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Reg. no. 1271 of 15 December 2000: Regulations governing the safety and supervision of watercourse structures

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Regulations governing the safety and supervision of watercourse structures

Chapter 1. General provisions

Section 1-1. *Purpose*

These regulations shall help ensure that watercourse structures are adequately safe for people, the environment and property.

Section 1-2. *Authority*

These regulations are administered by the Norwegian Water Resources and Energy Directorate (NVE).

Section 1-3. *Definitions*

In these and subsidiary regulations, the following terms and definitions apply:

Chartered dam engineer (Vassdragsteknisk ansvarlig - VTA) is a qualified person employed by the responsible entity who has particular professional responsibility for seeing that the classified watercourse structures and the organisation in question comply with current safety provisions in the Water Resources Act as well as in these and subsidiary regulations.

Design discharge flood is the outflow at design flood water level.

Design flood water level is the highest water level that can occur in the reservoir at design inflow flood.

Design inflow flood is the inflow flood, given the return period that is specified for the dam class, that results in the highest water level in the reservoir under certain circumstances relating to the operation of the spillways and the reservoir's initial state.

Design lifetime is the time period for which an installation or an installation component is intended to meet the specified safety, environmental and economic requirements.

Design load is the characteristic value of load multiplied by an appropriate load coefficient.

Design material strength is the material strength used to calculate the capacity.

Discharge flood is the resultant flood from a reservoir.

Inflow flood is the flow into the reservoir from an unregulated area, plus the discharge flood from any upstream reservoirs and transfers.

Inspection personnel are qualified personnel employed by the responsible entity who perform inspection work and report to the chartered dam engineer.

Internal quality control is systematic measures that shall ensure that the responsible entity plans, builds and operates its watercourse structures in accordance with the safety requirements specified in the Water Resources Act and in these and subsidiary regulations.

Load is any effect that causes movement, deformation, stresses or strains in the structure.

Load coefficient is a prescribed coefficient with which a characteristic load or standardised load value shall be multiplied.

Maintenance consists of measures that are necessary in order to maintain a watercourse structure at a specified level of quality.

Manager is a qualified person employed by the responsible entity who has the overall responsibility for the safety of the watercourse structures and to whom the chartered dam engineer reports.

Material coefficient is a prescribed coefficient with which characteristic material strength or a standard value for structural strength shall be divided in order to determine the design material strength.

Maximum flood water level is the highest water level that occurs in the reservoir at probable maximum inflow flood.

Probable maximum discharge flood is the maximum discharge that is diverted at maximum flood water level.

Probable maximum inflow flood is the highest inflow flood that is estimated to occur and that results in the highest water level in the reservoir under certain assumptions about the operation of the spillways and the reservoir's initial state.

Reconstruction consists of physical measures for altering a watercourse structure's dimensions, functions, land use or standards.

Rehabilitation consists of work to bring a watercourse structure up to required functional and technical standards after damage, abnormal deterioration or deficient maintenance. In practice, this work is more extensive than maintenance.

Renewal is a collective term for rehabilitation and reconstruction.

Risk is an expression of the hazard represented by undesirable events for people, the environment and property. Risk is expressed as the probability and consequences of the undesirable events.

Risk analysis is a systematic procedure for describing and/or estimating risk. Risk analysis is performed by surveying undesirable events and their causes and consequences.

Structural condition analysis is the comprehensive analysis, definition of the task, planning, registration of the condition of the installation, evaluation and reporting at a given time.

The entity responsible for a watercourse structure (the responsible entity) is the owner of the installation. In response to an application, NVE may authorise someone other than the owner to be the responsible entity if there are special reasons for so doing. The owner and the entity that assumes responsibility must have entered into a written agreement that regulates the relationship between them.

Watercourse structures include dams, waterways, diversion works, sluice systems, adit gates and plugs and can also include roads, spoil tips and material pits in connection with watercourse structures.

Waterway includes tunnels, shafts, pipes, channels and other systems that conduct water in connection with watercourse structures.

Section 1-4. *Classification*

All watercourse structures that are covered by these regulations shall be classified in one of three main classes where the criteria for the classes reflect the impacts that a possible failure may have for people, the environment and property. A failure of watercourse structures in class 3 will have the greatest impacts.

