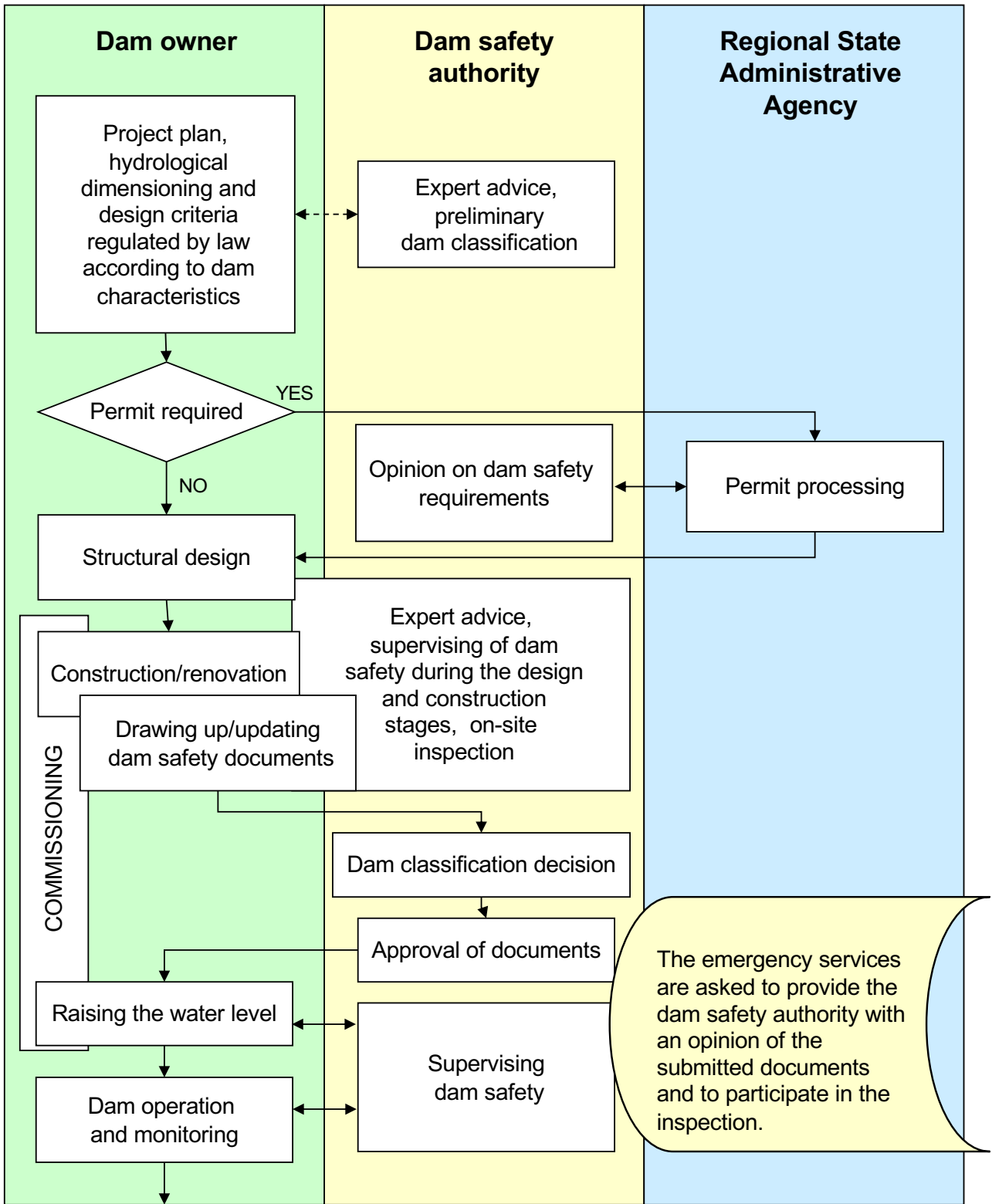


Fig. 1 Dam construction or major renovation.

# 4 CLASSIFICATION OF A DAM AND DAM SAFETY DOCUMENTS

## 4.1 Dam classes and classification criteria



DSA Section 11 – *Classification of a dam*

- (1) Based on the hazard the dam is placed in one of the following classes:
  - 1) Class 1 dam, which in the event of an accident causes danger to human life and health or considerable danger to the environment or property;
  - 2) Class 2 dam, which in the event of an accident may cause danger to health or greater than minor danger to the environment or property;
  - 3) Class 3 dam, which in the event of an accident may cause only a minor danger.
- (2) Classification need not be made if the dam safety authority considers that the dam does not cause any danger. However, the provisions of section 15 on the maintenance of a dam, section 16 on the operation of a dam, section 24 on preventing accidents and Chapter 6 on the control of these provisions apply to such a dam.

The dam safety authority classifies dams by the type of hazard they pose. The classes are 1, 2 and 3. The classification is not necessary, however, if, according to the dam safety authority, the dam poses no danger. The dam classification referred to in the Dam Safety Act applies to waterbody dams, waste dams, tailings dams and flood embankments. The classification also applies to temporary dams, such as cofferdams.

Classification is based on the damage that may be caused downstream from a flood wave caused by dam failure and also on the hazard posed by a sudden drop in the water level upstream from the dam. When classifying a waste dam, the authorities also take into consideration the nature and quantity of the impounded substance, land use in the area as well as the potential short- and long-term harm to water reserves and the environment that may arise from releasing the substance.

As the classification affects the properties required of the dam (item 3.1, appendices 10-13), the class must be established at the planning stage.

Classification criteria are expanded below.

### **Class 1 dam**

A class 1 dam is a dam which in the event of an accident causes danger to human life and health or considerable danger to the environment or to property.

A danger to human life and health arises, for instance, where there is permanent or recreational habitation downstream of the dam in an area where a flood wave caused by a dam break may destroy even one such building. The legal definition means the loss of a single human life or serious injury of a single person. Human life and health are also at risk if people in public buildings, schools, hospitals, shops and other public places are in a flood wave danger zone. In the case of waste dams, human life and health may be at risk not only from the flood wave, but because of the nature of the released waste.

When weighing environmental concerns, a dam is classified as a class 1 dam if, in the event of an accident, the flood wave or substance released from a waste dam or tailings dam, causes significant loss of natural amenity, for instance loss of a protected area or a rare species or if an important source of water or a ground water reservoir is in danger of being polluted. In the case of waste dams, the impounded waste may be hazardous or it may cause significant and lasting harm to the environment.

When weighing economic concerns, a dam is classified as a class 1 dam if, in the event of an accident, the downstream loss of property is substantial. Property losses may constitute residential or public buildings or objects that are important to the community, such as water and power plants, sewage plants or communications centres, production plants or roads, railways or bridges that are flooded.

A class 1 dam classification is always confirmed on the basis of a hazard assessment, the drafting of which is presented in detail in chapter 5.

Large hydroelectric dams in rivers and large reservoir dams are generally classified as class 1 dams. Dams that impound less significant water volumes can also be classified as class 1 dams if the downstream area is densely built-up.

Flood embankments that protect residential areas can be classified as class 1 dams, if, in the event of a flood, the dam breaks, causing a hazard which is characteristic of class 1. As a rule, dams are also included in class 1 when they pose a hazard as set out in the Environmental Protection Act (527/2014) or when a tailings pond poses a disaster risk as defined in the Decree on Waste from the Extractive Industries (190/2013).

### **Class 2 dam**

The definition of a class 2 dam is clarified by the definitions of class 1 and 3 dams. A class 2 dam may constitute a danger to health but not danger to human life. A class 2 dam may constitute a greater than minor danger, but not a substantial danger dam, such as a class 1 dam would pose.

In the event of a break in a class 2 dam, the height of the flood wave may damage residential buildings. The water may not, however, rise to a level that constitutes a risk that people are swept along with the wave.

Waste dams and mine dams are placed in class 2, when, in the event of a dam break, they pose a greater than insubstantial hazard to the long term quality of, for instance a waterbody used for recreation or fishing or to an extensive agricultural area with long term quality consequences and utility restrictions or to household wells.

As a rule, the dam structures of hydroelectric plants on rivers and regulating dams associated with fairly large waterbodies are placed in class 2.

Waste dams are placed in class 2 when used to separate the oxygenation ponds of industrial waste treatment plants from a waterbody and, generally, when used as tailings ponds and settling basins. A range of other process ponds and slurry ponds are also included in class 2.

### **Class 3 dam**

A dam can be considered to constitute only a minor danger if, in the event of an accident, it quite manifestly cannot endanger human life or health or, minor damage excluded, the environment or downstream property.

As a rule, class 3 dams may not, in the event of an accident, cause damage to residential buildings downstream. Substances in class 3 waste dams are of a quality and volume that, in the event of a dam break, have no more than a temporary effect on the downstream water system. The dam may not pose any danger of spoiling ground water resources.

Class 3 dams in waterbodies are usually natural feed ponds and other small ponds with a dam structure taller than 3 metres. Where a hydroelectric dam is put in class 3, it is usually a small dam, frequently one associated with an old mill or sawmill. As a rule, the water regulation dams of smaller waterbodies are also included in class 3.

Class 3 waste dams include, for instance, waste dump seepage ponds, farm slurry ponds in the vicinity of waterbodies, various industrial regulating ponds or emergency pond dams that are used only in emergencies and then constantly monitored as long as they are used.

### **Unclassified dam**

As a general rule, the boundary between a class 3 dam and an unclassified dam is three metres. In this guide the term dam height is defined as the difference in height between the upper level of the impounded substance and the ground level outside the dam. The cross sections in appendix 9 show various ways to define dam height. If a dam poses even a marginal hazard, the dam safety authority may order a classification for it. Conversely, the dam safety authority may find that a dam higher than three metres does not pose a hazard, and decide to leave it unclassified.

Dams may be designated unclassified, if the location is remote or the impounded volume is so insignificant, that a flood wave caused by a dam break would not threaten even the downstream buildings.

A situation is not defined as a hazard where, on land owned by someone other than the dam owner, the water level rises momentarily to the level of a natural flood in the downstream area, but remains more or less in the watercourse. As a rule, unclassified dams have a reservoir with a minor water volume.

A waste dam may be unclassified, provided the dam, in the event of a dam break, does not endanger human health or the environment.

If a dam is substantially lower than three metres and the quality and quantity of the impounded substance are such that no danger can be unambiguously identified, the dam need not be classified. In this case no action by dam safety authorities or the dam owner is required. The dam owner is in any event responsible for dam maintenance, operations and accident prevention (DSA Section 11). The dam safety authority is authorised to inspect any dam, classified or not.

Dams that remain unclassified are, as a rule, flood embankments on farmland and wetland ponds, weirs, natural feed ponds in remote locations and small reservoir dams built for recreational purposes. Dams can remain unclassified provided they pose no hazard.

Certain waste dams are excluded from classification, e.g. landfill deposit ponds, minor agricultural sludge pond dams and secondary clarifying pond dams in water treatment plants. In this case a dam can also remain unclassified, provided it poses no hazard.

## 4.2 Information systems and dam safety file

### 4.2.1 Information systems



#### DSA Section 33 – *Information systems*

- (1) The Finnish Environment Institute maintains an information system for control of dams under this Act. (1511/2009)
- (2) The owner of a dam must provide his or her contact information and information on the staff operating the dam as well as technical information concerning the dam laid down by Government Decree to the dam safety authority to be entered to the information system.
- (4) The owner of a dam must notify essential changes in information referred to in subsection 2 to the dam safety authority. - - -

#### DDS Section 10 – *Information to be provided to the information system*

- (1) The owner of a dam must provide to the information system:
  - 1) permit decisions and other official decisions concerning the dam;
  - 2) information on the hydrological dimensioning of the dam;
  - 3) planning documents concerning the plan which show the realisation of the technical safety requirements when the dam was being constructed and in the alteration and repair works on the dam;
  - 4) dam monitoring programme;
  - 5) dam break hazard analysis, if such an analysis must be prepared for the dam;
  - 6) emergency action plan, if such a plan must be prepared for the dam;
  - 7) description of the safety arrangements, if such a description must be prepared for the dam;
  - 8) periodic inspection data;
  - 9) condition studies prepared on the dam.

Information on classified dams within the scope of the Dam Safety Act, as well as dams that remain unclassified by order, shall be entered into the information system. Information on unclassified dams is also available in the environmental administration water management database.

Documentation and other material should primarily be submitted to the authorities in digital form. Documentation and other material can be submitted as agreed on a case by case basis.

Section 10 of the DDS defines the specific information required from the dam owner to be delivered to the dam safety authority, to be fed into the dam safety information system.



In addition, data on improvement construction projects and disturbances, if any, are entered into the database. Where coffer dams have a classification, they too are entered into the database. The dam safety information system allows authorised users to enter timetables for obligations or projects that have been agreed, for instance submitting documents or undertaking construction work. It is a simple matter to locate omissions or project delays in the system.

Dam owners, their representatives and relevant authorities, such as the emergency services, the official water supervisor and the environmental protection officer may be given access codes to the dam safety information system. The information system was made available to dam owners in 2013. In November 2018 dam owners were given the right to enter data. The digital system allows a user to access dam safety information regardless of time and place.

## 4.2.2 Dam safety file



### DSA Section 33 – *Information systems*

- (3) The dam safety authority and owner of the dam must keep up-to-date printouts from the information system for each dam as well as other important documents as regards dam safety so that these are readily available in case of disturbance (*dam safety file*).
  
- (4) - - - When the owner of the dam changes the owner who gives up the ownership must deliver the dam safety file to the new owner and notify the dam safety authority of the change of the owner.

The safety file of each dam is compiled case by case; the dam safety file contents presented in this chapter is a representative sample. Printouts from the dam safety information system represents a significant part of the safety file data. All of the safety file material need not be fed into the information system. The completion documents of the dam shall, however, be collated and appropriately arranged and located elsewhere for the purposes of safety evaluation and for dam repairs and maintenance.

### **Safety file contents:**

- cover page
- contents
- contact information
- safety arrangements
- permit decisions and other official decisions concerning the dam (e.g. classification, approval of submitted documents) and reports issued by authorities
- map of the area affected by the dam, a site map of the dam, and drawings and assessments of the dam structure
- main dimensions of the dam (appendices 4a and 4b)
- main dimensions of the reservoir area (appendix 5)
- discharge rating curves of controlled and uncontrolled spillways
- discharge rating curves of the starting sills of the inflow and bypass channels of a regulation reservoir
- volume and area curves of a regulation reservoir
- damming and discharge provision, regulation instruction (e.g. as a drawing).
- hydrological dimensioning (item 3.1.2, appendix 10)
- monitoring program (item 4.3, appendix 7)
- description of dam hazard submitted as a basis for classification (DSA section 9(1))
- dam break hazard analysis (for class 1 dam or a dam other than class 1 dam, DSA section 12)
- emergency action plan (class 1 dam)
- periodic inspection reports
- annual inspection reports
- other documents relevant to dam safety.

## 4.3 Monitoring programme



### DSA Section 13 – *Monitoring programme*

- (1) The owner of a dam must prepare a programme concerning a classified dam on the monitoring of factors which may impact on dam safety when the dam is brought into operation and during operation (*monitoring programme*).
- (2) A specific monitoring programme is, however, not needed if similar factors are being monitored under other law in a way that is approved by the dam safety authority.
- (3) Further provisions on the preparation and content of the monitoring programme are issued by Government Decree.

### DDS Section 8 – *Monitoring programme*

- (1) A monitoring programme presents the dam monitoring frequency, objects to be monitored and measures relating to monitoring separately for the time when the dam is brought into operation and when it is being operated.
- (2) A monitoring programme also presents how the monitoring of a dam is intensified during floods, heavy rainfall, strong winds and other similar specific strains.

The monitoring programme consists of continuous monitoring as well as annual inspections and regular inspections. The programme must be structured in such a way that every factor affecting dam safety is monitored and inspected. The monitoring programme comprises both the commissioning inspection and the subsequent programme. The monitoring programme for a new dam should be drafted by the dam designers. The monitoring programmes for old dams are usually drafted by an expert on periodic inspections.

Dam monitoring and inspections are described in detail in item 6.3. The draft monitoring programme can be drawn up in the form shown in Appendix 7, supplementing it as necessary. The monitoring programme shall unambiguously show the monitored object as well as the location and technical fitting data of the monitoring equipment. The proposal for the monitoring programme for a class 1 dam shall be submitted to the dam safety authority two months in advance, and for a class 2 and 3 dam one month in advance of the projected commissioning date, unless otherwise agreed.

Monitoring frequency is determined on a case by case basis in such a way that any problems are detected in time to take action. When the dam reservoir is filled for the first time, monitoring may, depending on the dam characteristics, be continuous or take place a number of times a day or once a day. As the raising of the water level progresses and proceeds without incident, the number of monitoring visits can be reduced to several times a week, once a week, several times a month, once a month etc. As a rule, monitoring personnel visit concrete dams less frequently than embankment dams. The monitoring frequency of waste dams and tailings ponds is defined according to dam type and use. Monitoring inspections may occur daily or less frequently, as with other dams.

Dam monitoring involves the following procedures:

- monitoring the height of water or other substance impounded in the basin
- inspection of the visible parts of the dam structures (embankment and concrete dams, regulation and discharge structures, etc.) and the dam downstream area during each inspection visit
- the observations and measurements listed in the monitoring programme and other issues relevant to the dam
- for waste dams, other special items, if any, related to dam safety, for instance the condition of waste release pipes and of the geomembranes of the reservoirs
- inspection visits occasioned by exceptional circumstances (defined in the monitoring programme: floods, heavy rainfall, storms, other extra strain, DDS Section 8 (2)).

The monitoring of embankment and concrete dams is presented in detail in appendices 11 and 12.

Where a waste dam or tailings pond is associated with operations subject to an environmental permit, the monitoring requirements are defined in the permit as set out in the Environmental Protection Act (527/2014) and the Environmental Protection Decree (713/2014). A monitoring plan and programme shall, as provided in the Environmental Protection Act, present the measuring methods and frequency, methods of calculation and reporting to the supervisory authorities. These plans may complement a monitoring plan as set out in the Dam Safety Act or even replace such a plan.

The draft monitoring plan shall be submitted to the dam safety authority for approval. The approved monitoring plan is entered into the dam safety monitoring database and a copy entered into the dam safety file.

If it is necessary to revise the monitoring programme, the same procedure shall be followed as when drafting a new monitoring programme.

#### 4.4 Classification decision and approval of documents



##### DSA Section 10 – *Classification obligation*

- (1) Before bringing into operation the dam must be classified and a dam break hazard analysis and monitoring programme must be approved for it as laid down in this Chapter.

##### DSA Section 14 – *Classification decision and approval of documents*

- (1) The dam safety authority makes a decision on the classification of a dam and approval of documents referred to in sections 12(1) and 13.
- (2) The owner of a dam must submit the explanatory note needed for the classification decision and monitoring programme as well as, where necessary, a dam break hazard analysis and emergency action plan of a dam to the dam safety authority well before the dam is to be brought into operation.
- (3) Before making the classification decisions and approval of documents referred to in subsection 2 the dam safety authority must give an opportunity to be heard to the owner of the dam and the rescue authority of the region concerned.
- (4) The decision shall be delivered to the owner of the dam, regional rescue authority and municipalities of the area affected by the dam.

##### DSA Section 21 – *Change of class*

- (1) The class of a dam may be changed by a decision of the dam safety authority if on the grounds detected in the inspection of the dam or otherwise the dam hazard can be considered to have changed in an essential way due to a change in circumstances.
- (2) The provisions of sections 11 and 14 on the classes and classification decision apply to a decision concerning the change of class.
- (3) The provisions of subsections 1 and 2 on the change of class also apply to a dam which has not been classified before by virtue of this Act. The owner of such a dam must deliver a report needed for the classification to the dam safety authority upon request.

The dam safety authority decides on dam classification and changes in classification and also approves the monitoring programme and hazard analysis. The safety plan is a continuously updated document and not subject to separate approval. An appeal against the decision on the monitoring programme can be submitted to the provincial administrative court as stated in the Administrative Judicial Procedure Act (586/1996). The decision of the provincial administrative court may be appealed in the supreme administrative court.

The procedures of dam classification and document approval are presented in chart in fig. 2.

#### 4.5 Communication and public access to dam safety documents



##### DSA Section 28 – *Communication*

- (1) In addition to provisions laid down in the Act on the Openness of Government Activities (621/1999), the dam safety authority shall communicate and keep available information on the dam hazard.

The openness principle is defined in section 1 (1) of the Act on the Openness of Government Activities (hereafter the Act on Openness): “Official documents shall be in the public domain, unless specifically otherwise provided in this Act or another Act.” Section 24 in the Act on Openness sets out which official documents shall be secret (32 items). Two of these may apply to dam safety: 7) documents relating to the security arrangements for buildings and 8) documents concerning preparations for accidents and emergency conditions. Section 10 of the Act

on Openness requires officials to grant access to the public part of a document when only part of the document is secret. The decision to grant access to an official document shall be made by the authority in possession of the document (Openness Act, section 14), unless otherwise provided in section 15 (3) of the Act on Openness or in another Act. The Decree on the Openness of Government Activities and on Good Practice in Information Management (1030/1999) was enacted on the basis of the Act on Openness.

The dam safety authority shall communicate and keep available information on the dam hazard. From a citizen's point of view, important information includes dam classification and the extent of the hazard area. The authority can fulfil their obligation to keep the public informed by, for instance, keeping information available on their website.

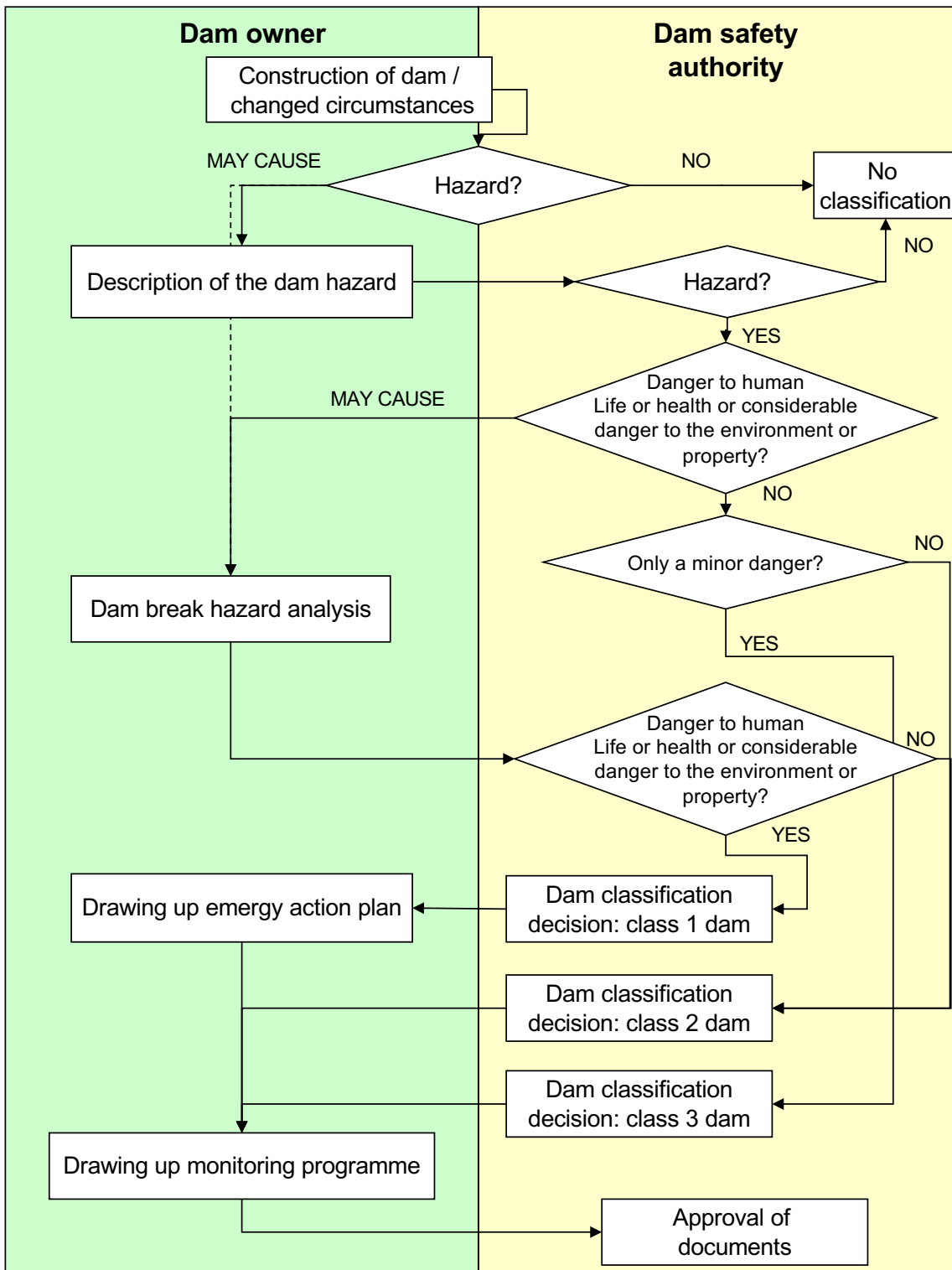


Fig 2. Dam classification and document approval.

# 5 DAM BREAK HAZARD ANALYSIS, EMERGENCY ACTION PLAN AND EMERGENCY SITUATIONS

## 5.1 Dam break hazard analysis

### 5.1.1 General



#### DSA Section 9 – *Dam safety studies in the case of permit*

- (1) In a permit application concerning the construction of a dam under another Act the owner of the dam must describe sufficiently the dam hazard and its impact on the dam dimensioning and design criteria.

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#### DSA Section 12 – *Dam break hazard analysis and emergency action plan*

- (1) To establish the hazard caused by a dam, the owner of a class 1 dam must prepare a more detailed analysis than that referred to in section 9 of the dam hazard to humans and property as well as the environment (*dam break hazard analysis*).
- (2) The dam safety authority may decide that the dam break hazard analysis must also be prepared on a dam other than class 1 dam if this is necessary for the classification of the dam or assessment of the need to change the class.
- (4) Further provisions on preparing and updating of a dam break hazard analysis and emergency action plan of a dam are issued by Government Decree.

#### DSA Section 14 – *Classification decision and approval of documents*

- (1) The dam safety authority makes a decision on the classification of a dam and approval of documents referred to in sections 12(1) and 13.
- (2) The owner of a dam must submit --- where necessary, a dam break hazard analysis --- to the dam safety authority well before the dam is to be brought into operation.
- (3) Before making the classification decisions and approval of documents referred to in subsection 2 the dam safety authority must give an opportunity to be heard to the owner of the dam and the rescue authority of the region concerned.
- (4) The decision shall be delivered to the owner of the dam, regional rescue authority and municipalities of the area affected by the dam.

#### DDS Section 6 – *Dam break hazard analysis*

- (1) A dam break hazard analysis:
  - 1) describes the spread of water or other impounded substance in case the dam collapses in places where the collapse causes the greatest hazard;
  - 2) determines the maximum coverage of a flood caused by the dam failure (*flood hazard in case of dam failure*);
  - 3) specifies the objects of damage in the flood hazard area;
  - 4) gives an estimate of the damage to the objects of damage caused due to the flow, depth or type of the water or other impounded substance.
- (2) Where necessary to establish the class of the dam or prepare the emergency action plan and rescue service plan, the progress of the flood wave must be established by means of relevant calculations using, for example, a terrain model.

The description of the dam hazard (DSA section 9 (1)) must have the detail and scope to allow the dam safety authority to determine, with sufficient certainty, a preliminary dam classification in the application stage, because the dam class affects, among other things, hydrological dimensioning to a significant extent (item 3.1.2).

The dam break hazard analysis (DSA section 12 (1)) is more detailed than the description of the dam hazard described in section 9 (1). The scope of a dam break hazard analysis for a class 1 dam is determined by the requirements of the emergency action plan and of the rescue service plans. It is not always necessary to obtain flood wave progress calculations based on terrain models or, in some cases, accurate damage assessments with projected amounts in euros. The dam safety authority may, as provided in DSA section 12 (2), decide that a dam break hazard analysis must also be prepared for a dam other than a class 1 dam if this is necessary for

the classification of the dam or for the assessment of the need to change the class. This includes class 2 and 3 dams as well as unclassified dams.

The scope of a dam break hazard analysis is described in section 6 of the DDS: the spread of water or other impounded substance in case of a dam break, the extent of maximum flood coverage, the objects of damage and an estimate of the damage to these objects. A dam break hazard analysis describes one or more very serious breach scenarios. A dam breach may occur at a point other than the one chosen as an object of scrutiny in the dam break hazard analysis.

Items 5.1.2 and 5.1.3 cover the flood damage assessments associated with dams in waterbodies. The special characteristics of dam breaks in waste dams and tailings ponds are covered in item 5.1.5.

The risk due to a sudden drop in water level upstream from the dam should also be considered.

### **5.1.2 Comparison of breach cases**

In a dam break hazard analysis, the discharge site where a collapse causes the greatest hazard is chosen for the assessment (DDS Section 6). For the purposes of drafting the safety plan and the rescue service plans, it may be necessary to establish a less dangerous breach site as well.

Various possible dam breach scenarios should be compared with each other at the discharge sites. The events resulting in breaches shall be defined by assuming that the breaches take place and develop as dictated by the structure of the dam. The assumptions shall be based on known breach cases or on the results of a computation model tested experimentally or with true cases, or on scale model tests, taking into account the structure of the dam and its resistance to erosion.

The impact of a dam breach is assessed for both normal and flood situations. Dam break scenarios should be determined for the following situations at least (for flood embankments, see below):

- a sudden collapse of an embankment dam due to internal erosion in a normal situation with an average (MQ) discharge
- sudden collapse of an embankment dam due to excess flow/internal erosion in a flood situation where the calculations are based on discharge data for a flood with a return period of 20 years HQ1/20 (naturally occurring flood during which the dam is assumed to collapse).

Flood embankments and dams in waterways have different computational points of departure. The outside of a flood embankment is typically dry. The point of departure for flood embankments is based on the level of flood water that the embankment is dimensioned to withstand. The relevant parameter is not the frequency of flood conditions as the water level may also rise as a consequence of ice or ice slurry jams. Seaside flood embankments are assessed on a case by case basis.

The discharge shall be determined with the aid of appropriate computation methods. The method and computation procedure shall be described and arguments presented for their applicability considering the properties of the basin. The computation must be described in a way that accounts for the inherent uncertainty and the effect of that uncertainty on results and conclusions must be assessed. The initial values and assumptions must be given. If no better method is available, the Froechlich (1995) model presented in appendix 14 may be used to describe the formation of a dam breach. The model is designed to show the final width of the breach and the time elapsed for the formation of the breach. These data can be used to calculate the discharge from the breach.

### **5.1.3 Establishing the progress of the flood wave**

Where necessary to establish the class of the dam or prepare the emergency action plan and rescue service plan, the progress of the flood wave must be established by means of relevant calculations using, for example, a terrain model (DDS Section 6). To determine the maximum coverage of a flood, that is, the flood hazard in case of dam failure, does not always require extensive data computations: the discharge caused by a flood embankment breach, for instance, can be described using a flow data map based on topographical data.

One- or two-dimensional equations of irregularly changing flow (dynamic flow equations) shall, with the aid of an appropriate computer program, mainly be applied to the calculation of channel flows. Reservoir equations may also be used for side reservoirs and basin-like channel sections. Flows over sills or through gates can be

calculated using formulas of a wide sill or surface and bottom gate flows, depending on the shape of the flow path. A dam break hazard analysis shall show that the software is appropriate for dam breach flood wave calculations.

Estimates must be made as to whether dams and bridges located in a channel will resist a flood or fail. The estimates shall include an assessment of the possible effects that bridges creating blockages can have on the water level and on the flow.

The advance of a flood shall be followed to the extent necessary for assessing the hazard risk.

#### **5.1.4 Assessing potential damage**

A dam break hazard analysis shall include damage assessments for the main flood wave calculations mentioned in item 5.1.3. The specific break cases shall be chosen for damage assessment together with the dam safety authority. Damage assessment is focussed on objects in the flooded area as well as objects in the adjacent area and objects that would be surrounded by the flood. Objects at risk include for instance:

- permanent and seasonal residents in the area
- people present temporarily or routinely in public buildings, schools, hospitals, shops or other places
- buildings (residential, public etc.)
- important community utilities (power and water distribution, sewage treatment, telecommunications)
- production plants (interruptions in production)
- flooded roads, railroads and bridges
- water works located downstream of the dam that in themselves pose a hazard risk
- sites where hazardous or toxic materials are stored
- objects of importance to the rescue services
- environmental damage objects.

The flow velocity and water level at the objects at risk are assessed using flood wave calculations (item 5.1.3) or, in uncomplicated cases, basic hydraulics. The assessment takes account of whether the object at risk is affected by a dynamic flood wave or, for instance, the impounding effect of a large volume of water. Appendix 15 shows damage parameter values,  $vd$  (flow velocity multiplied by water level), used for estimating damage to structures and loss of human life.

The assessment shall tabulate the estimated damage to each object. Where a great number of objects are assessed, they can be grouped in order to clarify the data.

Where it is necessary to assess the risk of losing even a single human life, the Graham model (Graham 1999) can be used for assessing borderline cases. The model is based on real dam breach events in the United States in the years 1960-1998. The main factors contributing to loss of life are 1) the number of people at risk, 2) the level of success in warning the population in the area and 3) the force of the flood wave. The model is described in appendix 16.

#### **5.1.5 Waste and tailings dam hazard**

The assessment of waste dam and tailings pond hazard includes not only the possible effects of a flood wave in the event of a dam failure, but also the effects of exposure to the harmful or dangerous substances. As a rule, the hazard posed by a waste dam is assessed on the basis of a worst-case scenario, that is when the dam is completed and filled to capacity. Dams are generally built in layers. The hazard during operational use is therefore frequently significantly smaller than assessed, since the dam level is lower and the volume of impounded substance is smaller.

A dam break hazard analysis should describe the nature of harmful substances, their possible paths of spreading as well as damage objects and the possible effect on them. The extent and duration of damage in a dam failure situation depends, among other factors, on the spreading (see flood wave calculation), dilution, retention and transformation of the substance. In addition to land use, the assessment should include the effects on protected objects, such as groundwater areas, nature reserves, endangered flora and fauna. The damage magnitude can be assessed by using, for instance, quality criteria for groundwater, tap water, surface water, soil

and foodstuffs. The natural background concentrations should be included when assessing the environmental and health impact of a dam breach.

The environmental permit application – and the decision (Environmental Protection Decree 713/2014, section 3) as well as an environmental impact assessment, if any – usually include sufficient information on the properties of the impounded substance and on environmental concerns that affect the classification of a dam. The aforementioned sources and public documents provide a summary of the material needed for dam classification and for the classification proposal included in a hazard analysis.

The hazard posed by a flood wave caused by a collapsed dam is assessed as detailed in item 5. The classification of a waste dam is determined by the more serious risk (substance toxicity or flood wave force) posed by the dam.

### 5.1.6 Results of the dam break hazard analysis

**The hazard analysis shall include the following items**

1. General
2. Description of the drainage area
3. Computation model
4. Comparison of dam breach cases
5. Flood wave calculations
6. Hazard posed by dam break
7. Operational assessment
8. Dam class proposal

Appendix 15 describes the presentation of dam break hazard analysis results in more detail. The dam safety authorities website includes guidelines for preparing maps for a dam break hazard analysis.

### 5.1.7 Updating a dam break hazard analysis



DSA Section 20 – *Updating a dam break hazard analysis*

- (1) Based on a periodic inspection the dam safety authority may order the owner of a dam to update a dam break hazard analysis prepared for the dam.
- (2) The owner of a dam must deliver the updated dam break hazard analysis to the dam safety authority for approval in connection with the periodic inspection or separately.
- (3) The dam safety authority shall notify the decision on the approval of an updated dam break hazard analysis to the owner of the dam, rescue authority of the region concerned and municipalities of the area affected by the dam.

A dam break hazard analysis shall be updated when necessary, for instance, when new residences or structures that change the flow paths of a flood, are built. When the dam level is raised or the nature of the impounded substance is changed, the dam break hazard analysis shall be reviewed and updated as necessary. The dam break hazard analysis shall also be updated when the previous analysis is out of date and the methods used in the analysis have developed substantially and there is reason to suppose that a new analysis will materially improve the baseline data required for the safety plan or for emergency planning.



## 5.2 Emergency action plan

### 5.2.1 General



#### DSA Section 12 – *Dam break hazard analysis and emergency action plan*

- (3) The owner of dam must prepare and regularly update a plan of measures in case of accidents and disturbances concerning a class 1 dam (emergency action plan of a dam).
- (4) Further provisions on preparing and updating of a dam break hazard analysis and emergency action plan of a dam are issued by Government Decree.

#### DSA Section 14 – *Classification decision and approval of documents*

- (1) The dam safety authority makes a decision on the classification of a dam and approval of documents referred to in sections 12(1) and 13.
- (2) The owner of a dam must submit the explanatory note needed for the classification decision and monitoring programme as well as, where necessary, a dam break hazard analysis and emergency action plan of a dam to the dam safety authority well before the dam is to be brought into operation.
- (3) Before making the classification decisions and approval of documents referred to in subsection 2 the dam safety authority must give an opportunity to be heard to the owner of the dam and the rescue authority of the region concerned.
- (4) The decision shall be delivered to the owner of the dam, regional rescue authority and municipalities of the area affected by the dam.

#### DDS Section 7 – *Emergency action plan of a dam*

- (1) An emergency action plan of a dam presents the measures to be taken by the owner of the dam:
  - 1) to prevent accidents in case of disturbances as well as to prevent and limit damages at the dam;
  - 2) to protect humans, property and the environment against damage;
  - 3) to report an accident.
- (2) The plan also presents the materials and equipment to be kept ready for preventing an accident and the available staff.
- (3) In addition, an emergency action plan for a waste dam presents the type of the impounded substance, properties causing hazard, volume, contents, movement and conversion and other special characteristics of the dam.

The dam safety authority reviews the emergency action plan for a class 1 dam, but does not take the decision to approve it. If the dam owner has a copy of the rescue service plan or the civil defence plan of the municipality, such copies should be attached to the dam safety plan.

The emergency action plan describes the independent readiness of the dam owner and their action in an emergency or during a disturbance. The people who draw up the plan should note that different dams and their inundation areas have special characteristics that vary a great deal. The contents of the plan can therefore not be defined in detail and must be designed to fit specific risk factors and conditions. For dams in a waterbody, emergency action plans should be designed to prevent and minimise damage to the waterbody and to attendant structures in the event of a dam failure. Waste dams and tailings ponds require plans for active measures to collect and process the impounded material in the event of a dam failure.

The emergency action plan is based on the dam break hazard analysis described in item 5.1.

When several class 1 dams are located in the same watercourse and the failure of one may cause the failure of dams downstream or a significant hazard to people, property or the environment, the dam owner's plans for waterbody regulation must reflect the risk of sequential failures or emergency discharges in excess of the permitted volumes. If necessary, the emergency action plans of individual dams or parts of their plans can be combined to form an action plan for the entire waterbody.

The emergency action plan must be completed before the dam is commissioned. A complete set of the latest update of the emergency action plan must be available to those responsible for operations and for maintenance at the dam, as well as to the dam safety authority and rescue services.

The emergency action plan must be kept up to date. Those parts of the plan that are central to rescue action or to emergency repair work shall be updated continuously or at least once a year. Such parts of the plan include the information on

- communications in the event of a dam failure or the threat of a failure
- communicating the failure notification and alarm messages to the employees of the dam owner and to the relevant authorities
- warning the population at risk.

The safety plan shall be gone through thoroughly and updated as necessary at least every five years in connection with the periodic inspection. The update shall include an assessment of the hazard analysis and a critical evaluation aimed at assessing whether or not the plan reflects the risks posed by the dam.

If a plan for a class 1 waste or tailings pond has been drafted under another act, and the plan meets the safety plan requirements of the Dam Safety Act and Decree, no separate document need be drafted under the Dam Safety Act. The policy document for any waste site for extractive waste which poses a risk of a major accident as set out in the Environmental Protection Act (527/2014) together with the safety management system and internal emergency plan comprises such a plan. If, however, the safety file is drafted under another act, the data on the dam shall be clearly presented, for instance in a separate chapter.

## 5.2.2 Dam break hazard information



### DSA Section 28 – *Communication*

(1) In addition to provisions laid down in the Act on the Openness of Government Activities (621/1999), the dam safety authority shall communicate and keep available information on the dam hazard.

The population at risk shall be informed of the hazard posed by a class 1 dam and of the drafted emergency action plan. Preliminary information can be given on the Internet, by distributing leaflets with information about the breach hazard to the population of the inundation area and, if necessary, by organising information meetings. The rescue services will distribute information about their own emergency planning. The dam owner shall participate in the distribution of information.

The hazard posed by a dam shall be taken into account as an external risk factor in the emergency plans for residential buildings and of businesses and official establishments within the danger zone (rescue act, sections 14 and 15).

## 5.2.3 The responsibilities of the dam owner and of different authorities in the event of a dam accident

### **Dam owner's responsibilities**

Anyone who observes or receives information about a fire or other accident that is either occurring or about to occur and cannot immediately extinguish the fire or combat the danger is obliged to notify those endangered, make an emergency call and take rescue action without delay to the best of their abilities (Rescue Act section 3). This obligation, as set out in the Rescue Act, concerns the dam owner in particular and the responsible maintenance personnel employed by the owner. The other responsibilities a dam owner has in the event of a dam failure are defined in sections 24 to 27 of the Dam Safety Act and in item 5.3 of this guide. The division of responsibility for a class 1 dam is defined in detail in the emergency action plan.

When a dam accident is imminent or has occurred, the dam owner's responsibilities include, among other things

- making certain that the emergency response centre has been notified
- notifying the dam safety authority and, in the case of a waste dam, the environment protection authority
- assessing the seriousness of the situation and, together with the rescue services, determining the necessary extent of warnings

- warning the population at risk in the danger zone of the dam (in cooperation with the rescue services)
- coordinating, with the emergency response centre, calls to alert the personnel and equipment needed for channelling a flood and repairing a breach
- initiate channelling the watercourse as indicated by the circumstances, in order to facilitate repair work or to minimise damage caused by the breach
- begin emergency repairs on the breach and supervising repair work
- keep rescue services leaders and other authorities abreast of breach developments and the progress of dam repairs and efforts to direct the watercourse
- take part in keeping the public informed as the situation warrants.

### **Responsibilities of the authorities**

The various tasks and responsibilities of authorities and official establishments are primarily set out in the Rescue Act and Decree and other relevant law.

*The rescue services* are responsible for measures called for by the dam breach and the resulting flood to the extent appropriate for available rescue services. The measures are those that have to be taken urgently, and which require the operational readiness, facilities, and professional skill that the rescue services have. The main responsibilities include notifying various operational units as well as warning, sheltering and rescuing the population and supervising the rescue activities as a whole. If the rescue services are deemed to have the capacity to undertake other urgent action in the appropriate way, for instance initial repair work, the rescue services personnel should receive training and local orientation for this purpose for each dam specifically.

*Dam safety authority* (The ELY centre with authority in dam safety matters) supervises the dam owner's performance of their obligations in the initial stage and provides the rescue services and the dam owner with expert assistance. The dam safety authority reports on dam failures to other official departments as necessary and participates in warning the public as necessary.

*The ELY centre* can, if necessary, take action concerning waterbodies and hydraulic structures. The ELY centre also takes part in preparatory action planning and provides guidance for such action and, local conditions permitting, participates in such action. The ELY centre is the local expert who provides support and guidance for rescue units in matters concerning regulation of the waterbody where regulating can be used to reduce damage. In case a waste dam or tailings pond failure has caused environmental damage, the ELY centre supervises the action taken by the dam owner and provides rescue services with expert assistance. The ELY centre makes an assessment of environmental consequences of a dam failure and provides information on the state of the environment.

*The police* are responsible for public order and safety, isolating the danger zones, traffic control, organising the search for missing persons, guarding evacuated areas, investigating the cause of an accident and other measures within their purview.

The division of tasks as well as authority and management responsibilities between the dam owner and different authorities and response units shall, for a class 1 dam, be defined before the dam is commissioned and the definition recorded in the dam safety plan. The tasks require training and emergency response exercises that shall primarily be undertaken by the dam owner, the rescue services and the dam safety authority.

## **5.2.4 Maintaining readiness – training and exercises**

A dam owner has a particular responsibility to maintain a readiness to respond to a dam failure. The responsibility is shared by other persons, authorities and emergency response units whose task it is to take action if a dam fails.

The safety plans and instructions that are drawn up for the eventuality of a dam failure are not enough to ensure a rapid and efficient response in an emergency. Maintaining readiness requires regular training and exercises.

### **Dam owner personnel training**

In planning personnel training, the owner of a dam shall maintain a particular focus on the following

- the ability of personnel to observe and evaluate changes in the dam that point to a dam failure or to damage
- the ability of personnel to initiate the alarm and warning procedures required in a dam emergency

- the ability of personnel to initiate the dam owner’s measures for channelling the waterbody and repairing dam damage
- coordinating response action and cooperating with the authorities.

If certain tasks of the dam owner, such as operating the gates, are given over to outside organisations (rescue services) in an emergency according to the safety plan, the dam owner shall organise their training, too. Emergency repairs can be speeded up if the rescue services have the necessary information concerning the materials and equipment needed to repair a dam.

### Joint exercises

Training exercises for class 1 dams should be organised as joint exercises that include both the dam personnel and response units of different authorities, since only this will provide sufficient assurance of effective action in a real situation. The initiative may come from the dam safety authority or the dam owner, both of whom also take part in planning. The exercise itself, however, is organised by the rescue services who are responsible for it.

A joint exercise comprises processing and developing existing plans, site inspections in the danger area and training exercises. The training exercises are “response games” led by the responsible leaders, where a dam failure is simulated using maps and projected situations in the site terrain. Joint exercises should include emergency response centre personnel, in order to test the warning and alarm communications as well as the response to emergency instructions.