The classification is done by the entity responsible for the installation and shall be submitted to NVE for approval.

Section 1-5. *Scope*

These and subsidiary regulations apply to the planning, construction and operation of watercourse structures, including the area that must be used for ensuring safety, as specified in litra a - e below. Liability pursuant to these regulations applies even if the installation is not in use.

These regulations also cover the supervision of the planning, construction, operation and maintenance of watercourse structures that are subject to government supervision.

These and subsidiary regulations will also apply to tunnels and pipes that conduct water under pressure.

These and subsidiary regulations also apply to watercourse structures that were built before these regulations came into force, but for decisions made in accordance with these regulations and to the extent that it is justifiable on the basis of safety considerations, NVE shall take into account that the decision applies to an existing installation.

These and subsidiary regulations apply to:

a) Dams that meet the following criteria:

- allow the possibility of raising the water level to a static water pressure against the dam of at least 4 m or the damming up of a volume of at least 0.5 mill. m^3 for classes 3 and 2
- allow the possibility of raising the water level to a static water pressure against the

dam of at least 6 m or the damming up of a volume of at least 0.5 mill. m^3 for class 1.

Static water pressure is defined as the height from the lowest point on the dam foundation at the upstream side of the impervious element to the highest regulated water level or normal water level.

These and subsidiary regulations include all components that are important for the dam's design and functioning, including equipment up to the first permanent sluicing device and equipment for diversion or flood discharge. The components' class will be the same as the dam class.

b) Exposed, buried and embedded penstocks in connection with power plants where the largest diameter is greater than 0.4 m and

- $P \times D > 0.4$ for class 3
- $P \times D > 0.7$ for class 2
- $P \times D > 1.0$ for class 1

where

P = highest internal static pressure in MPa (1 MPa is equivalent to 100 m of water pressure)

D = internal diameter (m)

For hydropower plants, including pumping plants, these and subsidiary regulations cover pipes as far as the upstream and downstream sluicing devices in a power or a pumping plant.

These and subsidiary regulations cover all components that are included in the pipe's design and functioning. The components' class will be the same as the pipe class.

c) Sluicing and diversion works excluding those that are covered by a) or b) where the area is greater than 0.5 m^2 and

- $P \times A^{0.5} > 0.1$ for class 3
- $P \times A^{0.5} > 0.2$ for class 2
- $P \times A^{0.5} > 0.3$ for class 1

where

P = highest internal static pressure in MPa (1 MPa is equivalent to 100 m of water pressure)

A = largest aperture area (m^2)

If the sluicing and diversion device is not the only closing device for the reservoir or waterway, cf. litra a), these and subsidiary regulations will not cover sluicing devices for turbines, pumps or pump turbines, when these are integrated into the hydraulic machine's system and included in the machine's starting and stopping procedures.

d) Other structures and components of structures:

- Tunnels, shafts and intakes where the inflow and discharge of water or air can cause damage to people, the environment and property.
- Pressure shafts, pressure equalisation devices, adit plugs and adit gates where a failure can cause damage to people, the environment and property.
- Channels, sluice chambers and sluice gates where a failure can cause damage to people, the environment and property.

e) Other conditions:

In special cases, NVE may decide that these and subsidiary regulations shall apply to other watercourse structures or to installations like those mentioned above, but with smaller dimensions and lower pressure, if a failure in the installation may cause damage to people, the environment and property.

Coffer dams and other temporary installations are covered by these and subsidiary regulations when they constitute a particular safety hazard for people, the environment and property.

Section 1-6. *Guidelines*

NVE can issue guidelines pertaining to the ways in which the requirements in these regulations can be met. These guidelines indicate a way of meeting the regulations' requirements.

If a solution is chosen that is at variance with the guidelines, the responsible entity for the installation shall document that this kind of solution meets the safety requirements that are specified in the regulations.

Section 1-7. *Dispensation*

After a safety evaluation, NVE may grant dispensation from provisions in these and subsidiary regulations.