On a waste site for extractive waste which poses a risk of a major emergency, the Environmental Protection Act requires the emergency services to organise a “major emergency exercise” at least every three years, as set out in the ministry of the Interior Decree on Emergency Plan for Waste Sites for Extractive Waste which Pose a Risk of a Major Emergency (612/2015, Finnish). Dams on waste sites for extractive waste which pose a risk of a major emergency are generally class 1 dams as defined by the Dam Safety Act.

## 5.3 Preparing for dam emergencies and emergency action



### DSA Section 24 – Preventing accidents

- (1) The owner of a dam must, with due consideration of the dam hazard, take the necessary actions to prevent a dam accident and to limit the damages caused by an accident.

### DSA Section 25 – Rescue service plans

- (1) Provisions on rescue service are laid down in section 9 of the Rescue Act. [*new Rescue Act 379/2011: Section 47*] The dam safety authority delivers the information in its possession necessary for preparing the rescue service plans as requested by the rescue authority.

### DSA Section 26 – Rescue activity

- (1) Provisions on rescue activity are laid down in the Rescue Act. The owner of a dam and dam safety authority must assist the head of the rescue activity in performing rescue activity. In addition, the dam safety authority participates, where necessary, in the work of the steering group referred to in section 44(3) of the Rescue Act. [*new Rescue Act 379/2011: Section 35(2)*]

### DSA Section 27 – Emergency call and notice of an exceptional situation as regards safety

- (1) Provisions on an emergency call to the Emergency Response Centre are laid down in section 28 of the Rescue Act. [*new Rescue Act 379/2011:Section 3*]. The owner of the dam must notify the emergency call made to the dam safety authority without delay.
- (2) The owner of the dam must give notice concerning an exceptional situation as regards dam safety which has occurred at the dam other than those referred to in subsection 1 to the dam safety authority without delay. The notice must describe the situation and give the necessary accounts for control measures to the dam safety authority. Where necessary, the dam safety authority delivers the notice to the regional rescue authority.

The general obligation of a dam owner to prevent accidents and to limit the damage of an accident is described in item 5.2. in the safety plan, as applied to a class 1 dam. The need for preventive measures for other dams is evaluated case by case.

The Environmental Protection Act (527/2014), section 15 requires an operator subject to a permit to prepare action plans for preventing emergencies and other exceptional circumstances in order to limit damage to human health and the environment. The emergency plan is based on a dam break hazard analysis. The owners of waste dams should note the obligation to be prepared, set out in the Environmental Protection Act, when assessing the risk of dams other than class 1 dams. The information needed for emergency response operations, which the dam safety authority shall give the regional rescue services, is attached to the the hazard analysis and emergency action plan of a class 1 dam.

An internal emergency plan for waste sites for extractive waste which pose a risk of a major emergency, as set out in the Environmental Protection Act (527/2014, Finnish), can be used as a substitute for the aforementioned dam safety plan as described in item 5.2.1. Provisions on rescue service are laid down in section 47 of the Rescue Act. The safety plan constitutes the preparatory emergency measures that dam owners take on their own initiative. In each case, the rescue authorities make a separate assessment for the need to prepare a plan as set out in the Rescue Act. The rescue services are required to prepare external emergency plans for sites posing a particular hazard (section 48, Rescue Act, 379/2011) on waste sites for extractive waste.

Provisions on an emergency call to the emergency response centre are laid down in section 3 of the Rescue Act. This section obligates anyone who observes or receives information about an accident occurring or about to occur to notify those in danger, to make an emergency call and take rescue action without delay to the best of their abilities. The obligation includes an occurring or imminent dam accident.

## 5.4 The use of risk analysis in dam safety

The Dam Safety Act and Decree do not oblige a dam owner to employ risk analysis for dams in Finland.

According to Laasonen (2009), risk analysis became routine in many other countries in the 1990's. In 1994 The Australian National Committee on Large Dams (ANCOLD) published Guidelines on Risk Assessment. In 1997 Trondheim hosted the Hydropower '97 conference, where one of the topics was dam safety and risk analysis (Broch et al, 1997). The 2000 ICOLD congress in Beijing took up risk analysis in support of dam safety decisions and management (Question 76: The use of risk analysis to support dam safety decisions and management).

The RESCDAM-project (1999–2001) coordinated by the Finnish environment centre reviewed risk analysis, among other topics. Calculations of the probability of dam failure at the Kyrkösjärvi embankment dam, Seinäjoki, was used as an example (Slunga, 2001), in addition to which the consequences, that is, loss of life, was assessed (Reiter, 2001) and the material damage was calculated in euros. An advanced training program in dam safety, PATU (2004 – 2005), included a course on earthfill dams with topics such as "Risk analysis in evaluating the need for repairs and the normal deterioration of an earthfill dam" (Slunga, 2005), where the Kyrkösjärvi embankment dam was used as an example. The presented conclusion about the importance of risk analysis:

*"A risk analysis based on probability theory provides a more rational basis for a dam safety assessment and a more comprehensive view than the traditional process that is based on standards. A complete risk analysis includes the examination of all load factors affecting dam safety. The intention is not to use the analytical method to replace the expertise represented by the engineering skills of the designer. Quite the opposite, as this method requires a great deal of expert input. The analysis does not provide a result in the form of an accurate breach probability. The results of an analysis can be used in a relative sense, when evaluating the effect of improvements and repairs on dam safety and the order in which such measures should be taken for optimum results."*

Appendix 17 "Dam risk analysis" includes a general description of the use of risk analysis for dam safety purposes.

# 6 MAINTENANCE, OPERATION, MONITORING AND INSPECTION OF A DAM

## 6.1 Maintenance



### DSA Section 15 – *Maintenance obligation*

(1) The owner of a dam is obligated to keep the dam in such a condition that it functions as intended and is safe.

The maintenance work on an embankment dam includes

- repair work on the wet slope facing (usually at the waterline)
- clearing the dry slope of trees and bushes that may impair visual observation or endanger dam operations
- drainage system maintenance (flushing out drains, keeping surface ditches open, clearing trees and bushes as necessary)
- keeping the dam crest open for traffic by clearing away impeding vegetation and undertaking necessary repairs (depressions, ruts).

The maintenance work on concrete dams include, among other things, visual observation of erosion and repairs as necessary.

Gates are kept in working order by regular maintenance and repairs as necessary.

Monitoring equipment is kept in working order by maintenance as necessary. Maintenance includes flushing out or replacing the gauge pipes for measuring pore pressure and aquifer water level as well as removing silt that accumulates above and below measuring weirs.

The safety of the Tammerkoski dams in Tampere has been greatly improved by, for instance, rebuilding the Frenckell dam wall, 2012 (Milla Torkkel)



## 6.2 Dam operation

### 6.2.1 General

Dam operation is subject to regulation and orders contained in the dam construction permit. The water level and discharges are regulated as ordered in the permit (damming and discharge provision) issued for dams in a watercourse as set out in the Water Act.

The environment permit of waste dams and tailings ponds may include rules on water levels, the nature of an impounded substance, the maximum height of embankments or waste areas as well as piping waste water into the downstream waterbody. The staff responsible for the operation of the dam must possess sufficient knowledge and expertise on the circumstances which impact on dam safety, operation of the dam and related safety systems (DSA section 6, DDS section 1(2), item 2.5).

### 6.2.2 Safety arrangements for dam operation



#### DSA Section 16 – *Operation of a dam*

- (1) A dam shall be operated in such a way that it causes no danger to human life and health.
- (2) Sufficient safety arrangements shall be in place for class 1 and 2 dams to ensure the safety of the operation of the dam. Further provisions on the safety arrangements are issued by Government Decree.

#### DDS Section 9 – *Dam safety arrangements*

- (1) The safety of a class 1 and 2 dam shall be ensured by means of:
  - 1) arrangements to ensure the operation of the dam in case of disturbances;
  - 2) warning and other arrangements concerning the discharge of a watercourse dam to prevent danger to those above or below the dam;
  - 3) where necessary, arrangements to prevent damage caused by sabotage or vandalism.
- (2) The owner of a dam must prepare and keep up to date a description of safety arrangements and provide this to the dam safety authority if this is not shown in the other documents provided to the dam safety authority.

#### DDS Section 1(2) – *Competence requirements*

- (2) The staff responsible for the operation of the dam must possess sufficient knowledge and expertise on the circumstances which impact on dam safety, operation of the dam and related safety systems.

The safety arrangements for a dam consist of technical arrangements and the arrangements for operating personnel readiness. The required expertise of operating personnel referred to in DDS section 1(2) is accomplished through guidance and training. Operating personnel must know how to correctly interpret monitoring data, be familiar with the local circumstances, safety systems and risk factors. They must also know what to do in an emergency and what procedure to follow if the dam is operated from another location.

Remote control of a dam and water level monitoring must be dependable and potential disturbances must be factored into the operating procedure. Section 4 of the DDS requires that an emergency hoisting system or plan must operate within the time margin allowed by the dam (item 3.1.3 and appendix 13).

Arrangements concerning the discharge of a watercourse dam to prevent danger to those above or below the dam may consist of

- warning signs
- entry to the area restricted by a fence or a barrier
- maintaining visual or camera observation in the area in order to keep out unauthorised people during a discharge
- sounding a warning signal
- beginning a discharge at the gates with a smaller volume and increasing the volume by stages
- warning the public by, e.g. a local radio broadcast about a discharge and the changes in the local ice conditions this may cause in the vicinity of a power station.

Canal discharges carry the same risks and should consequently be subject to the same procedure. Arrangements to prevent damage caused by sabotage or vandalism may include

- warning signs
- locks on control gear
- security patrols
- closing the area.

DDS section 9 requires the owner of a dam to prepare and keep up to date a description of safety arrangements and submit this to the dam safety authority if it is not shown in the other documents submitted to the dam safety authority. Appendices 8a and 8b show forms for the description that may be adapted to apply to a specific dam.

Tailings dams raised using tailings sand require a systematic filling of the pond. The tailings beach is always sufficiently long and free water does not come into contact with the tailings sand or quarry material that comprises the elevated part.

## 6.3 Monitoring and inspections

### 6.3.1 General

Monitoring is the observation that takes place between annual and regular inspections, visually or using measuring devices, of the condition and operation of a dam. The person responsible for monitoring and inspections must be sufficiently competent in dam safety matters (DSA section 6).

The monitoring requirements and the substance of annual and regular inspections is defined in DSA sections 17-19. Arrangements for a dam are defined in the monitoring programme of each specific dam. A monitoring programme is set up as described in item 4.3.

### 6.3.2 Monitoring



#### DSA Section 17 – *Monitoring*

(1) The owner of a dam must organise the monitoring of the condition and functioning of a classified dam in accordance with the monitoring programme.

The people who implement the monitoring programme shall be given appropriate orientation and training to ensure that they know the various types of potential damage and accident and how to recognise the initial stages of a problem. The surveyor who undertakes measurements shall be well informed about the limits of the normal values and, if these limits are exceeded or are not reached, he shall immediately inform the person responsible for the dam. The personnel shall also be informed of the steps to take if they observe anything that may imperil the safety of the dam. The dam owner shall train operating and maintenance staff to watch for changes that occur in structures in dam areas and dams, and make sure that they know whom to inform about changes observed. The employee responsible for dam safety decides whether or not the changes observed are significant from a dam safety point of view and what measures to take. A record shall be kept of monitoring and observations.

In addition, and if necessary, during floods and after exceptionally heavy rainfall and storms, inspection visits shall be made to dams which are or may have been subject to unusual strain. Unusual conditions are defined for each dam in the monitoring programme which includes a description of the measures to be taken in connection with such conditions.



The submerged structures of dams in watercourses shall be adequately monitored. The submerged structures of concrete dams shall be inspected at set intervals by, for instance, a diver. It is also recommended that submerged structures of embankment dams be inspected at low water. Inspections by a diver have not been routinely undertaken but such inspections may be useful in some cases. If the foundation rock is cracked, for instance, there may be depressions in the dam basin near the lower channel. This may indicate a safety problem and the need for repairs.

Waste dams and tailings ponds subject to an environment permit are monitored according to the monitoring obligation set out in the permit. The monitoring data is reported to the environment permit supervisory authority. The monitoring mandated by dam safety concerns is carried out on a dam-specific discretionary basis and organised in such a way that the dam owner is not obliged to perform overlapping monitoring, but nevertheless so that the requirements of the Dam Safety Act monitoring requirements are met. In addition, the condition of filling and drainage structures of waste dams and tailings ponds must be monitored. The raising of the level of impounded substance shall also be monitored and proceed systematically and to plan.

Waste dams and tailings ponds subject to an environment permit are monitored according to the monitoring obligation set out in the permit. The monitoring data is reported to the environment permit supervisory authority. Where the environment status monitoring programme includes the monitoring objects required for dam safety purposes, no overlapping monitoring programme is required.

### 6.3.3 Annual inspection



#### DSA Section 18 – *Annual inspection*

- (1) The owner of a dam shall inspect the condition and safety of a class 1 and 2 dam at least once a year. The owner of a dam must notify the written report prepared on the inspection of a class 1 dam to the dam safety authority.

The annual inspection of a dam shall be made when the ground is not frozen. The recommended period is right after the thaw. In the course of the annual inspection the measurements and observations made during the year are reviewed, the operational state of measuring devices is checked and the parts of the dam and the associated equipment requiring repair are investigated.

During the annual inspection, special attention shall be paid to checking the condition, performance and alarm systems of the dam spillways, sills and power plant discharge gates. The operation of discharge equipment must be checked by test runs. In flood years in particular, the flood preventive measures taken are reviewed, so that even in abnormal flood years the operating personnel have the correct instructions for handling the situation. Likewise, the ice impact data, their effect on discharge structures and other possible risk factors are assessed. Any investigations undertaken by reason of unusual weather conditions or other situations (e.g. HW exceeded) are also reviewed.

The filling and discharge channels of the basins and associated structures should be inspected when the spring flood has subsided. Correspondingly, the structures and equipment of waste dams, such as the inflow and outflow systems, are inspected once a year.

The contact information for personnel included in the dam safety plan is checked and updated in connection with the annual inspection. Other relevant data is also updated if they have a bearing on the safety plan. The dam section data of waste dams and tailings ponds are reviewed and updated as necessary, especially for dams that are raised on a regular basis. The equipment for detecting dam damage and for warning the local population as well as emergency communications are of particular importance in the annual inspection.

A record is made of the annual inspection and test runs. The inspection record is filed in the safety file of the dam owner and, in the case of a class 1 dam, a copy is sent to the dam safety authority. The dam safety authority files the report in the dam safety database and keeps a printout copy in their safety file.

Where a periodic inspection includes measures that are part of the annual inspection, the measures may be omitted from the annual inspection that year. The important thing is that every measure of the annual inspection is also accounted for in a year when the periodic inspection is undertaken and that the measures are recorded and the record is available.

### 6.3.4 Periodic inspection



#### DSA Section 19 – *Periodic inspection*

- (1) The owner of a dam must organise a periodic inspection of class 1-3 dams at least every five years and, where necessary, more frequently, to which the dam safety authority and rescue authority has the right to participate.
- (2) A summary of the dam monitoring data from the past five years and a preliminary assessment of the condition of the dam by an expert who fulfils the competence requirements laid down in section 6 must be presented to the dam safety authority in good time before the inspection.
- (3) In the periodic inspection changes in the conditions of the dam and factors which impact on its safety are studied, with due account for the changes in land use and weather and hydrological conditions. If in the periodic inspection it cannot be established with sufficient certainty that the dam fulfils the safety requirements set for it, the owner of the dam must prepare a thorough study of the condition of the dam or its part (*condition study*).
- (4) The owner of a dam must notify the written report prepared on the inspection of a class 1 and 2 dam to the dam safety authority.

The periodic inspection is undertaken by the dam owner and the inspection team shall include a competent expert, either a representative of the dam owner or an outside expert (DSA section 6). The dam safety authority and rescue authorities have a right to attend the inspection. The established practise is that representatives of the dam safety authority always attend the inspection and representatives of the rescue authority attend when they deem it necessary. Inspections of waste dams and tailings ponds are attended by representatives of the ELY centre responsible for supervising adherence to the Environmental Protection Act.

The date of the first periodic inspection is reckoned from the date of commissioning. The periodic inspection of a dam shall be made when the soil is not frozen.

All dam structures of a dam basin area are inspected on the same occasion whether or not the structures have the same owner (e.g. an embankment dam and a power plant dam).

The agenda of the periodic inspection, together with the reports of annual inspections and measurement data, are sent in advance to those participating in the inspection. Section 19 (2) of the DSA provides for a summary of the dam monitoring data from the past five years and a preliminary assessment of the condition of the dam by an expert who meets the competence requirements laid down in section 6 of the DSA, to be presented to the dam safety authority in good time before the inspection. The agenda of the periodic inspection includes at least the following, to be included in the inspection report

- A review of the report of the previous periodic inspection and the measures required by it.
- The annual inspection reports written after the previous periodic inspection including a summary of monitoring and measured data, if any (graphic presentation). An analysis of the periodic inspection results and a summary to be appended to the periodic report.
- A review of repairs undertaken since the previous periodic inspection and the reasons for them.
- Inspection of dam structures (on site), including the condition of parts and equipment that are essential from a dam safety point of view, including gates and the emergency hoisting system. Trees and other vegetation are inspected from a dam safety point of view. The inspection includes checking for any substances or objects that do not belong on the dam (structures), that may pose a hazard to a dam structure or impede



maintenance or inspection of the dam. Access to the dam is checked: the crest of class 1 and 2 dams (dams in a waterbody) must be passable for traffic. Inspection of the dam safety arrangements.

- The dam classification is verified by on-site inspection. Establishing whether changes have taken place in conditions or, in the case of waste dams, in the type of impounded substance affecting the dam class. A dam break hazard analysis may be necessary to verify the dam classification or the existing hazard analysis may have to be updated.
- A dam break hazard analysis is evaluated to establish whether it is up to date and compatible with emergency action plans.
- The emergency action plan of a class 1 dam and the practical arrangements therein are evaluated. In addition to evaluating and updating the emergency action plan, an inspection is undertaken of the equipment and communications systems used for detecting damage, warning the public and alerting different response units and personnel. The inspection shall include equipment test runs.
- The hydrological dimensioning of the dam is evaluated to establish whether it is up to date, changes in the physical condition of the waterbody and any necessary changes are noted. The dam safety authority makes certain that the dam owner is informed of changes in the weather conditions or physical environment that concern dam safety and that such changes are noted in the dam safety documentation. The discharge capacity of the dam is evaluated to determine whether it is sufficient (calculation methods in use, discharge values). The water balance of waste dams and tailings ponds is checked.
- The monitoring programme and any improvements are evaluated.
- In addition to the aforementioned, the dam safety monitoring data system and the dam safety file are evaluated to determine whether they are up to date and whether any improvements are called for.
- The preliminary evaluation of the expert concerning the condition and safety of the dam is processed, including any suggested measures or evaluations arising.

The periodic inspection report shall include an evaluation of the condition and safety of the dam. Reports on class 1 and 2 dams are submitted to the dam safety authority. The report is entered into the database and a printout filed in the dam safety file. The report can be improved visually with drawings, photographs, videos, etc. The report shall reflect all noted suggestions for improvement and updates as well as measures arising and their timetables.

If in the periodic inspection it cannot be established with sufficient certainty that the dam meets the safety requirements set for it, the dam safety authority may order a thorough study of the condition of the dam or its part (condition study). The need for this may arise when, for instance, the report on the periodic inspection of the condition of the dam submitted by the expert reflects uncertainty or there are other grounds to suspect the structural integrity of the dam. The condition study may propose additional surveys or calculations designed to either ensure that the dam meets the dam safety criteria or to detect the need for repairs. The condition study may target the dam as a whole, a part of it or a specific point.

Deterioration of the operational condition of an embankment dam may proceed slowly over decades and it is not always easy to detect changes that affect dam safety. The age of a dam is not automatically a reason for undertaking an evaluation of the condition. In some cases, a dam may have been built to specifications that, in the light of current knowledge, can be suspect from a safety point of view.

A condition study may be necessary if, for instance, the following risk factors are detected in the case of an embankment dam:

- There is reason to suspect internal erosion in the core or filtering layers.
- The drainage system has been found insufficient or abnormal changes have taken place, such as increased/decreased seepage or murky seepage water detected.
- Changes on the dam crest, the slopes or the background have been observed, e.g. depressions, slides or water springs.
- Erosion is suspected at the structural junctions (pipes running through a regulating dam, power plant or dam structure).

A condition study may also be necessary at a concrete dam if, for instance:

- The structure has deteriorated over time to the point that repairs must be considered.
- Seepage through the rock or earthfill foundation has increased and/or the water has turned murky and the observations call for an evaluation of the need for repairs.

A condition study requires special competence relating to the dam type and associated structures. The competence level is comparable to that required by the chief designer of a new dam of a corresponding type.

### 6.3.5 Disturbances



DSA Section 27 – *Emergency call and notice of an exceptional situation as regards safety*

- (1) Provisions on an emergency call to the Emergency Response Centre are laid down in section 28 of the Rescue Act. [*new Rescue Act 379/2011: Section 3*]. The owner of the dam must notify the emergency call made to the dam safety authority without delay.
- (2) The owner of the dam must give notice concerning an exceptional situation as regards dam safety which has occurred at the dam other than those referred to in subsection 1 to the dam safety authority without delay. The notice must describe the situation and give the necessary accounts for control measures to the dam safety authority. Where necessary, the dam safety authority delivers the notice to the regional rescue authority.

From a safety perspective, exceptional situations are structural or functional disturbances that affect dam safety. The dam safety authority should be immediately notified of a disturbance, by phone or by e-mail. Disturbances must be reported. The disturbance report can be submitted afterwards, provided the authorities have already been informed. When the dam safety authority is notified, the report shall include a description of events at the dam, measures taken and the situation at the time of the report. Disturbances at waste dams must also be reported to the environment authority, particularly if the disturbance constitutes an environmental hazard.

Normal structural maintenance measures need not be reported. Structural maintenance measures are processed at the periodic inspections. Disturbances include

- high water level raised significantly higher than the normal HW level due to, for instance, discharge structure malfunction, exceptional flood, frazil ice, or, on the coast, a storm flood.
- gate malfunction or control gear malfunction or a power cut at the dam
- structural damage to the dam, requiring emergency repairs or further inspections
- external erosion, internal erosion, sudden changes in seepage water volume or characteristics (colour, murkiness)
- blocked drainage system or frost damage
- fire or vandalism at the dam
- damage to the pump pipe at a waste dam that may be a danger to the dam.

The dam safety authority gathers data on disturbances in their dam safety database. The collected disturbance report data is used for evaluating the risk of future disturbances.

### 6.4 Dam decommissioning



DSA Section 23 – *Dam decommissioning*

- (1) A dam is recorded as removed from service to the information system of the dam safety authority when it is established in the inspection that the dam structure has been pulled down or the dam has been decommissioned in such a way that it can no longer cause hazard referred to in this Act. The inspection is performed in the presence of the dam safety authority after the obligations relating to pulling down a dam structure or dam decommissioning under other law have been fulfilled. The obligations under this Act cease to be applicable when the dam has been recorded as removed from service.

Section 23 of the DSA provides for dam decommissioning from the perspective of the Dam Safety Act, that is, from the time when a dam is recorded as decommissioned in the dam safety database. A dam is recorded as decommissioned in the database when it is established by inspection that the dam structure has been dismantled or the dam has been decommissioned in such a way that it can no longer cause hazard referred to in the DSA and that the dam no longer meets the criteria of section 4 of the Act. The inspection is undertaken by the dam owner and in the presence of a representative of the dam safety authority.

Before the inspection commences, the dam owner must make certain that the obligations under provisions of other Acts (Water Act, Environment Protection Act and Mine Act) are met. The dam construction permit and the associated legislation generally include provisions for decommissioning the dam and the obligations of the owner to dismantle the dam structures. The owner shall also inform the dam safety authority of the completion of decommissioning and the dismantling obligation according to a specified timetable. The obligations set out in the Dam Safety Act cease to be in force when the dam is recorded as decommissioned in the database.

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# APPENDICES

## Appendix 1 The cover page of a dam safety file

Date \_\_\_\_\_

### SAFETY FILE

Name of dam \_\_\_\_\_

Location municipality and site of dam \_\_\_\_\_  
Index number and name of dammed waterbody \_\_\_\_\_

Dam class \_\_\_\_\_ Class \_\_\_\_ dam

Purpose of dam \_\_\_\_\_  
Commissioned, date \_\_\_\_\_

Owner \_\_\_\_\_  
Address and phone number \_\_\_\_\_

Date and signature of dam owner \_\_\_\_\_  
Name in block letters \_\_\_\_\_

## Appendix 2 Contact information of dam owner and of responsible authorities

Date \_\_\_\_\_

### DAM DATA

Name of dam
Address and coordinates of dam
Dam owner
Address and phone number

### PERSONS RESPONSIBLE FOR SAFETY MONITORING, OPERATION AND MAINTENANCE OF THE DAM ON BEHALF OF THE DAM OWNER

1. Name and job description	Phone, e-mail	Address
2. Name and job description	Phone, e-mail	Address
3. Name and job description	Phone, e-mail	Address
ADDITIONAL INFORMATION (stand-by etc.)		

### CONTACT INFORMATION OF DAM SAFETY AUTHORITIES

ELY centre		
Address		Phone
1. Responsible supervisor	Phone, e-mail	Address
2. Deputy supervisor	Phone, e-mail	Address

### RESCUE SERVICE CONTACT INFORMATION

1. Rescue service	Phone, e-mail	Address

### WASTE AND TAILINGS DAMS: SUPERVISORY AUTHORITY (AS SET OUT IN THE ENVIRONMENTAL PROTECTION ACT)

1. Supervisor (as set out in the environment protection act)	Phone, e-mail	Address

### Appendix 3 List of completion documents

Date \_\_\_\_\_

Name of dam			ELY Centre		
Project			Municipality		
Document archive and archivist					
Contents	Scale	Drawing No.	Date	Designer	Notes

The completion documents of a dam may be compiled as one or several files as necessary. They include the design documents of structures with any changes made during construction noted, or such documents without changes but supplemented with a description and relevant drawings showing the changes. A summary of work supervision and records of inspections and the commissioning inspection are also needed.

## Appendix 4a Dams and dammed sections

Date \_\_\_\_\_

NAME OF DAM \_\_\_\_\_ (including all dams within the same reservoir system)

DAMS AND DAMMED SECTIONS

Elevation system:

Dam section, name	Stationing (or length of section, if stationing is not defined) (m)	Dam materials and type (e.g. a homogenous earthfill dam, zoned earthfill dam, concrete dam)	Width of crest (m)	Maximum height (m)	Lowest elevation of crest (m)	Lowest level of core top (m)	Minimum freeboard (m)	Slope inclinations		Changes / repairs, year	Notes
								wet	dry		

In this guide the term dam height is defined as the difference in height between the upper level of the impounded substance and the ground level outside the dam.

## Appendix 4b Gates and sills

Date \_\_\_\_\_

NAME OF DAM \_\_\_\_\_ (including all dams within the same reservoir system)

GATES AND SILLS (within the above dammed sections or separate)

Elevation system: \_\_\_\_\_

Structure and functional type (e.g. turbine gate, drainage spillway, flood spillway, log chute)	Location within dam (section and stationing) (m)-(m)	Length of sill (m)	Maximum discharge (m <sup>3</sup> /s)		Elevation of sill and the upper edge of bottom outlet		Outlet pipe		Gate closing installations:					
			at HW	at emergency HW	lower (m)	upper (m)	diameter (m)	elevation (m)	type	power source	control	de-icing	fixed emergency hoisting system	

## Appendix 5 Main dimensions of the reservoir area

Date \_\_\_\_\_

### MAIN DIMENSIONS OF THE RESERVOIR AREA

NAME OF DAM \_\_\_\_\_

RESERVOIR AREA	ELEVATION	AREA	VOLUME	
technical	NW	_____ m	_____ km <sup>2</sup>	_____ million m <sup>3</sup>
	NW	_____ m	_____ km <sup>2</sup>	_____ million m <sup>3</sup>
	HW	_____ m	_____ km <sup>2</sup>	_____ million m <sup>3</sup>
emergency	HW	_____ m	_____ km <sup>2</sup>	_____ million m <sup>3</sup>

Elevation system: \_\_\_\_\_

- technical NW = the technical low water level is the lowest possible water level structurally allowed by spillways
- NW = the lowest permitted upstream water level or, if not determined, the lowest design water level when the dam is in use
- HW = the highest permitted upstream water level or, if not determined, the highest design water level when the dam is in use
- emergency HW = high water level which, when exceeded, may cause changes in dam structures

### RESERVOIR AREA

reservoir storage capacity  
(volume HW–NW): \_\_\_\_\_ million m<sup>3</sup>

emergency storage capacity  
(volume emergency HW–HW): \_\_\_\_\_ million m<sup>3</sup>

Explain the basis for the proposed HW

---



---

Explain the basis for the emergency HW

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## Appendix 6a Hydrological parameters

HYDROLOGICAL PARAMETERS

Date \_\_\_\_\_

Name of dam \_\_\_\_\_

### 0. ELEVATION SYSTEM \_\_\_\_\_

#### 1. TOTAL CATCHMENT AREA ABOVE THE DAM:

(including the catchment area of the dam basin itself)

- 1.1 area \_\_\_\_\_ km<sup>2</sup>  
 1.2 lake percentage \_\_\_\_\_ %  
 1.3 mean annual maximum discharge \_\_\_\_\_ m<sup>3</sup>/s

#### 2. CATCHMENT AREA OF THE DAM BASIN:

- 2.1 area, incl. the surface area of the reservoir \_\_\_\_\_ km<sup>2</sup>  
 2.2 lake percentage \_\_\_\_\_ %  
 2.3 mean annual maximum discharge \_\_\_\_\_ m<sup>3</sup>/s

#### 3. DESIGN FLOOD AT DAM:

- |                                  | 3A. From the whole catchment area | 3B. With any by-pass discharges subtracted (see item 4) |
|----------------------------------|-----------------------------------|---|
| 3A.1 return period               | _____ years                       |   |
| 3A.2 maximum discharge (inflow)  | _____ m <sup>3</sup> /s           | 3B.2 _____ m <sup>3</sup> /s                            |
| 3A.3 maximum water level         | _____ m                           | 3B.3 _____ m  |
| 3A.4 maximum discharge (outflow) | _____ m <sup>3</sup> /s           | 3B.4 _____ m <sup>3</sup> /s                            |

#### 4. IF WATERS FROM THE UPSTREAM CATCHMENT AREA CAN BE CHANNELLED TO BY-PASS THE DAM, THE FOLLOWING INFORMATION SHALL BE GIVEN ABOUT EACH BRANCHING REACH:

- |                                    |                         |                         |
|------------------------------------|-------------------------|-------------------------|
| 4.1 location name                  | _____                   | _____                   |
| 4.2 catchment area                 | _____ km <sup>2</sup>   | _____ km <sup>2</sup>   |
| 4.3 catchment area lake percentage | _____ %                 | _____ %                 |
| 4.4 maximum discharge (inflow)     | _____ m <sup>3</sup> /s | _____ m <sup>3</sup> /s |
| 4.5 design high water level        | _____ m                 | _____ m                 |
| 4.6 by-pass discharge rate         | _____ m <sup>3</sup> /s | _____ m <sup>3</sup> /s |
| 4.7 by-pass discharge total        | _____ m <sup>3</sup> /s |                         |

#### 5. DISCHARGE AT THE DAM:

- 5.1 permit  
 5.1.1 maximum permitted discharge \_\_\_\_\_ m<sup>3</sup>/s  
 5.1.2 other regulations included in the permit (when applicable):

---

#### 5.2 discharge capacity of dam sills and flood gates (excluding flow through power plant):

- 5.2.1 at design high water level \_\_\_\_\_ m<sup>3</sup>/s  
 5.2.2 at high water level (HW) \_\_\_\_\_ m<sup>3</sup>/s  
 5.2.3 at emergency HW \_\_\_\_\_ m<sup>3</sup>/s

5.3 the shortest time for lowering the water level of the reservoir (e.g. 0.5 m, 1.0 m, 1.5 m, ... etc. per 24 hours), from the permitted HW level to the technical NW level when the inflow equals the mean annual maximum discharge \_\_\_\_\_ m<sup>3</sup>/s

5.3.1     \_\_\_ m                     \_\_\_\_\_ 24 h

5.3.2     \_\_\_ m                     \_\_\_\_\_ 24 h

5.3.3     \_\_\_ m                     \_\_\_\_\_ 24 h

6. MALFUNCTION OR DAMAGE:

6.1 time margin \_\_\_\_\_ hours from water level \_\_\_\_\_ to level \_\_\_\_\_, when the inflow equals the mean annual maximum discharge

6.2 time available to open all gates using the emergency hoisting system, for instance a hand-operated crank, a mobile emergency hoist or similar, from the time alarm \_\_\_\_\_ hours

7. ADDITIONAL INFORMATION:

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Design parameters are determined as set out in the instructions of appendix 10. The data on which the calculation was based and the time curves of the design flood, outflow and water level shall be given in an appendix if necessary (i.e. if the damping effect due to the reservoir is taken into consideration in the design).



## Appendix 6b Hydrological parameters of waste and tailings dams

Date:

Name of dam:

### 0. ELEVATION SYSTEM

#### 1. RESERVOIR CAPACITY

1.1 area  Mm<sup>2</sup>      volume  Mm<sup>3</sup>  
1.2 HW level       emergency HW

#### 2. DESIGN FLOOD AT DAM:

2.1 process inflow  m<sup>3</sup>/h  
2.2 reservoir catchment (meltwater and external catchment)  m<sup>3</sup>/h  
2.3 design precipitation  mm/24h  
2.4 design precipitation volume  m<sup>3</sup>  
2.5 reservoir emergency storage capacity (emergency HW-HW)  m<sup>3</sup>

#### 3. DISCHARGE CAPACITY INTO OTHER RESERVOIRS:

3.1 name/s of reservoirs   
3.2 water volume by gravitation  m<sup>3</sup>/h by pumping  m<sup>3</sup>/h

#### 4. DISCHARGE CAPACITY OUTSIDE DAM RESERVOIR:

4.1 Permitted discharge (environment permit)

4.2 Discharge volume at flood sills

#### MALFUNCTION OR DAMAGE:

5.1 time margin  hours from HW  to emergency HW  
 at mean annual discharge  
5.2 time available to activate emergency pumping system, from the time alarm is given  
 hours

#### 5. ADDITIONAL INFORMATION:

---

Design parameters are determined as set out in the instructions of appendix 10. The data on which the calculation was based and the time curves of the design flood, outflow and water level shall be given in an appendix if necessary (i.e. if the damping effect due to the reservoir is taken into consideration in the design)

## Appendix 7 Dam monitoring programme

### MONITORING PROGRAMME

Name of dam

#### Continuous monitoring:

Object	Measures and monitoring frequency

#### Special situations

In addition, monitoring is increased when occasioned by floods, heavy rainfall, severe winds or other similar specific strains as follows:

--

The annual inspection shall include:

--

**The periodic inspection** every five years (or more frequently, if necessary) shall include (itemised list):

**NOTES ON MONITORING BY PROGRAMME AUTHOR**

**Monitoring programme valid through:** \_\_\_\_\_

**Date:** \_\_\_\_\_

**Programme author's signature and name in block letters:**

\_\_\_\_\_

**Profession:**

**Address:**

**Phone:**

**e-mail:**

**NOTES OF DAM SAFETY AUTHORITY**

**Approval decision:**

**Approved at ELY** \_\_\_\_\_

**Date:**

**Docket number:** \_\_\_\_\_

**Signature and name in block letters of official:**

\_\_\_\_\_

## Appendix 8a Description of safety arrangements

Date \_\_\_\_\_

### SAFETY ARRANGEMENTS FOR DAM

Name of dam \_\_\_\_\_

Operating personnel have been trained as follows:
Operating personnel readiness arranged as follows (including malfunction):
Remote control of dam operation arranged as follows:
Technical arrangements to ensure the operation of the dam in case of disturbances:
Arrangements concerning the discharge of a watercourse dam to prevent danger to those above or below the dam:
Arrangements to prevent damage caused by sabotage or vandalism:
Other:

DDS section 9: The owner of a dam must prepare and keep up to date a description of safety arrangements and provide this to the dam safety authority if this is not shown in the other documents provided to the dam safety authority.

## Appendix 8b Description of waste and tailings dam safety arrangements

Date

Name of dam:

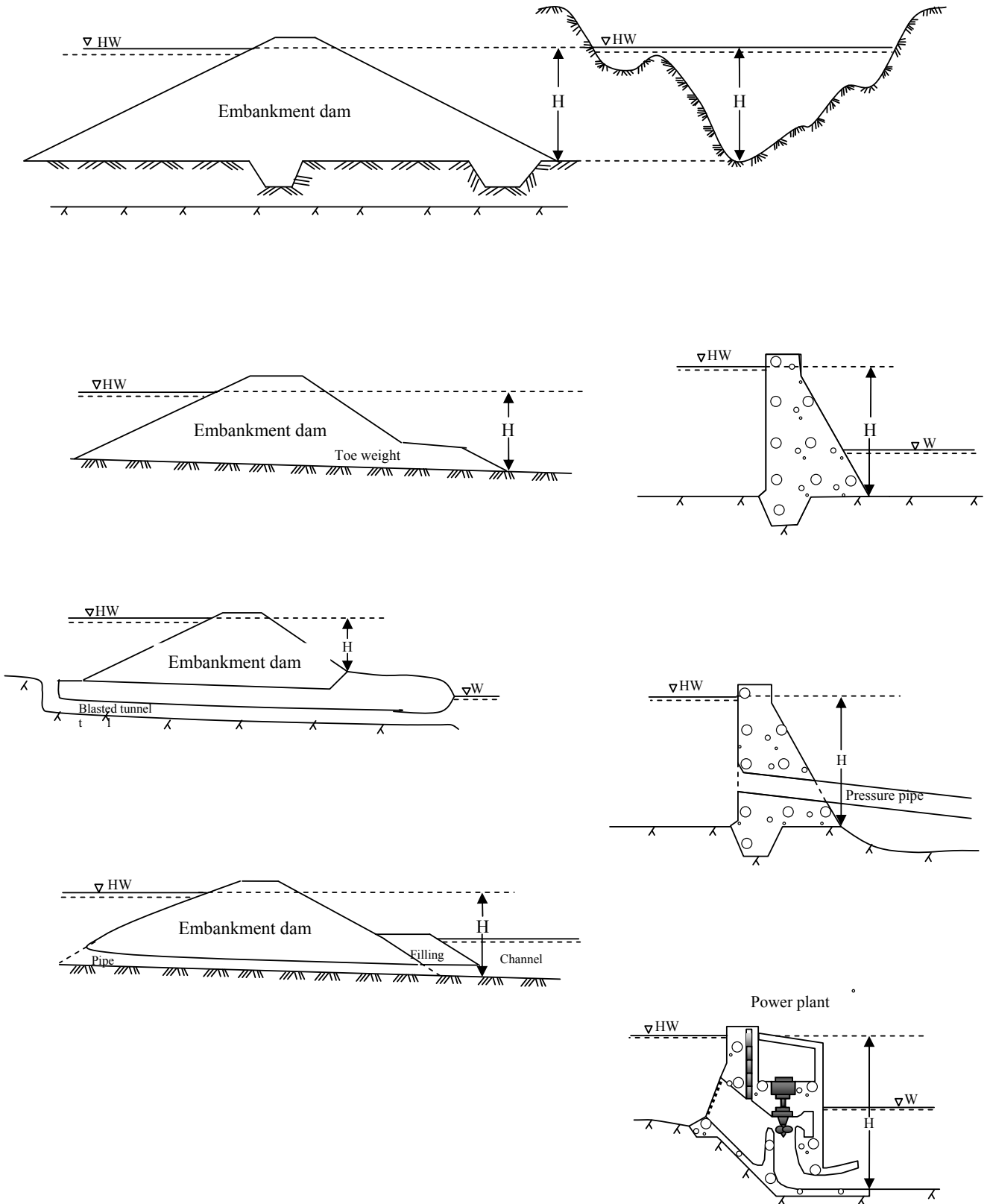
Operating personnel have been trained as follows:
Instructions for dam operator (e.g. OMS manual):
Operating personnel readiness arranged as follows (including malfunction):
Have the plant process risks that affect the dam and reservoir been identified? What measures have been taken?
Arrangements for warning/evacuating people in the dam break hazard area:
Are there structures in the mine area designed to minimise damage caused by a dam break flood wave?
Remote or automatic monitoring equipment at dam reservoir (monitors for pump houses, water levels, flow, camera monitors, CCTV etc.):
Arrangements to prevent unauthorised access to the dam area or to warn the public of danger:
Arrangements to prevent damage caused by sabotage or vandalism:
Other:

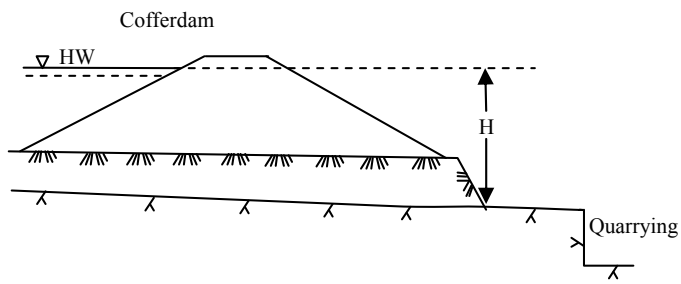
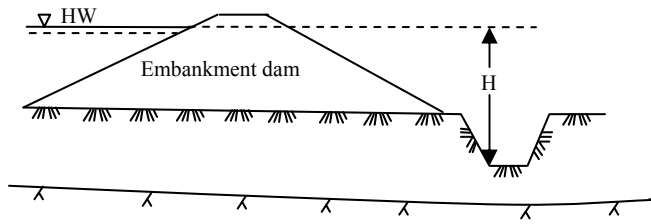
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DDS section 9: The owner of a dam must prepare and keep up to date a description of safety arrangements and provide this to the dam safety authority if this is not shown in the other documents provided to the dam safety authority.

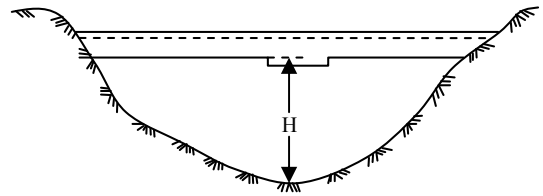
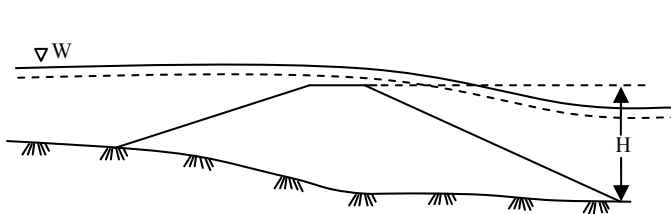
## Appendix 9 Defining dam height

In this guide the term dam height is defined as the difference in height between the upper level of the impounded substance and the ground level outside the dam.





Measuring weir height



## Appendix 10 Hydrological dimensioning of a watercourse dam

### 1 HYDROLOGICAL DESIGN REQUIREMENTS TO BE MET BY DAMS

A watercourse dam is designed for the water flow that causes the maximum need for discharge (DDS section 2). The dimensioning is presented as the annual probability or frequency of flooding which corresponds to such a water flow (design flood). Table 1 shows the probability or frequency of design flood for different dam classes. Example: The design flood used for a class 1 watercourse dam is one which has a probability 0,02 – 0,01 per cent of occurring, that is once every 5000 – 10000 years. The dam discharge capacity is determined on the basis of design outflow, excluding the flow through the power station machinery. In designing the basins and dams off the channel proper, the value of the design flood can be deduced from the catchment area of the basin, provided that the inflow channels of the basin can be shut if necessary. It is imperative to ascertain whether the inflow channels can also be shut under abnormal flood conditions. At the initial stage of dam planning it is important to ensure that the class and dimensioning of the dam are compatible with existing dams in the waterbody. Data on these are available from the owners of the dams and from ELY centres.

Where appropriate, lower design values can be used in designing cofferdams, but when determining free-board, for instance, special attention must be paid to the effect of ice, e.g. of frazil ice, in winter. There are no formal design rules for cofferdams because the needs and requirements of these dams vary greatly depending on local conditions.

Table 1. Design flood return period and probability calculations for different dam classes.

<b>Class</b>	<b>Return period, years (probability)</b>
1	5 000–10 000 (0.02–0.01 per cent)
2	500–1 000 (0.2–0.1 per cent)
3	100–500 (1–0.2 per cent)

### 2 DETERMINING THE DESIGN FLOOD

The selection of method to determine the design flood depends primarily on the hydrological data available. The selection is also influenced by the properties of the basin, the type of regulation, the regulation implemented in the upstream area, and other changes in the catchment area.

Depending on the data available, the determinations are made as follows:

- 1) If more than 20 years of maximum discharge data are available on the dam site a frequency analysis is made using the Gumbel method.
- 2) If a record of maximum discharge data covering 5–20 years is available on the site, the data are submitted to frequency analysis. It is recommended that an additional analysis be made on a long sequence of maximum discharge data from an adjacent watercourse using the same years as for the target waterbody.
- 3) If a set of data covering more than five years is available on the same watercourse close to the dam site (less than 20% change in catchment size, no major lakes in between), its maximum discharge data can be converted into those on the dam site directly in proportion to the catchment areas, thereafter proceeding as described in 1 or 2, depending on the length of the observation sequence.
- 4) If a set of data covering more than five years is available on the same watercourse (not unreasonably distant), but which, however, does not meet the criteria of item 3 above, its maximum discharge data are converted into those on the dam site using nomograms, other sets of data and general hydrological knowledge, thereafter proceeding as in 1 or 2, depending on the length of the observation sequence.
- 5) Otherwise, frequency analyses made using the Gumbel distribution on data sets exceeding 20 years are used on the two most appropriate reference watercourses. The results are corrected by taking into account the difference in hydrology between the reference and target watercourses. Even a short data set on the target watercourse, preferably from the dam site, is of particular importance.