Chapter 2. Safety

Section 2-1. *Internal quality control*

The entity responsible for a watercourse structure subject to these regulations shall carry out internal quality control in accordance with regulations governing internal quality control in order to comply with the Water Resources Act and these and subsidiary regulations.

Section 2-2. *Competency*

NVE sets professional competency requirements for, and approves and checks personnel who carry out the planning, construction, operation and inspection of watercourse structures.

NVE sets requirements for the manager, the chartered dam engineer (*VTA*) and inspection personnel employed by the responsible entity. In addition to meeting the professional competency requirements, these personnel shall be appropriately organised.

The competency requirements shall be linked to the classification of the watercourse structure, cf. section 1-4.

More details on the competency requirements and approval and the possibilities for checking are to be found in the subsidiary regulations, cf. section 11-1 of these regulations. NVE may impose specific requirements for professional personnel in special cases.

Section 2-3. *Contingency plans*

The responsible entity for a watercourse structure shall draw up a contingency plan. This plan is implemented whenever the situation at a watercourse structure increases danger levels significantly or has caused accidents to people, the environment and property. It shall include an operative plan that includes action plans based on analyses of possible abnormal situations. The plan shall be kept up to date, and NVE can demand that the plan be submitted to them.

In the construction of new installations, a contingency plan shall be available from the start of construction.

Exercises shall be conducted to train personnel and test whether the plan is adequate.

In watercourses where there are several responsible entities, NVE may demand that the contingency plans and emergency exercises be coordinated or that the contingency plan be drawn up by a joint organisation.

Section 2-4. *Dam breach flood analysis*

NVE may require that the entity responsible for a watercourse structure undertake analyses of the dam breach flood and prepare inundation maps.

Section 2-5. *Warning of dam failure*

NVE may require the entity responsible for a watercourse structure to establish systems designed to warn the authorities in charge of evacuation and rescue in the affected areas, in the event of imminent danger of a dam failure or in the event of a dam failure.

Section 2-6. *Plan for monitoring*

There shall be a plan for monitoring the watercourse structure's safety during construction, commissioning and operation. This plan shall be submitted to NVE for approval. The plan shall specify limit values for implementing measures.

Monitoring requirements will depend on the type and class of installation.

Section 2-7. *Instrumentation*

When the monitoring plan specifies instrumentation, the watercourse structures shall be instrumented in accordance with these specifications.

There shall be a detailed programme for the measurements that are taken. The results of these measurements shall be processed and presented in an easily understandable way. NVE may require that the programme and the results of performed measurements be submitted to them.

Systems for the transmission of data shall be especially resistant to malfunction.

Section 2-8. *Risk analysis*

NVE may require that the entity responsible for a watercourse structure conduct risk analyses.

Section 2-9. *Safety measures in the public interest*

The entity responsible for a watercourse structure shall establish and maintain safety measures that take into account the general public's normal use of and traffic on and near watercourse structures.

NVE may pass resolutions concerning these safety measures.

Chapter 3. The planning phase

Section 3-1. *Project description*

When the planning of new structures or renewal are initiated, a project description shall be drawn up and submitted to NVE. This project description shall provide an overview of structures and the distribution of detailed planning and its monitoring within professional fields related to the competency requirements specified by NVE.

Section 3-2. *Functional description*

A functional description shall provide an overview of the waterway and the various installation components in it and help ensure that the installation components are safely adapted to each other. The functional description shall also clarify which installation components may affect the safety. The functional description shall be prepared at the start of the planning or reassessment, cf. section 7-3, and be submitted to NVE.

Section 3-3. *Content and documentation*

The planning shall clarify the water discharge, water levels, loads and other parameters on which the dimensioning of the watercourse structure must be based and the way in which the installation will be designed so as to achieve adequate safety.

The documentation shall include any necessary assessments of engineering geology, hydrological calculations, capacity computations and dimensions for spillways and diversion works, choice of installation design with the main dimensions, and any other calculations and computations that are deemed necessary for the assessment of the installation's safety.

Section 3-4. *Approval of plans*

Based on the project description NVE decides what shall be submitted for approval.

NVE shall approve significant alterations to an already approved plan. NVE can process the matter as an application for a change of plans.