- 6) If there are no appropriate reference watercourses, the assessment must be based on nomograms, the hydrological properties of the catchment area and discharge data collected at the dam site during the design period.
- 7) The coefficients listed in table 3 can be used to determine a design flood flow corresponding to a return period exceeding 100 years.

The effect of other factors is taken into account as follows:

- A. If the volume of a basin is so large that it can be assumed to dampen the design flood, the entire design flood hydrograph shall be determined (Fig. 1):
  - 1 Maximum discharges of different durations (e.g. 1, 3, 5, 10 and 20 days) and their occurrence in relation to the flood peak are calculated from the annual maximum discharge peaks.
  - 2 An analysis of return periods is made on maximum discharges of different durations using the Gumbel distribution of extreme values.
  - 3 A hydrograph is compiled in which the maximum discharges of different durations are those referred to in A.2, and their relative occurrence corresponds to the average occurrence in A.1. If it is manifest from A.1 that the temporal distribution of major floods differs from that of minor floods, this fact can be taken into account when dating maximum discharges of different durations. It is not necessary to compile a hydrograph if the dimensions of the dam are sufficient to contain undamped floods.
- B. The analysis of return periods of rare flood cases can, as a rule, not be based on a set of data on regulated flows. Rather, the inflow from the upstream area of the regulation structure, the bulk of which at least comes from the unregulated region, shall be taken as the basis.
- C. If major regulation works have been built in the upper catchment area, calculation of the design flood should begin with the uppermost regulation works. The effect of each dam on the magnitude of the design flood is then assessed by moving downstream (if necessary, taking into account the impact of a dam breach). In practical terms this usually requires that data on dams in the watercourse - and the effect of those dams on the advance of the flood - be obtained from the dam owners and water authorities.
- D. Any extensive draining and other works affecting runoff in the upper catchment area must be taken into account when determining the design flood. Before the analysis of return periods is conducted, the maximum discharges predating the project shall be corrected to present-day conditions using a coefficient based on the estimated impact of the project. If the changes in the catchment area continue and their final magnitude can be estimated, this can be taken into account when determining the value of the coefficient.
- E. If a dam (and the associated basin) is located off the main channel or if, in the upper reaches of the watercourse, the flow has been directed from one part of the watercourse to another using canals or other structures, the distribution of the flow between the channels in the event of infrequently recurring floods should be assessed for each branching point. The distribution should be based on the prevailing conditions, because the value used in design rarely corresponds to actual conditions. If one of the channels at a fork can be completely closed, this can be taken into account when determining the design flood. However, it is imperative to know with certainty that the channel can be closed if necessary. During infrequently recurring floods water may take unusual paths in some watercourses even if there are no structures such as those mentioned above.

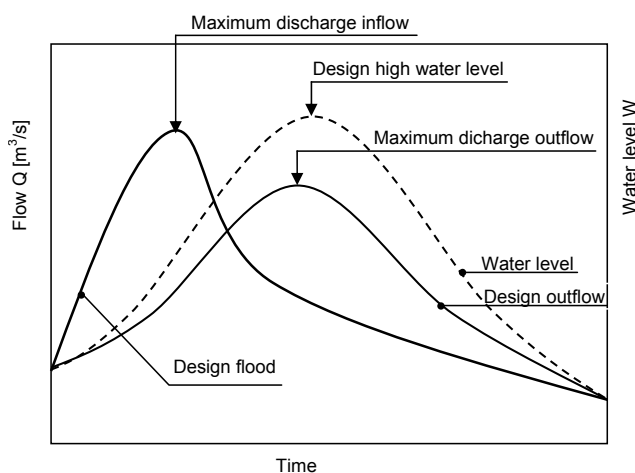
### **3 DETERMINING DESIGN HIGH WATER LEVEL AND DESIGN OUTFLOW**

Design high water level and design outflow are determined from the design flood, the water level at the onset of the flood and the surface area curve of the reservoir. For existing dams, the design high water level is derived exclusively from the design flood and the initial water level. The best combination of design high water level and design outflow is sought for dams being designed. In both cases allowances must be made for wind, flow changes and the impact of ice and these factors added to the design high water level calculations to the extent it is deemed necessary. When the discharge capacity of a dam is determined, the flow through the power station machinery is excluded from calculations.

If the volume of the reservoir is very small, the design outflow equals the design flood. In such a case the initial water level is not of major significance and the design high water level is determined by the design flood, the channel and the discharge capacity of the dam. Where the reservoir volume is greater, the design high water level and the design outflow are calculated using either a simple water balance method or a method that takes into account the inclination of the water surface in the reservoir. The latter is applied to long, narrow reservoirs. The length of the time step used in the calculation depends on the surface area of the reservoir and on the magnitude of the inflow. The results can be presented graphically as shown in Figure 1. For summer and winter floods and for reservoirs with minor water resources it is recommended that the highest permitted water level of the reservoir be taken as the initial water level of the reservoir and, for the spring flood, the water level that existed before the flood, determined from the operational data.

An ice jam or frazil ice in a river may cause a high water level with a return period significantly longer than that of the maximum discharge occurring during the existence of the ice jam or frazil ice. The high water level in the reservoir may be markedly affected by the volume of ice gathered in the reservoir or by the impact of ice on the discharge structures.

The return period of the inflow chosen for use in dimensioning the spillways depends not only on the safety factor against a dam breach but also on dam construction costs. The return period is a statistical parameter and the probability that the design flood will be exceeded increases along with the operational age of the dam. If, for instance, the operational life of a dam is assumed to be 100 years, then there is a 63% probability that a flood with a frequency of less than once in 100 years will occur during this time and an 18% probability that a flood with a frequency of less than once in 500 years will occur (table 2). Since dams, excluding temporary structures, are designed to last for a long time, there is no point in dimensioning them on the basis of a short return period.



Dam design is facilitated by the fact that a change in the design flood decreases relative to an increase in the return period. If a flood with a frequency of once in 1000 years is taken as the design flood, the design discharge is only 30% greater than if a flood with a frequency of once in 100 years had been selected as the design flood (Table 3). Hence, the dam construction costs do not, as a rule, increase very much when the return period of the design flood is lengthened.

Figure 1. An example of reservoir routing (Figure: Pekka Vuola, 2006).

Table 2. Probability (%) of design flood being exceeded during return period as a function of design operational life of structure.

Flood return period (years)	Design life of dam (years)					
	10	50	100	200	500	1000
10	65	99	100	100	100	100
50	18	64	87	98	100	100
100	10	40	63	87	99	100
200	5	22	39	63	92	99
500	2	10	18	33	63	86
1 000	1	5	10	18	39	63
5 000	0.2	1	2	4	10	18
10 000	0.1	0.5	1	2	5	10

Table 3. Ratios of maximum discharges at some observation sites determined using the Gumbel distribution of extreme values.

	Observation site	<u>HQ1000</u> HQ100	<u>HQ5000</u> HQ100	<u>HQ10000</u> HQ100
4:6	Lieksanjoki, Ruuna	1.28	1.47	1.55
4:24a	Koitaajoki, Lylykoski	1.27	1.46	1.54
4:8087	Kallavesi, Konnus + Karvio	1.28	1.48	1.57
14:9	Vuosjärvi, Huopanankoski	1.27	1.46	1.54
14:29	Nilakka, Äyskoski	1.28	1.48	1.56
14:50	Petäjävesi, outlet	1.30	1.51	1.60
16:1a	Koskenkylänjoki, Pyhäjärvi	1.35	1.59	1.70
28:3	Aurajoki, Hypöistenkoski	1.32	1.55	1.65
35:94	Loimijoki, Maurialankoski	1.30	1.50	1.59
42:10	Kyrönjoki, Lansorsund	1.26	1.44	1.51
44:5	Lapuanjoki, Pappilankari	1.29	1.49	1.57
51:2	Lestijoki, Lestijärvi	1.28	1.47	1.56
54:4	Pyhäjoki, Pyhäkoski	1.29	1.49	1.58
57:7	Siikajoki, Länkelä	1.30	1.51	1.60
59:19	Lammasjärvi, outlet	1.29	1.49	1.58
60:4	Kiiminginjoki, Haukipudas	1.30	1.50	1.59
61:19	Iijoki, Merikoski	1.26	1.45	1.52
65:17	Kemihaara, Kummaniva	1.26	1.43	1.51
65:36	Ounasjoki, Marraskoski	1.31	1.48	1.56
67:8	Muonionjoki, Muonio	1.25	1.43	1.51
67:22	Tornionjoki, Karunki	1.25	1.42	1.49
71:8	Juutuanjoki, Saukkoniva	1.28	1.48	1.56

## 4 DETERMINING DESIGN FLOOD USING HYDROLOGICAL MODEL CALCULATIONS

Where a hydrological model comprising runoff, river, flood area and lake models is already made for the waterbody for prognosis or planning purposes, the model can be used for calculating the design flood. Care should then be taken that the calculations of water height and discharge are based on the exceptionally large water volumes of a design flood, for example, by calculating the advance of discharge within and outside the river channel using a hydraulic river model.

The use of hydrological and hydraulic models is recommended in extensive and regulated waterbodies. If necessary, the models can also be used to calculate the design highwater level and design outflow of reservoirs and lakes. If there are insufficient hydrological observations of the dam site, model calculations can be used instead of the comparative waterbody method. Models can also be used to calculate the possible effects of exceptional conditions, such as climate change. The following method of calculation is based on a hydrological model and can be applied when calculating the design flood for a class 1 dam, that is floods recurring every 1/5000-1/10000 years.

With the hydrological model, the design precipitation that produces the design flood must be determined (Flödeskommittén, 1990). The Finnish Meteorological Institute report Patoturvallisuuden mitoitussadannat ("Dam safety design precipitation") provides design precipitation data. Design precipitation values are derived from data available in the Finnish Meteorological Institute report on dam safety design precipitation (Solantie & Uusitalo, 2000). The report gives the design precipitation volumes repeated once every 10 000 years for 1, 5 and 14 days at different times of the year for catchment areas of different sizes in Finland. Multiplying the 1/10 000 years precipitation by 0,83 produces an estimate of the 1/ 1 000 years precipitation, which is generally used as the design precipitation in dimensioning class 1 dams. The 14 day design precipitation used comprises the sum

of rainfall in the report over 14 days corresponds to the 14-day design precipitation, the sum of rainfall over days 7-11 corresponds to the 5-day design precipitation and the precipitation on day 5 to the 1-day design precipitation. Figures 2 and 3 show examples of different volumes of design precipitation during different months and in areas of different size in eastern Lapland and southern Ostrobothnia. The May-June precipitation presented by Solantie and Uusitalo are mainly based on observations in June. The values are therefore inflated, particularly in early May. Moving from the March-April design precipitation to the May-June design precipitation should therefore progress steadily during May in such a way that the May-June values are arrived at only in early June.

The hydrological model design flood calculation is found by moving the design precipitation forward a day at a time over the available period of meteorological data (40 years) and by calculating the flood resulting of the design precipitation at each move. The maximum flood of the period is used as the design flood. A period of 40 years is recommended, whereby sufficient values for the water equivalent of snow and different meteorological phenomena are included.

It is important, particularly in springtime, to avoid unrealistic combinations of warm periods associated with high pressure systems and increased rainfall associated with low pressure systems. To avoid these, the temperatures of the design precipitation period are limited so that they do not exceed 75% of the probability value of the month in question. The temperatures can then be estimated on the basis of the daily mean temperature distribution given in Climate statistics of Finland (Tilastoja Suomen ilmastosta 1961–1980, Heino & Hellsten, 1983).

One should also avoid including the unrealistically high precipitation values that may be observed at the beginning or end of the precipitation period. The rainfall values next to the design precipitation period should be limited in such a way, that a 14-day precipitation sum under no circumstances exceeds the previously determined design precipitation.

In large catchment areas with numerous lakes, where the delays are long and the storage capacity is plentiful, the design flood is determined by adding another 14 days to the precipitation period. The critical duration of precipitation at Oulunjärvi is about one month and at Saimaa two to three months. However, the calculations for objects of this kind can be determined on the basis of a 14-day design rainfall provided a long enough time series, 40 years, is used. The timing of the design rainfall will then, in the final design flood situation, be bordered by the precipitation sums of extensive observation periods. The one-month precipitation sum can be limited to the 14-day precipitation sum multiplied by 1.55. Where a period significantly shorter than 40 years is used, large waterbodies of extensive lake systems indicate the use of one month as the design precipitation period. In cases like this, the 14-day precipitation sum multiplied by 1.55 should be used as the one-month design precipitation period.

A design flood determined from precipitation, snow or temperature data with the hydrological model cannot be given exact return periods. The estimated frequency of the design rainfall recommended above is once in 1 000 - 10 000 years, based on a 40-year period of daily observations. The derived flood frequency is generally about 1/5 000-1/10 000, when compared to the results of analysis by statistical methods (Veijalainen & Vehviläinen, 2008). The design flood frequency is therefore sufficient for class 1 dams, and corresponds well to international frequency values.

The design flood calculated with the waterbody model should be checked, as far as possible, with frequency analyses based on discharge or water height observations as specified in section 2.

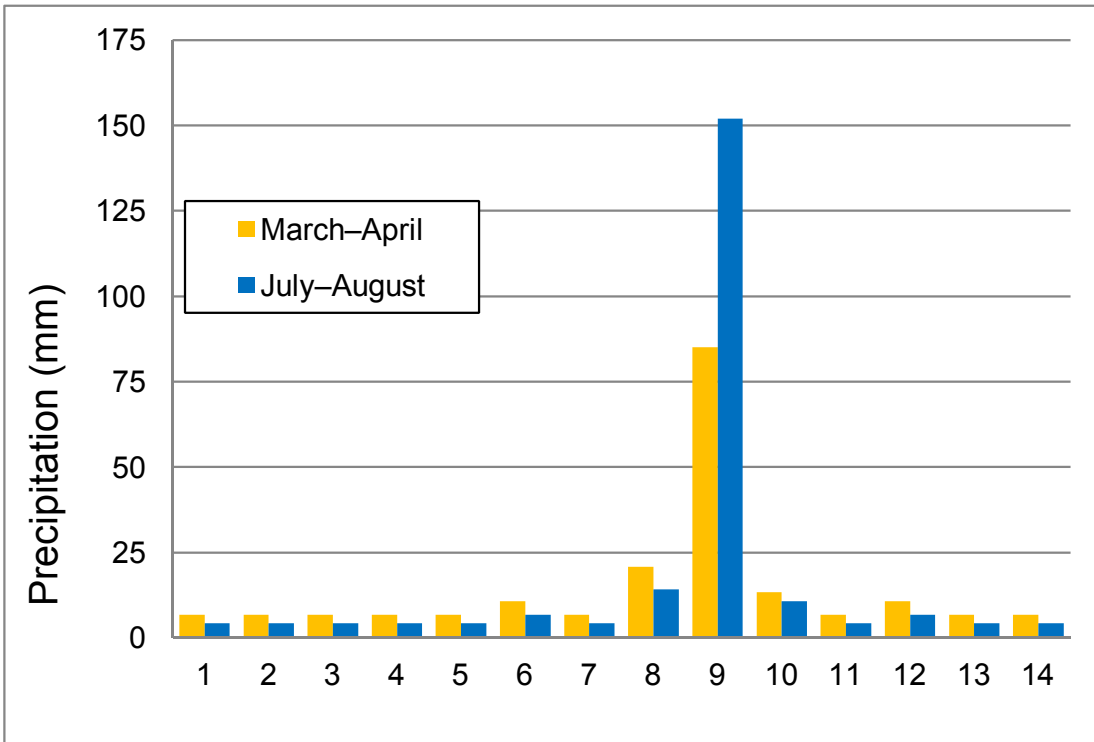


Figure 2. Design precipitation in March-April and July-August in a 71 km<sup>2</sup> area at Lapuanjoki in southern Ostrobothnia.

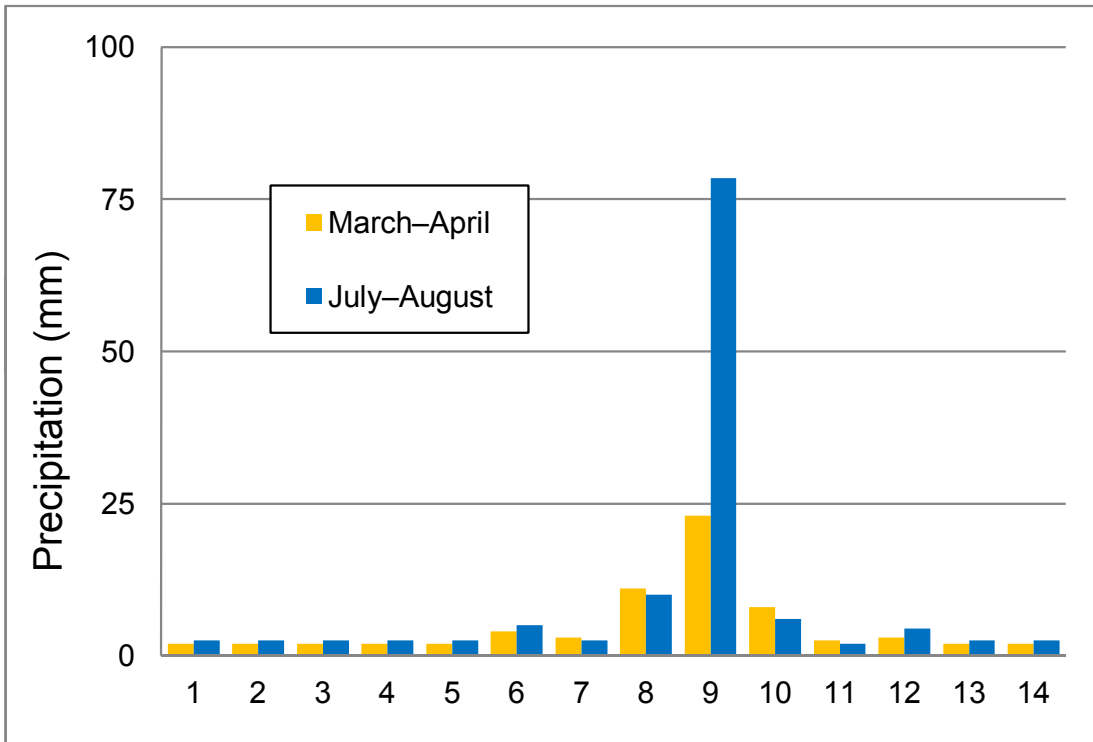


Figure 3. Design precipitation in March-April and July-August in a 27 100 km<sup>2</sup> area at Kemijoki in eastern Lapland.

# Appendix 11 Embankment dams

## 1 PLANNING

### 1.1 Competence of the designer

In this context, planning is defined as every type of planning and similar preparatory design work, for instance designing a new dam, planning the alteration or repair work of an existing dam or undertaking an assignment as an expert, assessor or risk manager associated with the dam operation.

The competence of the designer is based on training and experience in the field. The required competence depends on the demands of the designing task at hand. The FISE website [www.fise.fi](http://www.fise.fi) shows information on qualified ground construction designers of different grades. The information on the FISE website can be used to assess the competence of a designer. However, the fact that a person's name is not found on the FISE website does not mean that the person is not qualified to design embankment dams.

It is important to note that the responsible designer of an embankment dam should have the right training and also sufficient experience in embankment dam design. The design standards and the competence requirements of the designer are not diminished even if a dam is temporary or intended for short-term use. Cofferdams and flood embankments, for instance, should be designed to the same standards as permanent dams.

### 1.2 Loads and calculations

The different parts of the dam are dimensioned taking into account the weight of the materials in the structure, the loads due to seepage (pore water pressures), the forces caused by waves and frost, and the traffic load on the dam crest. Vibrations due to blasting may also create loads during construction. Depending on the case, other external loads shall also be taken into account in calculations.

Figure 1 shows an embankment dam cross-section with the structural parts named. Names vary in the literature: the shoulder may be called the shell and the core may be called the central section or impervious core. The different structural parts of a dam are presented in detail in this appendix, items 1.5.2–1.5.7.

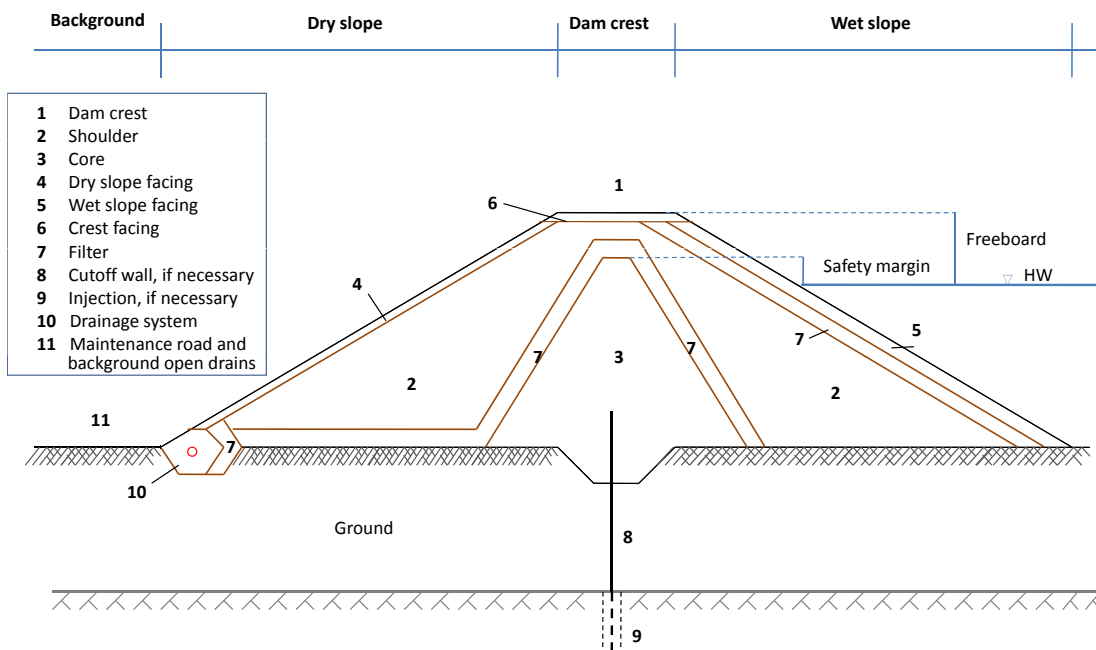


Fig. 1 Cross-section of an embankment dam and its structural parts.

The stability of a dam is calculated during construction (as a rule, the critical moment comes on completion of the work), in normal operational situation and after a fast drop in the water level (as a rule, the critical moment comes when the water level drops from HW to technical NW). Other loads are determined case by case. Stability calculations include the stability of both the dam and the foundation.

Dam and foundation settlement shall be assessed using normal calculation methods.

Every assessment shall account for the effects of internal erosion. Internal erosion can at times progress very swiftly and must be assessed even if the intended period of dam use is short.

When defining the assessment loads and stability calculations, the age and operation of the dam can be taken into account by designing the dam for the intended period of use and according to the dimensioning design situations. Examples:

- dams built for long-term use are, for instance, normal dams in a waterbody and waste dams that are dimensioned for long-term use
- embankment dams are dams that allow the designer to take into account temporary nature of a flood
- with cofferdams the designer can take into account the possibility of regulating the waterbody on order to control the design water level; the effect of the seasons can be taken into account by, for instance, excluding frost penetration from freeboard dimensioning calculations, if construction is completed in one summer.

### 1.3 Calculation of seepage flow

Seepage flows through embankment dams via the foundation or rock and from the side are assessed for different cross-sections. The calculations are performed using methods of proven reliability. The sites where the dam joins rock or concrete structures shall be inspected separately. Seepage flows shall also be inspected on the boundary surfaces of all other structures associated with or running through the dam. Flows on these surfaces must be cut off or restricted to ensure that the flow is smaller than in the enveloping dam. A site where a dam is connected to a river bank shall usually be assessed in terms of seepage flow.

When determining the dimensioning parameters, the inhomogeneous and anisotropic nature of the foundation and the dam zones must be taken into account.

The water level difference on the different sides of the dam reservoir as well as weather conditions, e.g. precipitation, ice-melt, affect the water retention and pore pressure of the dam and foundation. When determining flow channels and water retention in terms of dam stability and seepage flow, the designer must weigh all pertinent factors that may contribute to the threat of internal erosion.

### 1.4 Internal erosion

An embankment dam must be designed to resist the development of harmful internal erosion. Internal erosion should be assessed for each dam zone and foundation level as well as for boundary areas (groins). The possible effect of the bedrock on erosion shall also be taken into account.

Internal erosion means that the materials contained in different zones, foundation layers and in rock formations separate and are transported, primarily through seepage flow. The seepage flow is concentrated in the affected areas and in cracks, where it is strengthened, causing yet more internal erosion. The result can be either a significant change in the seepage flow with reduced dam stability as a consequence or the formation of an erosion pipe. In both cases the dam may collapse.

If cracks are formed in the dam, these may trigger internal erosion and the formation of an erosion pipe. Cracks can form when the foundation settles unevenly or when internal strain is caused by significant variations in height. Other causes include insufficient stability and dry-shrinkage. In Finland, frost is a major cause of cracking. In the cold season frost causes cracks in a dam and during the thaw the dam material is loosened. Melting frost lenses are local cracks in a dam that may also create the beginning of an erosion pipe.

## 1.5 Minimum requirements for dams

### 1.5.1 Stability

The total safety factor of dams in a state of constant seepage flow should be at least 1.5. At the final stage of construction and on a sudden fall in water level (HW-NW) total safety factor should not be less than 1.3.

### 1.5.2 Freeboard of a dam

The freeboard of a dam (difference between the dam crest and the HW level) is derived from the maximum wave height at HW and the design frost penetration. As a rule, the depth of frost penetration is the deciding factor. When assessing the effect of depth of frost penetration, the structure of the dam should be considered, since certain types of structure avoid the dangers of frost.

A preliminary calculation of wave height can be made solely from the length of open water using the formula  $h = 0.36 \times \sqrt{L}$ , where  $h$  is the height of the wave (m) and  $L$  the length of open water (km). The freeboard should then be at least 1.75 times the height of the maximum wave. More detailed dimensioning, and always when the length of open water exceeds 10 km, takes account of the direction, duration and velocity of the prevailing winds, for instance, as set out in the publication Kjaernsliin et al, (1992) *Rockfill Dams, Design and Construction*.

Frost penetration for class 1 and 2 dams should be derived from the cold content F10 occurring once every 10 years for class 3 dams F5 occurring once every 5 years (Routasuojaus – rakennukset ja infrarakenteet Suomen Rakennusinsinöörien Liitto RIL ry, 2013). The section on frost protection in this publication uses the Dam safety guide as a source. The publication also contains the statistical cold content for the whole of Finland, derived from observations of the Finnish Meteorological Institute in the period 1978 – 2007.

The effect of snow as a factor reducing frost penetration is not usually taken into account when the freeboard is dimensioned. This is always the case where a public road or other regular traffic runs on the dam crest or if snow on the road is ploughed even at random times.

The freeboard requirements of old dams can be determined on the basis of sufficiently representative observations of frost penetration and snow depth as well as cold content.

In table 1 the depth of frost penetration of a homogeneous moraine dam, a clay-core zoned embankment dam and a moraine-core zoned embankment dam is determined with the square root of the cold content and values of coefficient  $k$  of the dam type from the formula  $Z = k \times \sqrt{F}$  (Kuusiniemi 1995). The values in the table can be applied to determine the freeboard of the crest in embankment dams built of natural materials. In this case the effect of snow as frost insulation is not included in the calculations.

The frost penetration of a zoned embankment dam with moraine core can be determined by applying the value of coefficient  $k$  for homogeneous embankment dams, provided the impervious core and the sand and gravel filters are wide and extend to the crest in such a way that airflow in the stone material does not affect the frost penetration depth of the dam.

Determined as above, the freeboard can be reduced by insulating the crest against frost, in which case, however, the frost insulation must be dimensioned separately. It is recommended that extruded polystyrene cellular plastic boards at least 50 mm thick should be used for insulation. Thinner boards are not recommended due to the risk of fracture and the decline in thermal insulation capacity due to more rapid waterlogging. All of the insulation and the sand layer beneath it must be located above the emergency HW level.

The freeboard determined on the basis of frost penetration can be reduced by ensuring that the upper part of the dam is sufficiently watertight down to the frost penetration depth estimated as above. The dam can be made watertight using insulation film, bentonite matting or fill, or some similar structure. This structure must be located so as not to impair dam stability.



Table 1. Estimating frost depth on snow-free dam crest with the formula  $Z = k \times \sqrt{F}$ .

Cold content F (Kh)	Frost depth (m)		
	Homogeneous moraine dam	Zoned earthfill dam	
	k = 0.0120	clay core k = 0.0105	moraine core k = 0.0130
10 000	1.20	1.05	1.30
15 000	1.47	1.29	1.59
20 000	1.70	1.49	1.84
25 000	1.90	1.66	2.06
30 000	2.08	1.82	2.25
35 000	2.24	1.96	2.43
40 000	2.40	2.10	2.60
45 000	2.55	2.23	2.76
50 000	2.68	2.35	2.91
55 000	2.81	2.46	3.05
60 000	2.94	2.57	3.18

### 1.5.3 Safety margin of a dam

The safety margin of class 1 and 2 dams (difference between the top of the core and the HW level) should be no less than 0,4 m, and for class 3 dams 0,3 m. Allowance must also be made for settlement of the structure and foundation. The safety margin of a tailings pond is defined as the difference between the HW level and the bottom of the core.

### 1.5.4 Wet slope facing

The size of blasting stones and boulders in wet slope facing and the thickness of the facing are determined by the maximum wave height. The range of variation in high water determines the extent of facing. If the damaging effect of ice loads is to be taken into account, the average diameter of the boulders should be 0.4 - 0.6 m. If smaller stones are used, the structures may need to repairs from time to time.

### 1.5.5 Dam crest

The crest width of class 1 and 2 dams should be at least four metres. The width must be increased by 0.5 m if the height of a dam exceeds 10 m, and by a further 0.5 m for each successive 10 m. In special cases the crest width of class 2 dams less than 4 m high can be less than 4 m. The crest of class 3 dams should be no less than 3 m wide. The crest should be passable for maintenance vehicles over its entire length. Waste dams with release pipes on the dam crest should be widened by the width taken up by the pipe system.

### 1.5.6 Filtering structures and drainage system of a dam

The filtering structures and the drainage system should be so dimensioned that they are capable, in all circumstances, of protecting the core against erosion and of discharging the waters seeping through, under or around the dam and to smooth any peaks in flow gradients. The filtering structures must meet the grain size criteria, and their permeability must be 100 times that of the protected structure. The drainage system must be able to put through a volume which is ten times that of the calculated total seepage water. Drainage systems for dams include filtering layers, drain pipes and ditches. No part of a drainage system may be impermeable. Calculating the thickness of the filtering layers is part of the calculation of seepage flow. The potential effects of internal erosion shall be taken into account in dimensioning the filtering layers.

### 1.5.7 Vegetation

The amenity of the dam area and its impact on the landscape can be enhanced with trees, bushes and ground vegetation. Vegetation prevents erosion of the dam surface. The vegetation must not, however, endanger the structure or impede dam maintenance. The effect of vegetation on dam safety varies from case to case, depending on the structural characteristics of the dam and on environmental aspects. The homogenous structure of an earthfill dam or embankment dam provide a habitat that is completely different in comparison with a zoned dam. No general instructions can be laid down concerning trees and other vegetation at a dam: each case must be judged on its own. Vegetation in connection with dams has been studied in "Kasvillisuuden, eläinten ja luvattomien toimenpiteiden vaikutus maapatoihin" (The effect of vegetation, animal life and illegal acts on earthfill dams) (Saarinen, 2010).

A number of earthfill dams and many embankment dams have been left to grow trees almost unchecked. Even in these cases it is important to reflect on which trees to cut down and which to leave, or whether to cut down all the trees. Removing trees and bushes after the dam is commissioned is, however, a secondary method of managing the vegetation of a dam. In the first instance, any planted vegetation types and the location of plants should be decided in the design and construction stages.

#### **Wet slope**

As a rule, no trees with trunks are allowed on the wet slope. Bushes growing on the bend between the wet slope and the crest are, however, advantageous for the accumulation of snow. In exceptional cases and subject to a separate investigation, larger trees can be permitted, provided they do not harm the dam in any way. Trees can grow on wider sections built during the construction or repair of a dam. Such sections can also serve to shelter boats or lessen the visual impact of the dam outline on the landscape.

#### **Dam crest and dry slope**

As a rule, trees are not permitted on the dam crest. Low bushes may grow at the bend between the slope and the crest, outside the access area of machines. On the dry slope, trees with trunks may grow provided they do not endanger the structure. Tree and bush growth on the slope should be sparse and not impede the view of the dam for inspection purposes. The area of dam and background subsurface drains that are part of drainage systems should be kept clear of trees and bushes in a zone 5 to 10 metres wide, depending on the conditions. At the back of the dam, trees at the foot of the dry slope must not prevent maintenance or inspection.

## 1.6 Transport connections and traffic on the crest

The crest of an embankment dam of class 1 and 2 must be passable to traffic throughout its length (DDS section 5 (2)). The aforementioned does not apply to flood embankments (DDS section 5 (3)). It is recommended that, apart from maintenance vehicles, no motor traffic be permitted on the dam crest. If other traffic is allowed, the dimensioning and structural solutions of the dam should correspond to the demands of such traffic.

The dam must have road access and, where necessary, the design must allow maintenance of the dam, even in case of flood or dam accident (DDS section 4 (3)). It is recommended that a maintenance road be built immediately by the dry slope of the dam and, for class 1 and 2 dams, at least two access roads from public roads. Under normal operating circumstances the maintenance road is needed for observation of the dry slope and the back of the dam, as well as for maintenance and repair work. Maintenance roads and access roads must be capable of bearing heavy traffic loads, even during the thaw. Maintenance roads should have wider stretches for meeting traffic, turnarounds as well as on-ramps to the dam crest.

Boulders for emergencies should be stored along maintenance roads or access roads or along comparable access paths.

## **1.7 Filing the design documents**

Calculations and data on materials and other design documents are filed so as to be available for later repairs should the need arise. The main design information is filed together with the completion documents.

## **2 CONSTRUCTION, MAINTENANCE AND REPAIRS**

### **2.1 Work management and supervisory personnel**

The management and supervisory personnel shall have sufficient experience of demanding earthworks construction, and the persons responsible for these works must have experience of previous work on embankment dams.

The supervisory personnel of the dam owner and the work management of the contractor shall have sufficient experience of carrying out demanding earthworks, and the persons responsible for these works shall have experience of previous work on embankment dams.

In the construction stage the designer shall be present as an expert. He shall participate in supervising the project by taking part in site meetings at least in the initial stages of construction and the more significant work stages. He shall also supervise the most demanding work, at least in the initial stages and inspect the site records.

### **2.2 Quality control of work and materials**

Work is controlled by continually monitoring its progress. The quality of work and materials is supervised at least to the extent indicated in the quality control programme of the design documentation. The programme shall define the minimum requirements for both testing materials and for structural inspection tests.

The structural inspection tests are recorded and the record shall show the time of the tests, the results, deviations, if any and repairs, if any etc. in such a way that the sample/test site can be unambiguously identified at a later date.

### **2.3 Filing work documents**

All results of quality control tests and control reports are collated and filed. A summary is added to the dam completion documents.

Record drawings showing all the structures made, including the foundation works and any changes in plans implemented during the work, are made on the basis of measurements undertaken during the work.

## **3 MONITORING AND INSPECTIONS**

### **3.1 Seepage water monitoring**

Seepage water can be monitored using pore water pressure gauges, groundwater wells, drain structures or drainage ditches. Special emphasis should be placed on changes in pore water pressure, water level or rate of water flow and on water quality (colour, turbidity, etc.). After completion of the dam (by the first regular inspection at the latest) alarm limits should be set for pore water pressure, the water level in groundwater tubes and/or the measured water volumes. If the limits are exceeded/not reached, an expert should be called in for an assessment of the situation. Objects subject to special surveillance are springs, wet areas in the downstream area, changes in vegetation (e.g. proliferation of willow) and areas that remain ice-free in winter or where the snow melts early in spring.

In areas where the tail water extends to the dry slope of the dam it is not usually possible to measure seepage water flow. To determine the quality of seepage waters the inspections should be made when there is no flow in the downstream channel.

### **3.2 Monitoring the structure**

The structure can be monitored both by measurement (levelling, settlement observations, frost depth measurements etc.) and visually. The visual monitoring should primarily focus on changes that have taken place (settlements/cracks in the crest or slopes, state of facing, unusual frost heaves etc.).

The condition of the dam should be assessed during abnormal weather conditions. These include high winds, storms and heavy rainfall. The monitoring programme should define the limits for a special inspection. The limits include at least the direction and strength of the wind and the volume and duration of rainfall.

### **3.3 Filing the monitoring data**

Monitoring data are filed and summaries are made for the annual and regular inspections.

## Appendix 12 Concrete dams

### 1 PLANNING

#### 1.1 Competence of the designer

In this context, planning is defined as every type of planning and similar preparatory design work for a concrete dam, for instance designing a new dam, planning the alteration or repair work of an existing dam or undertaking an assignment as an expert, assessor or risk manager associated with the dam operation.

The designer of a concrete dam shall have sufficient training and competence as required by the dam class and structure, and the appropriate experience in concrete structure design. The competence of the designer is based on training and experience in the field. The required competence depends on the demands of the design task at hand. These demands also apply to the modification and repair of existing concrete dams and an evaluation of the condition of such dams. Concrete dams classified as class 1 and 2 dams shall be designed as class 3 structures conforming to Finnish Transport Agency Eurocode guidelines on Concrete structure design - NCCI 2 and the designer must be a qualified class AA concrete structure designer. Class 3 dams are designed according to the above guidelines as class 2 structures and the designer must be a qualified class A designer.

The FISE website [www.fise.fi](http://www.fise.fi) shows information on qualified concrete structure designers of different standards of competence. The information on the FISE website can be used to assess the competence of a designer. However, the fact that a person's name is not found on the website does not mean that the person is not qualified to design concrete dams.

#### 1.2 Loads and load calculations

The loads of concrete dams are calculated as set out in the Finnish Transport Agency Eurocode guidelines for Structural loads and design standards for bridges – NCCI 1 and Geotechnical design NCCI 7 as well as Finnish Transport Agency guidelines for geotechnical bridge design. The design discharges and corresponding water levels can be calculated from the statistical data as shown in Appendix 10. The dam must withstand the loads present at emergency HW.

The buoyant force at the bottom of the dam can be calculated from the seepage flow analysis, provided experimental permeability values are available for the basement rock/soil. The calculation can be made in two or three dimensions. The computer software must be well-trying and approved for these applications. If necessary, the results should be checked against measurements.

#### 1.3 Combining loads

The loads are determined by combining those loads that, with a simultaneous effect constitute the combination most dangerous to the structure.

The design of concrete dams must take the loading cases listed below into account and these must include at least the following combinations. Loading situations 1 and 2 are treated as normal and 3 and 4 as exceptional.

1. During construction
  - dead load
  - restraint actions caused by temperature variations (if relevant)
  - earth pressure
  - loads caused by construction machinery and installation cranes
  - machinery loads (included or not)
  - roof structures (included or not)

## 2. Normal operation

- dead load
- restraint actions caused by temperature variations (if relevant)
- earth pressure
- normal high water (HW)
- normal or minimum low water (whichever causes the greatest stress)
- buoyancy
- loads caused by machinery and equipment
- ice loads

## 3. Exceptional operational situation (flood)

- dead load
- maximum high water (emergency HW)
- maximum low water
- buoyancy
- collision load of ice float if relevant

## 4. Maintenance

- dead load
- earth pressure
- maximum high water
- maximum or minimum low water (whichever causes the greatest stress)
- buoyancy
- crane loads
- waterways when empty (powerhouse, flood gate)
- without machinery and equipment
- ice loads

## 1.4 Dimensioning the structures and calculating their stability

The structures must be designed and dimensioned in such a manner that they are sufficiently safe against breaching. The structures must also be sufficiently safe, considering the intended operational use, against deformations, settlements, cracks, vibrations or other damaging effects.

The safety of a structure on bedrock foundation against overturning or sliding as determined with the total safety method is considered sufficient if it is  $\geq 1,5$  under normal and  $\geq 1,3$  under exceptional loading conditions. The safety values are calculated using service live loads. Total safety does not conform to the Eurocode, which requires stability calculations to be performed using partial safety calculations. In general, the geotechnical load-bearing capacity of structures built on normal, healthy bedrock is sufficient in Finland and locally there is a habit of choosing such sites for construction. Cracks and deformations have an effect on the long-term stability of bedrock.

A minimum requirement is that the effect of the load resultant inclination and of seepage on geotechnical stability is taken into account for structures built on an earth foundation. Dam structures are generally prone to sliding and tilting, sometimes as a consequence of external loads or internal erosion and frost. When assessing the motion of the ground and long-term stability, the inhomogeneous nature of the foundation and anisotropic nature of the dam layers must be taken into account.

## 1.5 Measures to improve stability

The stability of concrete dams can be improved with prestressed rock anchors. If these anchors are such that their stress cannot be checked afterwards, the safety of the structure, without the contribution of anchors, must be 1.25 under normal load conditions and 1.1 under exceptional load conditions. Even if the need to calculate the anchor forces is minimal, at least two anchors must always be installed.

Should the contribution of the prestressed anchors to safety be higher than stated above, the designer must choose anchors that allow the stress to be checked later at regular intervals. The anchors must be so placed that their stress can be readily checked and non-functional anchors replaced with new ones if necessary. The design must include a sufficient number of anchors to ensure that the safety of the structure is not endangered during checking or when a new anchor is installed. Only double protected anchors can be used as prestressed anchors.

Conventional grouted deformed steel rock bolts, whether prestressed or not, are not taken into account as a stabilizing factor in the stability assessment of the structure unless their long-term duration and the displacement ability of the structure are ascertained. The contribution of the anchors to safety shall not exceed that of the unchecked prestressed anchors.

The pore pressure acting under the structures can be reduced with subsurface drains. It is important, however, that the functioning of the subsurface drains can be checked with pore pressure or other pressure gauges installed under the structure. If the bedrock is unfractured and very dense throughout, the development of pore pressure and the feasibility of lowering it must always be established case by case.

## **1.6 Mode of function of the structure**

The dam structure must be divided into parts with movement joints to prevent the cracks caused by thermal and drying shrinkage from becoming too large. Adjacent structures linked to each other must be designed in such a manner that the deformation and displacement differences across the joints in structures caused by loads are not great enough to damage the seal or that a displacing structure causes a load on another structure in a way not considered in the calculations.

The adverse effects of restraint action on structures caused by temperature differences during construction can best be eliminated by dividing the structures into casting blocks and making the casting sequence as appropriate as possible.

Concrete structures connected with embankment dams and lateral fillings must be designed in cooperation with the geotechnical designer of the facility.

## **1.7 Design documents**

The design materials are documented as stated in the instructions for structural calculation, and the location of the archive is entered in the list of completion documents.

# **2 SUPERVISION DURING CONSTRUCTION**

## **2.1 Competence of management**

The foreman responsible for concrete works shall have the competence required by the structural class. The foreman responsible for dam foundation works shall have the competence required by the structural class.

## **2.2 Work quality control**

The quality control of the concrete structures is performed in accordance with the concrete standards. Matters essential for dam safety are checked as construction proceeds. A record should be kept of inspections to the extent considered appropriate. Matters to be supervised and recorded include the type and permeability of the basement rock/soil, the stress and pressure grouting of the prestressed anchorage, temperature changes in cast structures and their junctions, information on the composition and reinforcement of the concrete, etc.

## **2.3 Recording construction data**

The results of the quality control tests and inspections made during the construction stage are summarized and added to the commissioning inspection documents. Quality control reports are filed with the completion documents.

## **3 OPERATIONAL MONITORING**

Monitoring objects important for dam safety during operational use include the waterlines, movement joints and work joints of the structures, the functioning of drains and anchors, the amount and type of leaks, and changes in them. Waterways and submerged structures are inspected, when possible, during maintenance while the structures are visible. If this is not possible the inspection is carried out with the aid of a diver, for instance. A record is kept of the inspections and added to the regular inspection's documentation.



## Appendix 13 Gates and water level measurement

### 1 STEEL STRUCTURES

The steel structures of gates shall be designed in accordance with the Finnish Transport Agency Eurocode guidelines on Steel and composite structure design - NCCI 4, taking into account the strength specifications required by operational conditions. The loads shall be considered as stated in the Finnish Transport Agency Eurocode guidelines for Structural loads and design standards for bridges – NCCI 1 and Geotechnical design NCCI 7 as well as Finnish Transport Agency guidelines for geotechnical design for bridges.

### 2 MACHINERY

#### **Devices to prevent overloading:**

If the structure is such that the machinery or gate can get damaged at overload, the machinery shall include a safety device provided with an appropriate alarm system.

#### **To prevent slanting:**

The slanting of gates shall be prevented either mechanically or electrically. The machinery shall have a detector to record any slanting that interferes with operations, and a system for straightening the gate.

#### **Chains:**

If the force acting on the gate is transmitted by chains, the operation of chains and winding drum in winter conditions must be verified.

#### **Greasers:**

It is important that the axles, chains, pintles and machinery of the gate can be readily and safely greased, and that the person responsible for the functioning of the gate sees to the necessary greasing in accordance with the maintenance programme.

#### **Test run:**

The proper functioning of machinery and monitoring devices shall be verified annually with a test run, the results of which are entered in the annual inspection record.

#### **Limit switches:**

The machinery shall be fitted with reliable limit switches (operational and emergency limit switches) that stop the movement at the extreme gate positions and in certain special circumstances.

#### **Heating:**

If gate use is necessary at sub-zero temperatures, the gate and its frame shall be provided with a heating system. Heating control is designed either by remote control and/or using thermostats, depending on the overall design. If the machinery and electrical devices require a warm room or operation centre these must be provided with effective heating facilities.