At any given time, NVE may require that the plans be altered if the actual circumstances are at variance with the conditions for approved plans. The same applies if new knowledge, or experience from other installations, suggests that the planned design will fail to meet the requirements in or pursuant to these regulations.

Chapter 4. Loads, dimensioning, materials and design

Section 4-1. *Loads*

The watercourse structures shall be dimensioned for the loads that have impacts on their safety throughout the installation's lifetime.

When loads occur in combinations, the most unfavourable load combination shall form the basis for the calculation.

When it is appropriate, loads shall be subdivided into the categories: permanent loads, variable loads and accident loads.

Special load conditions shall be taken into account.

NVE may specify load combinations, minimum dimensions for loads and load coefficients.

It shall be demonstrated that a watercourse structure will bear the relevant accident loads without failing.

Section 4-2. *Dimensioning*

The entity responsible for a watercourse structure shall check to make sure that loads and/or load effects do not exceed relevant limit values for capacity, load direction, material stress, deformation, crack width and vibration. This check shall be made on those of the following limit states that are relevant:

- Ultimate limit state
- Accident limit state
- Serviceability limit state
- Fatigue limit state

For accident limit state, each separate accident load and permanent load is checked if the combination is physically possible. For the other limit states, combinations of permanent and variable loads are evaluated if the combinations are physically possible. In the accident limit state, minor damage is acceptable.

NVE may specify the dimensioning standards or specific design and dimensioning criteria that shall be employed.

Section 4-3. *Materials and design material properties*

For the various structures, materials are chosen that make the structures adequately safe. Materials and use of materials in load-bearing structures shall meet requirements specified in approved and relevant dimensioning standards.

Design material strength shall be the basis for checking the structure's estimated capacities. When material parameters are uncertain, calculations shall allow for variations in the parameters so that the sensitivity of the results can be determined. NVE can specify minimum values for material coefficients.

Section 4-4. *Design*

Watercourse structures shall be designed so that their static load carrying ability is clearly defined, and so that loads are transferred to the foundation in a way that ensures the overall stability. In the design of watercourse structures, consideration shall be given to providing necessary access for inspection, operation and maintenance.

Section 4-5. *Flood calculations*

Flood calculations shall be performed to obtain the necessary data for dimensioning or control of dams and discharge and diversion works and to provide a basis for determining the capacity, design and manoeuvrability of the flood discharge and diversion works.

Depending on the dam class, the design inflow flood shall be used as a basis for dimensioning or reassessing the dam and spillways.

Depending on the dam class, the probable maximum inflow flood or a smaller flood shall be used as a basis in checking the dam's resistance to failure.

In calculating the inflow flood, it shall generally be assumed that any manoeuvrable structures in the transfer system may be out of operation. Consideration shall normally be given in the calculations to the fact that any water transfers to the natural catchment cannot be closed off and that transfers from the natural catchment can be blocked. In calculating the discharge flood and flood water level, consideration can be given to the reservoir's flood-reducing effect. The water level at the start of the flood shall be set at the highest regulated water level or the normal water level when the highest regulated water level has not been defined, unless something else has been particularly specified.

The flood calculations shall be documented and submitted to NVE with the information and assumptions that are necessary for NVE's checking and approval.

Section 4-6. *Flood discharge*

Dams shall have spillways that are dimensioned to handle the discharge that is estimated to be diverted past the dam. At design flood water level, the spillways shall be able to divert design discharge flood. The spillways shall be designed so that blockages can be avoided as much as possible.

If flood discharge is carried out through shafts or tunnels (closed spillways), these components shall be designed so that free-surface flow is definitely assured for the diversion of design discharge flood. For the diversion of the probable maximum discharge flood, it is acceptable that the entire conduit cross-section be filled with water. For the diversion of these floods in closed spillways, the overflow shall determine the water level in the reservoir.

The spillways' total capacity relative to water levels and sluice openings shall be calculated using approved methods or be documented in some other way. NVE may require model tests or drawdown tests where the empirical basis for the calculations is lacking or local conditions warrant it.

The responsible entity must have NVE's approval of the spillways that may be included in the calculation of the flood discharge capacity. Drawdown through bottom gates, stop logs, emergency spillways, and power stations shall not be included in the capacity calculations, but bottom gates and emergency spillways shall be operative for emergency drawdown. NVE may require that pin weirs not be included in the capacity calculations and that the blockage of the waterway is assumed in the calculation of discharge flood and flood water level.

Flood discharge shall not exacerbate the flood conditions in the watercourse relative to the natural state, unless this is permitted by provisions specified in a licence.

Section 4-7. *Earth dams*

An earth dam is defined as a dam that mainly consists of filled and compacted quantities of earth, gravel and rock.

Design load effects shall be determined by calculations performed according to approved methods and based on realistic assumptions about the structure's properties and performance.

In the dimensioning, the structure shall be checked for the following limit states:

- Ultimate limit state
- Accident limit state

When checking for the ultimate limit state, it shall be shown that the dam has sufficient stability against slides and erosion.

When checking for the accident limit state, it shall be shown that load effects do not result in failure. Damage that does not result in failure may be accepted.

The dam shall meet the following structural and material requirements:

a) *Foundation, adjoining and built-in structures*

The dam's design shall be adapted to the ground conditions. The surface of the foundation shall have, or be given, a design that ensures a favourable interaction between the foundation and structure of the dam and a favourable diversion of water.

If necessary, the dam foundation shall be drained in order to avoid the build-up of pore pressure and a flow of water that can cause erosion or instability.

Adjoining and built-in structures made of other materials shall preferably have their foundations laid on rock and shall be given a design that ensures a favourable interaction between the structure and the embankment.

b) *Impervious element of the dam*

The impervious element of the dam shall consist of suitable materials of approved quality. The design, dimensions and execution shall ensure that the amount of water seepage does not become so great that it can reduce the dam's safety.

c) *Filters and transition zones*

Material zones in the dam that shall protect adjacent zones against damage from erosion shall have sufficient area, and their composition shall meet approved filter requirements.

d) *Shoulder*

The shoulders shall consist of materials that ensure that adequate stability and draining capacity have been established with regard to quality, design, dimensions and execution and so that deformations are kept at an acceptable level. The outer slopes must have an incline that results in only moderate deformations and ensures adequate stability.

e) *Upstream slope*

The upstream slope shall have slope protection dimensioned and constructed so that it resists the impacts of waves, ice, frost and other possible stresses. If the slope protection is composed of stone rip-rap, then stones of an adequate size and quality shall be used, and they shall be stably arranged. The transition to the shoulder must

be constructed in a way that prevents a flushing out of interior materials. If the upstream shoulder has its foundation on uncompacted material, the slope protection must protect the natural terrain against damage from waves and ice.

f) *Downstream slope and toe of the dam*

The downstream slope and toe of the dam shall resist the impact of frost and be protected against erosion and slides caused by surface water and outflowing water. Stone in the slope and toe shall be of adequate size and quality and be stably arranged. The slope and toe shall have sufficient drainage capacity to withstand heavy water seepage resulting from accident loads or damage to the dam. The transition to the shoulder must be constructed in a way that prevents a flushing out of interior materials.

g) *Top of the dam*

The width of the top of the dam shall be great enough to ensure that quality requirements are met in construction. The crest of the dam shall be able to resist damage caused by climatic impacts and accident loads.

h) *Camber*

The dam with its individual zones shall be built with a camber adapted to expected settlement.

i) *Freeboard*

The dam and wave screen, if any, shall have a freeboard that is so far above the design flood water level that water cannot wash over the dam through a combination of wave run-up and wind set-up.

The upstream impervious facing shall have the same freeboard that is required for the dam.

The central impervious core shall have a freeboard that is so high that water cannot spill over the impervious element of the dam at the design flood water level with an addition for wind set-up. To reduce uncertainty, NVE may require that this freeboard be given an addition.

For accident loads, the water may usually be permitted to rise above the impervious element of the dam, wash or run over the top of the dam, if the dam crest, downstream shoulder, slope and toe of the dam have adequate protection against failure.