#### **Gate attitude information:**

Operational and monitoring personnel must be fully and reliably informed about the attitude of the gate. If the gate is controlled remotely or by devices that monitor the water level, the gate attitude shall be displayed in the remote-control/monitoring room.

#### **Warning devices:**

If unexpected opening of the gate may endanger human life, the people at risk shall be alerted about the opening by an alarm siren or similar with a sufficient time margin before the opening commences.

### **3 ELECTRICAL DEVICES**

The design and use of the electrical devices shall comply with the regulations for electrical safety.

### **4 WATER LEVEL MEASUREMENT**

To monitor the water level of the dammed area, remote-controlled dams and dams at which the water level may change rapidly shall be provided with a reliable measuring system that is functional under all weather conditions, including a backup system if necessary. Regardless of automation, if any, the measuring data shall be transferred to the place where dam use is monitored and where, if necessary, the gates can be controlled. The system shall include appropriate alarm devices.

### **5 EMERGENCY HOISTING SYSTEM**

Section 4 (2) of the DDS requires that discharge gates and other operating equipment of a dam be functionally reliable and that an emergency hoisting system or plan must be in place for the operation of the discharge gates. The emergency hoisting system or plan must operate within the time margin allowed by the dam. The time margin is the period during which a disturbance or damage may develop into a dangerous situation. This may, for instance, be the time during which water rises from HW to emergency HW. The time margin depends on the volume of the upper reservoir, the rate of influx and the available discharge capacity.

The emergency hoisting system shall be designed to allow opening the gate even during a power failure or fire etc. If the emergency hoisting system is electrical, its cables and power source shall be separated from those of the hoisting system proper. The emergency hoisting system may also be a separate combustion engine-run electrical or hydraulic unit which can be readily connected to the gate system.

The static emergency hoisting system can in some cases be replaced by an emergency hoisting plan. The plan must, however, work under all circumstances at all times of day, in every season. The plan may be based on using a mobile crane or similar, provided such a crane is available in all circumstance and provided the gate can be opened within the time margin available.

### **6 INSTRUCTIONS FOR OPERATION AND MAINTENANCE**

Instructions for use and maintenance shall be drawn up for the gate and kept available in an appropriate manner. One set of the user manual and maintenance instructions as well as the wiring diagrams of electrical devices shall be available locally in the machine room of the dam, in the control room or similar.

## Appendix 14 Comparison of embankment dam breaches

Item 5.1.2. of this guide presents the different breach cases that are included in the hazard analysis. A dam break hazard analysis shall establish the risks involved in different cases; by breach location, by discharge path and by discharge flow.

As a rule, the hazard analysis for an embankment dam includes the following breach assumptions:

- overflow
- internal erosion.

Froehlich (1995), states that the final width of a dam breach can be determined using the equation

$$\bar{B} = 0.183 K_0 V_w^{0.32} h_b^{0.19}$$

where	$\bar{B}$	=	mean breach width
	$K_0$	=	coefficient (1.4 for overflow, 1.0 for internal erosion)
	$V_w$	=	dam basin volume (m <sup>3</sup> )
	$h_b$	=	breach height (m)

and the time it takes the breach to form using the equation

$$t_f = 0.00254 V_w^{0.53} h_b^{-0.9}$$

where	$t_f$	=	the time it takes the breach to form [h]
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The Froehlich model can be used to make a first estimate of the breach width and the time it takes the breach to form. The hazard analysis shall also compare the effects of different breach width and breach time parameters on the discharge flow and hence, on the flood path.

## Appendix 15 Presenting the result of the dam break hazard analysis

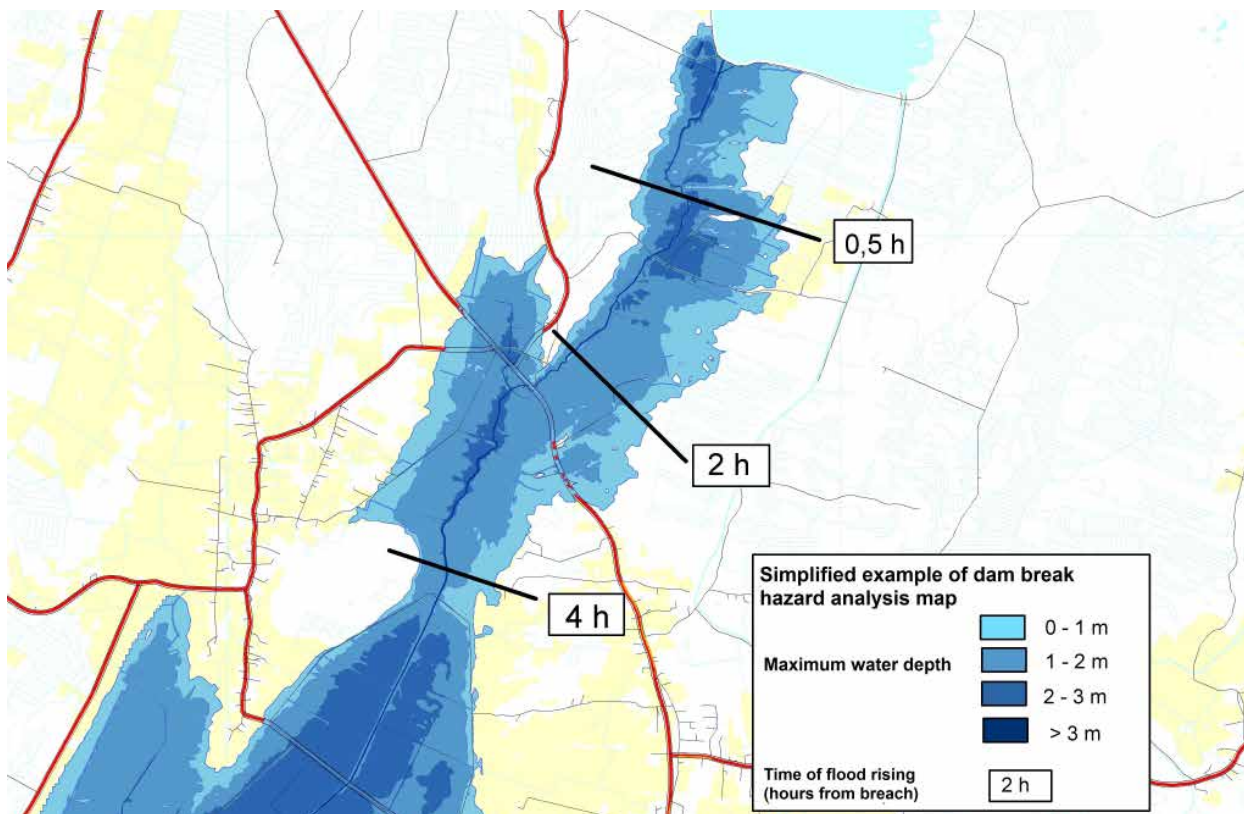


Figure 1. Example of a hazard analysis presentation (Map: Mikko Huokuna, 2010).

The results of the dam break hazard analysis comprise the point of departure for the safety plan and emergency action plan. The results of the analysis must be presented in such a way that the rescue authorities and other departments participating in the rescue operations can plan their own emergency response on the basis of the presentation.

The results of each flood case, derived from calculations representing at least two flood situations, shall be presented using maps of a convenient scale (e.g. 1:20 000) and in tables listing the data at different stages of flood by cross-section. The points shall be chosen with a view of aiding emergency response planning (e.g. bridges and significant damage objects).

### **The results of the dam break hazard analysis, including, where applicable, those for waste dams and tailings ponds as well as cases where flood wave calculations are not required as such - shall contain**

- a specification of the assessment method and guidelines for interpreting the results
- the initial values used in the analysis, such as the discharge volume preceding the breach, applied topographical data (sources, resolution, accuracy, combined materials, assumptions), structures that guide or limit the flow in the flow model (terrain break lines or hydraulic structures), if any, as well as roughness coefficients in digital form, a summary of a comparison of different breach cases, including, for each case, the tabulated
  - inclination of the walls of the breach opening and the final height and width of the bottom
  - time of the breach
  - water level in the basin at the onset of breach
  - cause of the breach (internal erosion, overflow, intentional damage)
  - maximum discharge
  - timed flow through breach in different failure scenarios (flow hydrograph)

- where applicable and to the extent a reasonable effort can determine: the sensitivity of the chosen variables and their impact on the results for the chosen hydrodynamic model (e.g. roughness coefficients, time step of computations, characteristics of model geometry)
- the results of each flood scenario, showing flood path data, water depth and flow rate, presented as graphs and maps (detailed description below). The presentation of results should be designed from case to case in such a way that it also serves rescue planning aimed at minimising damage.
- proposed dam class.

### **Objects at risk**

The damage assessment can be tabulated. Where a great number of objects are assessed, they can be grouped in order to clarify the data.

The table shall itemise at least the following objects at risk:

- population (permanent and transitory)
- infrastructure
- property
- environment
- elevation where damage first occurs
- arrival time of flood
- maximum height of flood
- maximum flow rate at specified object, if available

The elevation of objects at risk are presented as well as the water levels and, if available, flow rates. If necessary, the data on objects at risk can be used to estimate the cost in euros for the material damage total.

### **In addition to the above, where applicable, the results of the dam break hazard analysis for waste dams and tailings ponds shall present**

- an area map inundation projection for a breach scenario as well as objects at risk in the inundated area
- an assessment of the immediate danger to human life, health, the environment or property posed by the waste material in the event of dam failure
- a description of the waste or harmful or dangerous substances released and spread in the environment in the event of a dam failure, including a description of exposure risks
- an assessment of the impact on human health and the environment of long-term exposure to harmful or dangerous substances released in the environment (each failure path assessed separately):
  - waterbodies and their catchment areas
  - groundwater and groundwater aquifers
  - water intake plants and household wells
  - land use, such as residential, agricultural and recreation areas
  - local flora and fauna.

### **The data derived from the dam breach flood discharge calculations shall, to the extent necessary, be shown on maps as follows:**

#### **Flood maps**

- the maximum flood coverage of a dam breach case (dam breach flood risk map), fig. 1
- the map, or a separate presentation, shall show the extent of the flood 0.5, 1, 2 and 3 hours from the breach. (Where necessary, the flood coverage is also presented at e.g. 4, 6, 9 and 12 hours from the time of the breach. The points in time presented should be chosen case by case, keeping in mind the requirements of rescue work and efforts designed to minimise the damage.)

- maximum water depth by area, presented as depth intervals (for instance, 0-0,5 m, 0,5-1 m, 1-2 m, 2-3 m and > 3 m)
- the locations and code numbers of the computed cross-sections
- the points of time of the arrival of the flood wave and of maximum water level at each cross-section in hours from the failure.

If the flow calculations are made using a 2-dimension flow model, the presentation shall include maps showing

- maximum flow velocity by area, presented as set velocities (for instance, 0-1 m/s, 1-2 m/s, 2-3 m/s and > 3 m/s)
- a damage parameter  $vd$  (flow velocity multiplied by water depth) derived from flow velocity and water depth by area, presented as set values (for instance, < 0,3; 0,3 - 0,5; 0,5 - 1,0; 1,0 - 3,0; 3,0 - 7,0; >7,0).

### Flood data

The flood data on the calculated locations should be presented in tables as follows:

- water level (W), discharge (Q) (1D-flood calculation) and flow velocity (v) (2D-flood calculation) at each location at different moments during the flood
- a summary table, presenting for each location
  - the initial discharge ( $m^3/s$ ) before the onset of the flood (1D-calculation)
  - maximum discharge ( $m^3/s$ ) (1D-calculation)
  - the moment at which the maximum discharge occurred in hours from the failure (1D-calculation)
  - the initial water level (+m) before the flood
  - maximum water level (+m)
  - the moment at which the maximum water level was reached in hours from the failure
  - the maximum flood height (m) in the channel, i.e. the difference between the maximum water level and the initial water level
  - maximum flow velocities (m/s) (2D-calculation).

The flood data tabulated as above should be appended to the flood map so that the flood data on each cross-section are easily readable.

### Damage parameter $vd$

Tables 1 and 2 (Karvonen et. al, 2001) show damage parameter values that can be used to assess the damage caused by waterflow to buildings and human life. The damage to buildings is determined primarily by the building material. Human survival in flowing water (i.e. person not swept away) depends on a person's height and mass (hm) and on the circumstances.

Table 1. Damage parameter  $vd$  values applicable to buildings in Finland when estimating damage to structures caused by flowing water.

Building type	Partial destruction	Complete destruction
Wood		
not anchored	$vd \geq 2 \text{ m}^2/\text{s}$	$vd \geq 3 \text{ m}^2/\text{s}$
anchored	$vd \geq 3 \text{ m}^2/\text{s}$	$vd \geq 7 \text{ m}^2/\text{s}$
Masonry (brick, concrete)	$v \geq 2 \text{ m/s}$ and $vd \geq 2 \text{ m}^2/\text{s}$	$v \geq 2 \text{ m/s}$ and $vd \geq 7 \text{ m}^2/\text{s}$

Table 2. Damage parameter  $v_d$  values that depend on circumstances, applicable to human survival in flowing water. The  $hm$  factor is derived by multiplying the height [m] of a person with his mass [kg].

<b>Conditions</b>	<b>Not swept away</b>
Fair conditions	$v_d \leq 0.006hm + 0.3$
Normal conditions	$v_d \leq 0.004hm + 0.2$
Bad conditions	$v_d \leq 0.002hm + 0.1$

The weakening factors to be assessed when estimating conditions include

- uneven and slippery ground, obstacles
- low temperature of floodwater, low visibility, floating objects and ice
- personal loads, disabilities and age
- poor light.

## Appendix 16 Estimating loss of life caused by dam failure

The following is based on Graham's (1999) publication A Procedure for Estimating Loss of Life Caused by Dam Failure. The Finnish text is written by Laasonen (2009).

In the years 1960–1998, some 300 people died in dam accidents in the United States. 88% of the casualties occurred in accidents involving dams less than 15 metres tall. Most dam breaks, however, have not caused loss of life. In the years 1985–1994 there were more than 400 dam breaks, with only 10 fatalities. Most dam failures concerned small dams. Half the losses of human life occurred within 5 km and 99% within 24 km of the dam.

Several different factors affect the number of lives lost:

- the type of breach (flood overflow, internal erosion)
- number structure of population at risk (age, health etc.)
- time lapse for giving the alarm, time lapse for understanding the seriousness of the situation, time required for evacuation
- flow velocity and depth of water in the inundation area
- time of day (day/night), day of the week (weekday/weekend), time of year
- weather conditions
- emergency response (alarm, evacuation).

The main factors affecting the loss of life are 1) the number of people at risk, 2) the level of success in warning the population in the area and 3) the force of the flood wave. The highest dam failure mortality rate has, without exception, occurred when buildings have been destroyed and the alarm was given too late.

The Graham model has three variables: the forcefulness/severity of the flood wave, the warning time and understanding the seriousness of the flood wave.

The severity of the flood wave is divided into three categories:

- "*Very severe*" a flood wave sweeps the area clean and nothing is left standing.
- "*Moderate severity*" a flood wave destroys buildings, but the destroyed buildings and trees provide potential shelter for the population.
- "*Low severity*" a flood wave does not sweep away buildings from their foundations.

The warning time is also divided into three categories:

- "*No warning*": the flood wave arrives in the flood area without warning.
- "*Some warning*": the flood area is given a warning 15-60 minutes before the arrival of the flood wave.
- "*Sufficient warning*": the flood area is given a warning 60 minutes or more before the arrival of the flood wave.

The third factor is understanding the severity of the flood wave, which has a bearing on the fatality rate. Relative awareness of the severity of the flood wave is a function of distance and time. People located further from the dam have a better chance of obtaining accurate information on the seriousness of the situation. The variable is divided into two categories:

- "*Vague understanding*": the person giving a warning or alarm has a limited understanding of the dam failure (no knowledge of the extent of the breach, the flood area etc.).
- "*Precise understanding*": the person giving the warning or alarm has a precise understanding of the dam failure based, for instance, on personal observation.

Table 1 shows the recommended values of the Graham model. The model is based on the observations of 40 floods, many of which were cases of flood caused by dam failure. The model contains a number of uncertainties, including reason for dam failure, time of breach and warning time. The table does not show all the cases since the coefficient was determined on the basis of only one observation. The table can be used as a guide and the values must be adjusted case by case. The calculations must be subjected to sensitivity analysis.



Table 1. Human loss of life coefficients recommended by Graham in case of a dam failure (1999).

Severity of flood wave	Warning time	Understanding severity of flood wave	Mortality (% of people at risk in the area)	
			Recommended	Interval
Very severe	No warning	N/A	76 %	30–100 %
	15–60 min ("Some warning")	Vague understanding	Model does not have recommended values for number of people in the inundation area.	
		Precise		
	More than 60 min ("Sufficient warning")	Vague understanding		
Precise				
Moderate severity	No warning	N/A	14 %	2–43 %
	15–60 min	Vague understanding	1.4 %	Only one case
		Precise	1 %	Only one case
	More than 60 min	Vague understanding	5 %	Only one case
Precise		3.5 %	0–8 %	
Low severity	No warning	N/A	0.7 %	0–2.5 %
	15–60 min	Vague understanding	0.95 %	0.7–1.2 %
		Precise	0 %	Only one case
	More than 60 min	Vague understanding	No cases	
Precise		0.03 %	0–0.2 %	

## Appendix 17 Dam risk analysis

### General

The Finnish text in this appendix is written by Laasonen (2009). This appendix covers risk analysis models and their utility to the dam owner.

The failure risk (R) is the result of probability (P) and the dangerous effects (C) of the failure,  $R=P \times C$ .

Probability describes the future and it may be assessed using frequency and actual cases. Probability is presented as annual probability.

Traditionally, risk analysis has been applied in the aircraft and nuclear power industries. The IATA (International Air Transport Association) statistics, for instance, cover more than 18 000 aircraft (1998). The database contains the statistics of about 162 000 cohesive structural elements under near homogenous stress, based on 33 million annual flight hours and 16 000 annual take-offs (Kreuzer, 2000).

Dam safety risk analysis became more common in the 1990's. In 1994 The Australian National Committee on Large Dams (ANCOLD) published Guidelines on Risk Assessment. In 1997 Trondheim hosted the Hydropower '97 conference, where one of the topics was dam safety and risk analysis (Broch et al, 1997). The 2000 ICOLD congress in Beijing took up risk analysis in support of dam safety decisions and management (Question 76: The use of risk analysis to support dam safety decisions and management). The RESCDAM project (1999–2001) reviewed, among other topics, risk analysis (Finnish Environment Institute, 2001).

Up to 1996, dam risk assessment was almost exclusively based on probability models. That year quantitative approaches, such as failure mode and effect analysis were introduced in dam risk analysis, along with semi-quantitative models, such as fault & event tree analysis (Thukral, 2001 and Hartford & Baecher, 2004).

ICOLD (International Commission on Large Dams) Bulletin 99 "Dam failures. Statistical analysis" (1995) lists 176 large dam failures. The number of dam failures has decreased significantly over the past four decades. By the year 1950, some 5268 large dams had been built, 117 of which failed. Between 1951 and 1986 a total of 12 318 large dams were built, only 59 of which failed. The statistics do not include dam failures in China. 70% of dam failures occur within ten years of commissioning the dam and 45% within the first year. The most common cause of dam failure is overflow, which accounts for half the embankment dam failures. Another significant cause of dam failure is internal erosion through the dam structure or the foundation.

USCOLD (1975 and 1988) has reviewed cases of dam failure and accidents in the United States. Their report covers 516 events at various dams. The events are divided into dam failure, dam accidents, damage during construction and major repair work. Dam failures are divided into two categories: after the failure, the dam was beyond repair (F1) or repairable (F2). The dam accidents are put in four categories, where a dam breach in dam accident category A1 was avoidable by taking immediate action, for instance by lowering the water level. There have been 229 serious dam failures (categories F1, F2 and A1). In 38% of the cases, the failure was caused by dam overflow and problems with the spillways and in about 20% of the cases, failure was caused by internal erosion.

There are some 2700 dams in Great Britain, about 2100 of which are embankment dams. Dam failures are recorded in a database. Before 1975, 13 dam failures and 58 serious dam accidents, requiring rapid lowering of the water level, occurred at dams in use for more than 5 years. Between 1975 and 2001 there have been 13 serious dam accidents. The main cause of dam failure and serious dam accidents was internal erosion, in about 58,3% of the cases (Defra, 2002).

The structural elements of dams are not cohesive structural elements the way they are in aircraft construction. The stresses may vary considerably. The foundation conditions alone may be non-homogenous in a dam.

Embankment dam construction materials have variable characteristics depending on, for instance, where the fill material is taken from, how the core is designed, the quality of construction work and also on developments in construction technology. In addition, the condition of the dam deteriorates with age. In the light of the aforementioned, it is not possible to make a reliable assessment on the basis of the quoted dam failure statistics.

**Ways of approaching dam risk assessment**

Risk management can be presented using a chart, fig. 1. Risk management comprises risk analysis and risk assessment. Risk analysis is used to determine that which is known about a dam and the attendant uncertainties. Risk acceptability should be assessed. Only a few countries, such as Australia and the United States, have produced guidelines and values for risk acceptability.

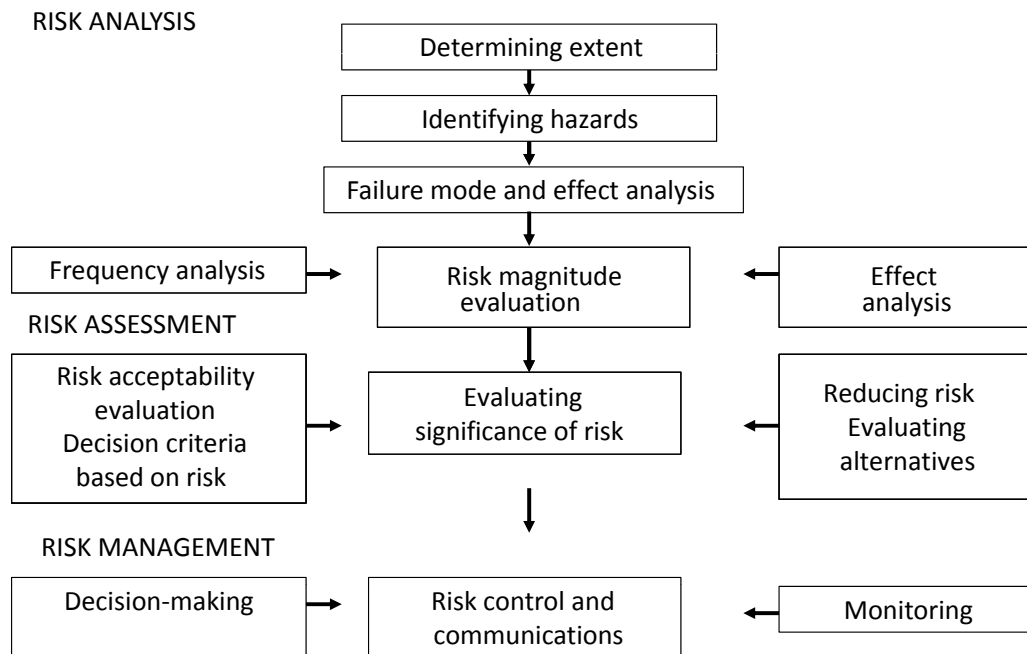


Fig 1. Risk management (Rettemeier et al, 2000).

A risk analysis may be qualitative or quantitative. Qualitative models do not describe uncertainty on the basis of mathematical probability; the failure is assessed using technical data and event trees in a failure mode and effect analysis that may present the risks in order of seriousness. The quantitative models include the Monte Carlo simulation and formal models that include mathematical descriptions, such as event trees and failure mode trees.

Failure mode and effect analysis as well as the event tree analysis is described in the following.

**Failure mode and effect analysis**

In the failure mode and effect analysis the dam (system) is divided into pre-set, cohesive parts and the parts into components. The failure of dam components and the effects are assessed as specific objects on the basis of physics. The assessing of components requires the construction of a logical model. The model has two tiers: on one hand a dam system description including components and their reciprocal effect, and on the other hand the failure mode mechanism of components.

The failure mode and effect analysis is divided into the following stages

- understanding the system and splitting it into parts and components
- determining the details of components
- basic parts failure and effects.

A failure description shows how a dam part or a component becomes inoperative. As an example, we will use an embankment dam in an overflow situation. When the overflow begins, grass on the dry slope is an obstacle to the flow and it delays the formation of a breach, but the dam is not designed to withstand overflow. As the flow increases in strength, the dam begins to erode at the toe and the erosion progresses upstream.

Supporting embankments are eroded and erosion advances towards the dam core. The breaking mechanism of a cleated wall is assumed to advance with the earthfill on the dry side being washed away from behind the cleat and the wall collapsing from the pressure of the earthfill. In the final stage, the wet slope embankment is also washed away and the dam is breached. In a similar way, an analysis may focus on the effects of sheet pile wall and grouting curtain failure or on the seepage status of the core and shoulder/ground moraine.

### Event tree analysis

An event tree analysis is used to determine the consequences of an event and also to assess probability.

The example in fig. 2 shows a probability calculation of internal erosion causing a failure. In this case, the probability of internal dam erosion is given as  $5 \times 10^{-4}$ , which is the base value for the event tree probability calculation. The event tree is based on the four stages of internal erosion. The depicted event tree is only a display of the principle employed for an event tree analysis and does not show real numerical values of probability. It should also be noted that the probability of erosion cannot be calculated at our present state of knowledge.

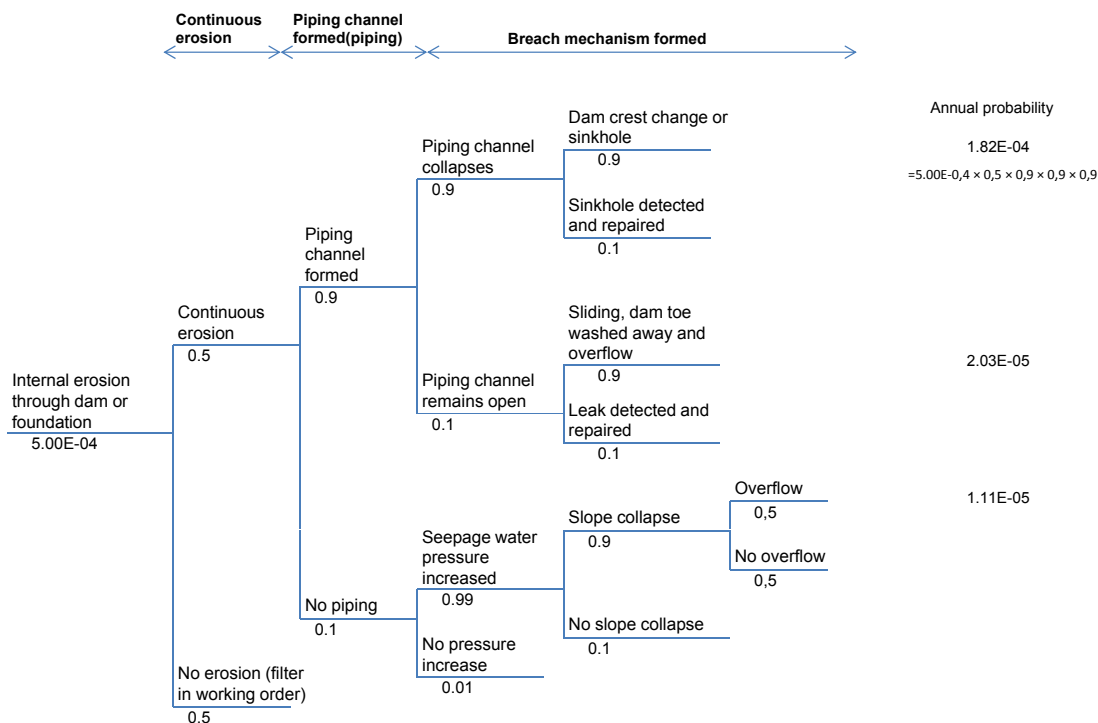


Fig. 2. Example of an internal erosion event tree analysis.

### Applications for models

The advantage of risk-based models is that they are systematic and logical, which makes it easier to apply them to dam safety assessments of old dams. The technical documentation of the parts of a dam, and the need of additional studies, can be analysed using a failure mode and effect tree.

When analysing the dam breach mechanism, calculations can be made in order to assess the effect of various repairs designed to stop a dam breach and to determine the need for instrumentation.

A dam owner can use the models to assess the dam risk. The assessment is based either on loss of life (loss of human life/year) or by accounting for the economic loss and environmental damage (euros/year). Probability assessments are uncertain and a dam owner may use their own system of classification based, for instance, on dam analyses, studies and observations made at dam inspections. Dams can be ordered in sequence by risk.

Dam repairs can be given priority on the basis of risk evaluation whereby investments are made where the greatest reduction of total risk is achieved. The model can also be used in assigning priority to repair work. Investments can be channelled to repairing or upgrading the dam with the greatest failure consequences, purely by studying risk evaluation results. It may emerge, that the dam with the greatest failure consequences needs only minor upgrading in order to decrease the total risk more than would a major investment in the dam with the least serious failure consequences.

### **Summary**

ICOLD (2005) defines risk evaluation as "the process of examining and judging the significance of risk". A risk assessment provides data for the decision-making process. Risk evaluation is not simple, however. The relationship between acceptability and tolerable risk must be evaluated by the decision makers.

There can be no absolute guarantee of dam safety, and hence the general aim of risk management is the ALARP principle (as low as reasonably practicable). The definition of the ALARP principle evaluates the cost involved in reducing the risk in proportion to the benefit gained (ICOLD, 2005).

Risk evaluation methods are still being developed and an absolute dam failure probability cannot be reliably determined. Risk assessment is a logical and systematic way to evaluate dam safety. Risk assessment models should be applied alongside other models.

The models can be used to evaluate the owner's dam risk. Dam repair and maintenance work may be given priority on the basis of risk assessment. The downside of this method is that investments may be directed to upgrading the dam with the greatest failure consequences.

When analysing the dam breach mechanism, calculations can be made in order to assess the effect of various repairs designed to stop a dam breach and to determine the need for instrumentation.

## Appendix 18 Terminology

### DOCUMENTS

Completion documents	Needed in dam maintenance and for assessing the dam strength characteristics, the completion documents are the key design and construction documents.
Dam safety file	The dam safety file is a collection of documents which should contain all the significant material on dam safety. Printouts from the dam safety information system represents a significant part of the safety file data.
Monitoring programme	The dam safety monitoring programme is a document that defines how all issues pertinent to dam safety should be monitored and regularly inspected.
Description of dam hazard	The description is an estimate in sufficient detail of the hazard that a dam may pose and the effect this has on design criteria. The description provides the dam safety authority with basis for dam classification.
Dam break hazard analysis	A dam break hazard analysis outlining the hazards posed by the dam to people, property and the environment is a more detailed assessment than the description required by DSA section 9. The analysis shall be provided by all class 1 dam owners. The dam safety authority may, if necessary, for determining classification or re-classification, order a dam break hazard analysis for a dam other than a class 1 dam.
Emergency action plan	The owner of a class 1 dam shall draw up and keep up to date an emergency action plan outlining the preparations and action on their own initiative in the event of a disturbance or dam emergency.

### STRUCTURAL TERMS

Height of dam	The height of a dam is the difference in height between the lowest point of the external boundary of the dam structure and the HW level. The height of an embankment dam or a submerged dam is calculated as the difference in height between the lowest point of the external boundary of the dam structure and the dam crest.
Submerged dam	A submerged dam or weir is a dam with water flowing over its crest.
Freeboard	Freeboard is the height difference between the HW level of the impounded substance and the dam crest.
Safety margin	The safety margin of a dam is the height difference between the top of the core and the HW level. At a tailings pond, the height difference between the highest level of free water and the lowest part of the core top.

## MONITORING TERMS

Commissioning inspection	The commissioning inspection is a site inspection performed at new dams before the impounded substance is raised and at old dams after significant alterations and repairs. The commissioning inspection is a step in the commissioning process. The inspection examines whether or not commissioning the dam is safe. The inspection may be undertaken in several stages.
Periodic inspection	Periodic (regular) inspections shall be performed at class 1, 2 and 3 dams once every five years or, if necessary, more frequently. The inspection's focus is on the condition and safety of the dam and it shall include a qualified inspector as set out in section 6 of the DSA. The dam owner arranges the inspection and the dam safety authority and rescue authorities have a right to attend. The owner of a dam shall submit a written report on a periodic inspection of a class 1 or 2 dam to the dam safety authority.
Annual inspection	The owner of a class 1 or 2 dam shall inspect the condition and safety once a year. The annual inspection includes the condition and operation of structures and equipment. The owner of a dam shall submit a written report on the inspection of a class 1 dam to the dam safety authority.
Monitoring	Monitoring is the continuous surveillance of the dam's condition and operation as set out in the monitoring programme.

## HYDROLOGICAL TERMS

Total catchment area	A catchment area is an area where the surface and aquifer water are drained by a specific lake or river. The origin of the water is rainfall or melting snow. The water consists of surface and aquifer runoff as well as precipitation on the reservoir surface. The surface area is defined as the total catchment area including the dam basin itself. The lake percentage is defined as the waterbody area percentage of the catchment area as a whole.
Immediate catchment area	The immediate catchment area is defined as the area the discharge of which cannot be regulated. The immediate catchment area includes the area of the basin.

High water level, HW	High water level is the maximum water level over a specific period. As a rule, it is the HW during 24 h (either the daily average or that recorded once a day). In addition to the water level, the data should include the period when the data were collected and on which the water level value is based, e.g. HW (1970–2006) = + 58,63. This means that the highest water level, +58,63, was reached in the years 1970–2006.
Waste dam HW	At a waste dam, high water is defined as the highest level of free water. At a tailings pond, for instance, the surface of the tailings sand may reach higher than the surface of the free water.
Medium high water level, MHW	Medium high water level refers to the mean value of the annual high water levels over a specific period.
Mean water level, MW	Mean water level refers to the mean value of the water levels over a specific period.
Low water level, NW	Low water level is the minimum water level over a specific period. As a rule, it refers to the NW recorded during 24 h. In addition to the water level, the data should include the period when the data were collected and on which the water level value is based, e.g. NW (1970–2006) = + 55,44. This means that the lowest water level, +55,44, was reached in the years 1970–2006.
Technical low water level, tech. NW	Technical low water level is the lowest structurally possible water level.
Emergency high water level, emergency HW	Emergency high water level is the water level which, when exceeded, may cause changes in dam structures.
Maximum discharge, HQ	Maximum discharge is the highest discharge in a given period. As a rule, it refers to the discharge during 24 h, but e.g. HQ (5 d) is the highest value of the mean discharge over five consecutive days. In addition to the discharge data, the period should also be given during which the data were collected and on which the maximum discharge value is based, e.g. 150 m <sup>3</sup> /s (1970–2006). If the part of the waterbody under consideration is a lake or other reservoir that levels out the flow peaks, the terms HQ(inflow) and HQ(outflow) are used with reference to the maximum discharge entering or leaving the basin, respectively.
Mean high water discharge, MHQ	Mean high water discharge refers to the mean value of the maximum discharge in different years over a specific period. Depending on the site, the discharge is either measured or calculated.
Hydrograph	Design flood is the time curve of the inflow i.e. a hydrograph. Design outflow and water level are corresponding time curves.



Return period, frequency, annual probability	Return period is a statistical term and means the period during which a given HQ value is reached once on average. For example, "HQ(1/1000) = 200 m <sup>3</sup> /s" means that a maximum discharge with a rate of at least 200 m <sup>3</sup> /s will occur, on average, once in 1000 years. This can be expressed as an annual probability, in the aforementioned example a probability of 0.1 per cent.
Design flood	A watercourse dam is designed for the water flow that causes the maximum need for discharge. The dimensioning is presented as the annual probability or frequency of flooding which corresponds to such a water flow (design flood).
Maximum discharge inflow	Maximum discharge inflow refers to the maximum value of the design flood flowing in from the catchment area.
Design high water level	Design high water level is the maximum water level that occurs during the design flood, when the total discharge capacity of the dam is in use, excluding the flow through the power plant machinery.
Design outflow	Design outflow is the hydrograph of the dam outflow calculated from the design flood, the storage volume of the basin and the discharge capacity of spillways, with the initial water level value determined by the mode of use of the dam.
Maximum discharge outflow	Maximum discharge outflow refers to the maximum value of the design outflow, generally the outflow that corresponds to the design high water level.

## **MISCELLANEOUS**

Temporary dam, cofferdam	A cofferdam is a temporary dam structure. Cofferdams are subject to the Dam Safety Act and the same practises as other dams.
Condition study	A condition study refers to an assessment which the dam safety authority may order the dam owner to undertake as part of a periodic inspection, to determine the condition of the dam. The condition study may refer to the dam as a whole or only part of it.
Safety arrangements for dam operation	The safety arrangements for dam operation are arrangements designed to guarantee the safe operation of a dam. These include warning signals for controlled discharges, monitoring cameras and standby arrangements. Safety arrangements are required for all class 1 and 2 dams.
Time margin	The time margin is the period during which a disturbance or damage may develop into a dangerous situation.
Dam safety information system	The information system of the dam safety authority is a database maintained by the Finnish Environment Institute and it contains current information on all classified, class 1, 2 and 3 dams.
Dam accident	A dam accident is an event in which the dam or auxiliary facilities are damaged or subject to failure to such an extent that the impounded substance is discharged or liable to be immediately discharged.

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		Hankkeen rahoittaja / toimeksiantaja Maa- ja metsätalousministeriö		
Julkaisun nimi Patoturvallisuusopas				
Tiivistelmä  Uusi patoturvallisuuslaki (494/2009) tuli voimaan 1.10.2009 ja valtioneuvoston asetus patoturvallisuudesta (319/2010) 5.5.2010. Tämä patoturvallisuusopas korvaa patoturvallisuusohjeet (MMM:n julkaisuja 7/1997), jotka poistuiivat käytöstä 1.10.2009. Patoturvallisuusoppaassa esitetty ei ole padon omistajaa sitovaa, vaan oppaan tarkoitus on täydentää ja selventää esimerkein ja selostuksin laissa ja asetuksessa esitettyä.  Oppaassa käsitellään padon suunnittelua kuten hydrologista mitoitusta ja padon teknisiä turvallisuusvaatimuksia, padon rakentamista ja käyttöönottoa sekä vahingonvaaraselvitystä, padon omistajan turvallisuussuunnitelmaa sekä padon kunnossapitoa, käyttöä, tarkkailua, vuosi- ja määräaikaistarkastuksia.  Padot luokitellaan vahingonvaaran perusteella luokkiin 1, 2 ja 3. Luokittelua ei tarvitse kuitenkaan tehdä, jos patoturvallisuusviranomaisen katsoo, että padosta ei aiheudu vaaraa. Jokaiselle luokitellulle padolle on padon omistajan laadittava tarkkailuohjelma, jonka patoturvallisuusviranomaisen hyväksyy päätöksellään. Padosta aiheutuvan vahingonvaaran selvittämiseksi 1-luokan padon omistajan on laadittava vahingonvaaraselvitys padosta ihmisille, omaisuudelle ja ympäristölle aiheutuvasta vahingonvaarasta. Myös muusta kuin 1-luokan padosta voi patoturvallisuusviranomaisen määrätä tehtäväksi vahingonvaaraselvityksen luokittelua varten. Padon omistajan on laadittava 1-luokan padolle turvallisuussuunnitelma onnettomuus- ja häiriötilanteiden varalle. Suunnitelmassa esitetään padon omistajan omatoiminen varautuminen em. tilanteiden varalle. Pelastusviranomaisen arvioi tapauskohtaisesti pelastuslain mukaisen suunnitelman laatimistarpeen. Padon omistajan on toimitettava patoturvallisuusviranomaiselle tietojärjestelmään vietäväksi patoturvallisuusasetuksessa mainitut tiedot. Patoturvallisuusviranomaisen ja padon omistajan on säilytettävä kustakin luokitellusta padosta ajantasaiset tulokset tietojärjestelmästä sekä muut padon turvallisuuden kannalta tärkeät asiakirjat patoturvallisuuskansiossa siten, että ne ovat mahdollisissa häiriötilanteissa nopeasti saatavilla.				
Asiasanat pato, vesistöpato, jätepato, kaivospato, tulvapenger, patoturvallisuuslaki, patoturvallisuusasetus, patoturvallisuusviranomaisen, padon omistaja, suunnittelu, rakentaminen, luokittelu, tietojärjestelmä, patoturvallisuuskansio, vahingonvaaraselvitys, turvallisuussuunnitelma, onnettomuus- ja häiriötilanteet, tarkkailuohjelma, tarkkailu, vuositarkastus, määräaikaistarkastus, kunnossapito, käyttö				
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Publikationens namn Dammsäkerhetsguide				
<p>Sammandrag</p> <p>Den nya dammsäkerhetslagen (494/2009) trädde i kraft 1.10.2009 och statsrådets förordning om dammsäkerhet (319/2010) 5.5.2010. Denna dammsäkerhetsguide ersätter anvisningarna för dammsäkerhet (Jord- och skogsbruksministeriets publikationer 7/1997) som togs ur bruk 1.10.2009. Dammsäkerhetsguiden är inte bindande för dammens ägare. Avsikten är att komplettera, och att genom exempel och utredningar förklara, det som lagen och förordningen föreskriver.</p> <p>Guiden tar upp dammplanering, bland annat den hydrologiska dimensioneringen och dammens tekniska säkerhetskrav, dammbygge och ibruktagandet samt riskutredning, dammägarens säkerhetsprogram och dammens underhåll, drift, kontroll samt årlig och återkommande inspektion.</p> <p>Dammar indelas på basis av skadekonsekvenserna i klasserna 1, 2 och 3. Klassificering krävs inte om dammsäkerhetsmyndigheten anser att dammen inte medför fara. Ägaren till en klassificerad damm skall utarbeta ett kontrollprogram som lämnas in till dammsäkerhetsmyndigheten för godkännande. I syfte att klargöra den skaderisk som dammen medför ska ägaren till en klass 1-damm göra en utredning om den skaderisk för människor och egendom samt miljön som dammen medför. Dammsäkerhetsmyndigheten kan besluta att en riskutredning ska göras också för andra än klass 1-dammar, om detta behövs för att klassificera en damm. Dammägaren ska göra upp en plan för åtgärder vid en olycka eller störningar vid en klass 1-damm. Säkerhetsprogrammet för en damm ska innehålla en redogörelse för dammägarens egen beredskap i ovan nämnda situationer. Räddningsmyndigheten bedömer från fall till fall behovet av en åtgärdsplan enligt räddningslagen. Dammens ägare ska till dammsäkerhetsmyndighetens datasystem lämna de uppgifter som avses i dammsäkerhetsförordningen. Dammsäkerhetsmyndigheten och dammägaren ska för varje klassificerad damm förvara uppdaterade utskriftur datasystemet samt andra handlingar som är av betydelse med tanke på dammsäkerheten på så sätt att de är lättillgängliga vid eventuella störningar.</p>				
Nyckelord (enligt Allärs) damm, damm i vattendrag, avfallsdamm, gruvdamm, översvämningvall, dammsäkerhetslag, dammsäkerhetsförordning, dammsäkerhetsmyndighet, dammägare, planering, byggande, klassificering, datasystem, dammsäkerhetsmapp, riskutredning, säkerhetsprogram, olycksfall, störningssituation, kontrollprogram, kontroll, årlig granskning, återkommande granskning, underhåll, drift				
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Abstract  <p>A new Dam Safety Act (494/2009) came into force on 1st October 2009 and a government decree on dam safety (319/2010) on 5th May 2010. This dam safety guide replaces the Dam Safety Code of Practice (Publication of the Ministry of Agriculture and Forestry 7/1997), removed from circulation on 1st October 2009. The dam safety guide is not binding on the dam owner; the purpose is to complement and elucidate the relevant law and decree through examples and descriptions.</p> <p>The guide takes up questions concerning dam design, for instance hydrological dimensioning and technical safety requirements, dam construction and use, the dam break hazard analysis and the dam owner's emergency action plan, maintenance, use, monitoring as well as the annual and periodic inspections.</p> <p>Dams are classified according to the hazard they pose into class 1, 2 or 3 dams. The classification is not needed, if, according to the dam safety authority, the dam poses no danger. The owner of a classified dam must prepare a monitoring programme, to be approved by decision of the dam safety authority. To establish the hazard caused by a dam, the owner of a class 1 dam must prepare an analysis of the dam hazard to humans and property as well as to the environment. The dam safety authority may also require a dam break hazard analysis for a dam other than a class 1 dam if deemed necessary for classification. The owner of a class 1 dam must prepare a plan of measures in case of emergency or operational failure. The plan shall present the dam owner's state of preparedness to act on their own initiative in the situations described above. In each case, the rescue authorities make a separate assessment for the need to prepare a plan as set out in the Rescue Act. The dam owner must provide the information specified in the Dam Safety Decree to be entered into the dam safety information system. The dam safety authority and owner of the dam must keep up-to-date printouts in their own dam safety files from the information system for each dam as well as other important documents connected with dam safety to ensure that these are readily available in case of disturbance.</p>				
Keywords dam, watercourse construction, waste dam, mine dam, flood embankment, Dam Safety Act, Dam Safety Decree, dam safety authority, dam owner, dam design, construction, classification, information system, dam safety file, hazard assessment, safety plan, emergencies and disturbances, monitoring programme, observation, annual inspection, periodic inspection, maintenance, use				
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A revised Dam Safety Act (494/2009) came into force on 1 October 2009 and a Government Decree on Dam Safety (319/2010) on 5 May 2010. The purpose of this Dam Safety Guide is to complement and elucidate the law and the decree through examples and descriptions. This guide replaces the Ministry of Agriculture and Forestry Dam Safety Code of Practice (MMM:n julkaisu 7b). The text of the guide is not legally binding.

The Dam Safety Guide is designed to support the tasks of dam owners and others who work at dams. The guide takes up the designing and construction of dams, classification, dam safety documentation as well as the dam break hazard analysis and the emergency action plan. The guide explains matters in connection with dam maintenance, use, monitoring and inspections as well as the obligations of the dam owner.

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