The requirements for freeboard do not apply to overflow dams that are designed for overtopping.

Section 4-8. *Concrete dams*

A concrete dam is defined as a dam that consists mainly of concrete. Insofar as they are appropriate, the provisions in this chapter also apply to concrete structures that are part of a dam of some other type.

Design load effects shall be determined by calculations performed according to approved methods and based on realistic assumptions about the structure's properties and performance.

Static and dynamic calculations can normally be based on linear theory. In the cases where non-linear effects of geometry and materials will have a significant influence on the safety of the structure, these factors shall be taken into consideration.

In the dimensioning, the structure shall be checked for the following limit states:

- Ultimate limit state
- Accident limit state
- Serviceability limit state

The stability with regard to overturning and sliding in the ultimate limit state and the accident limit state shall be verified.

Bolts and stays can be utilised to increase the stability. NVE determines the minimum concrete cover for reinforcement, bolts and stays and sets limits for the stabilising effects of bolts and stays.

For testing in the accident limit state, plasticity theory can be used. In such cases, it shall be shown that the structure can be deformed so that the expected yield lines can develop.

The dam shall meet the following structural requirements:

a) *Foundation*

The foundation of a concrete dam shall preferably be built on rock. On exception, the foundation can be built on some other kind of ground that is capable of bearing the load.

The surface of the foundation shall have or be given a design that ensures a favourable interaction between the foundation and the dam structure.

b) *Drainage*

If necessary, the foundation shall be drained in order to avoid the build-up of

pore pressure and a flow of water that can cause instability.

The drainage must be designed to prevent leakage and drainage water from causing ice problems that subject the dam structure to additional loads.

c) *Construction joints*

Concrete structures shall normally be divided with construction joints, located at certain points and intervals so as to avoid unintended cracking that could lead to damage.

The joints shall be watertight, durable and designed to transfer the loads that may arise.

d) *Freeboard*

The dam shall have a freeboard above the design flood water level that is sufficient to prevent overflow of water in amounts large enough to damage the dam or its foundation or to cause damage in the area downstream.

The following material requirements are specified:

a) *Concrete*

Constituent materials and the proportioning shall be such that the finished product will have the intended properties, including that the concrete when fresh is suitable for the relevant method of casting.

The concrete shall have adequate strength to meet the requirements that are specified for the individual structures and components of structures.

The concrete shall be sufficiently impermeable, frost-resistant and resistant to other forms of deterioration.

NVE can specify environmental classes.

b) *Reinforcement, bolts and stays*

Reinforcement, bolts and stays shall meet the requirements in relevant current Norwegian Standards.

Section 4-9. *Masonry dams*

A masonry dam is defined as a dam constructed of stone and stone blocks with an impervious element on the water side or incorporated as a component within the dam.

Design load effects shall be determined by calculations performed according to approved methods and based on realistic assumptions about the structure's properties and performance.

In the dimensioning, the structure shall be checked for the following limit states:

- Ultimate limit state
- Accident limit state
- Serviceability limit state

The stability with regard to overturning and sliding in the ultimate limit state and the accident limit state shall be verified.

Bolts and stays can be utilised to increase the stability. NVE sets limits for the stabilising effects of bolts and stays.

The dam shall meet the following structural requirements:

a) *Foundation*

For provisions relating to the foundation, section 4-8, paragraph 8, litra a) will apply likewise.

b) *Drainage*

Downstream of the dam’s impervious element, there shall be adequate drainage. Otherwise, section 4-8, paragraph 8, litra b) will apply likewise.

c) *Freeboard*

For provisions relating to the freeboard, section 4-8, paragraph 8, litra d) will apply likewise.

d) *The impervious element of the dam*

The dam shall have a defined impervious element. Design, dimensions and construction shall ensure that the water seepage does not become so great that it can diminish the dam's safety.

The following material requirements are specified:

a) *Stone*

The strength, resistance to erosion and weathering, form and size of the stone shall be adapted to the structure's building method, design loads and lifetime.

b) *Peat and earth*

Peat and earth that are used in the impervious element of the dam shall be of an approved quality.

c) *Concrete and reinforcement*

For provisions regarding concrete and reinforcement that are used in foundations,

joints, pillars, sealing elements, etc., section 4-8 of paragraph 9, litra a) and b) will apply likewise.

Section 4-10. *Other types of dams*

Other types of dams are defined as dams with other structural designs or dams that are partly built from other materials than those discussed in sections 4-7, 4-8 and 4-9. For example, these dams may be constructed as timber crib or trestle structures.

Design load effects shall be determined by calculations performed according to approved methods and be based on realistic assumptions about the structure's properties and performance.

In the dimensioning, the structure shall be checked for the following limit states:

- Ultimate limit state
- Accident limit state
- Serviceability limit state

The stability with regard to overturning and sliding in the ultimate limit state and the accident limit state shall be verified.

Bolts and stays can be utilised to increase the stability. NVE sets limits for the stabilising effects of bolts and stays.

The dam shall meet the following structural requirements:

a) *Foundation*

The dam shall have a foundation with sufficient strength to be able to bear design loads. The foundation shall be designed so that a favourable interaction with the dam structure is achieved.

b) *Drainage*

Downstream of the dam’s impervious element there shall be adequate drainage. Otherwise, section 4-8, paragraph 8, litra b) will apply likewise.

c) *Freeboard*

For provisions relating to the freeboard, section 4-8, paragraph 8, litra d) will apply likewise.

d) *The impervious element of the dam*

For provisions relating to the impervious element of the dam, section 4-9, paragraph 6, litra d) will apply likewise.

The following material requirements are specified:

Wooden materials, including timber, shall have a quality that ensures long durability.

Fasteners shall be rustproof or sufficiently corrosion-resistant, so that corrosion damage that impairs safety will not occur.

For stone materials, the material requirements in section 4-9, paragraph 8, litra a) will apply likewise.

For concrete, section 4-8, paragraph 9, litra a) and b) will apply likewise.

For steel materials, section 4-11, paragraphs 7 to 9 will apply insofar as they are applicable.

Section 4-11. *Diversion works*

Diversion works are defined as all types of sluices, valves and other devices for the purpose of closing, draining, regulating or diverting the flow of water that are not an integral part of e.g. turbines, pumps or pump turbines.

Design load effects shall be determined by calculations performed according to approved methods and based on realistic assumptions about the structure's properties and performance.

In the dimensioning, the structure shall be checked for the following limit states:

- Ultimate limit state
- Accident limit state
- Fatigue limit state
- Serviceability limit state

The manoeuvrability of diversion works shall be ensured for all relevant operating conditions.

Diversion works shall have sufficient capacity for all relevant operating conditions and operational situations. The need for emergency closure and draining facilities must be clarified.

The following structural requirements have been specified:

a) *Main functions*

Diversion works shall have adequate functional properties for all expected opening positions and water levels.

Important protective devices shall function even if components of the control system have been put out of operation.

The arrangement for the transmission of signals for remote control of important devices and the reading of important measurements shall be specially protected against malfunctions. It shall be possible to document this special protection, and NVE may demand that the documentation be submitted for approval.

Diversion works that shall be operated at low temperatures shall be protected against freezing shut and against damaging ice formation.

Emergency closure devices shall have a reliable shutdown function.

b) *Design*

There must be adequate access to diversion works for inspection and maintenance. In cases where it will be difficult to provide access by draining and lowering the water level, there shall normally be an audit shutdown. In cases where access is so limited that it will be difficult to conduct inspection and maintenance, this shall be reflected in the design lifetime.

Extra consideration shall be given to functional reliability in the choice of the type and arrangement of the diversion devices in the flood diversion system.

Diversion works with adjoining installation components shall have an appropriate hydrodynamic design and sufficient air supply.

The steel lining of the gate shall be embedded in concrete so that no damaging vibrations occur in the plate lining during drawdown. Gate guides shall have a secure anchoring.

Control systems shall be built so that no serious damage to diversion works occurs as a result of operative errors, and the arrangements shall be protected against unintended manoeuvring.

The following material requirements are specified:

Diversion works with associated equipment shall be constructed in materials that meet the safety requirements that are specified for the structure, so that the design lifetime can be achieved with ordinary maintenance.

Whenever possible, standardised materials or components with documented strength, ductility and other relevant properties shall be used during all operating conditions.

When other non-standard or less well-known materials are used, and these will have an important effect on the safety of the structure, NVE may demand that the material properties be specified and documented.

Section 4-12. *Pipes and adit gates*

Pipes are defined as enclosed structures for the transport of water from reservoir to power station, or between reservoirs, together with foundations and equipment that are normally associated with these structures.

An adit gate is defined as a pedestrian or vehicle gate for access to a waterway in a tunnel or cavern.

Design load effects shall be determined by calculations performed according to approved methods and based on realistic assumptions about the structure's properties and performance.

In the dimensioning, the structure shall be checked for the following limit states:

- Ultimate limit state
- Accident limit state
- Fatigue limit state
- Serviceability limit state

Pipes and adit gates with associated components shall be tested for load combinations with internal overpressure and for load combinations with internal underpressure. When evaluating the major consequences of failure, the possibility and consequences of a full internal vacuum shall be assessed. The consequences of sudden closure during the highest operational water flow in the waterway shall also be evaluated. Pipes and adit gates shall also be checked with regard to system stability given the forces that may occur in the structure.

Consideration shall be given to production and installation tolerances, deformation of pipes with couplings and foundations, if any, or gate leaves and gate frames, together with the other loads to which the structure will be exposed.

For exposed pipes, consideration shall be given to the risk of internal icing. Stress concentrations in supports or foundations shall be included in the design calculations.

For embedded pipes and steel linings, consideration can be given to the load reduction that is achieved when the forces from internal water pressure are partly transferred to the surrounding concrete and bedrock. Consideration shall also be given to the external pressure and the distribution of pressure along pipes or steel linings during casting, or perhaps injection, ordinary operation and subsequent draining of the waterway.

Foundations and anchoring blocks shall be tested for the loads they shall transfer.

The following structural requirements have been specified:

a) *Laying foundations and concrete casting*

Foundations for exposed pipes shall be built on stable ground and constructed in such a way that deformations or displacements do not add damaging additional loads to the structures. Foundations and anchoring blocks shall be stable with regard to overturning and sliding, cf. section 4-8, paragraphs 2 to 7.

For buried pipes, the pipe trench shall be dug in stable ground and the pipe shall be laid in such a way that no damaging settlement or axial or lateral displacement occurs. The back-filled material shall be chosen and deposited in such a way that the pipe is not damaged or deformed. Steps shall be taken to prevent damaging erosion from occurring in the material on the outside of the pipe.

Embedded pipes and steel linings shall be checked to ensure that the quality of the bedrock and casting will meet the design criteria. Concrete casting and injection, if any, are carried out in such a way that damaging deformations do not occur.

b) *Design*

Pipes and adit gates with associated components, foundations, etc. shall be designed to facilitate inspection and maintenance. In cases where the possibility of access makes it difficult to conduct inspection and maintenance, this shall be reflected in the requirements for design lifetime.

Pipes shall have a closing device at the upstream end and equipment for safe filling and draining of the pipe, including equipment for the inlet and outlet of air. Pipes where the consequences of a failure will be major shall be equipped with an automatic closing device.

Couplings, expansion boxes, etc. shall provide secure seals under all operating conditions, and the calculations shall take into consideration forces caused by water pressure, axial movements or a possible oblique position or shearing motion. Expansion arrangements shall ensure that unintended stresses do not arise. The seals

shall have adequate long-term properties.

Adit gates shall be protected against unintended closing and/or opening and shall have possibilities for checking the upstream water level.

The following material requirements are specified:

Pipes and adit gates with associated equipment shall be constructed in materials that meet the safety requirements specified for the structure, so that design lifetime is achieved with ordinary maintenance.

Whenever possible, standardised materials or components, with documented strength, ductility and other relevant properties shall be used during all operating conditions.

When other non-standard or less well-known materials are used, and these will have an important effect on the safety of the structure, NVE may demand that the material properties be specified and documented.

Section 4-13. *Spillways*

A spillway is defined as the whole waterway system from upstream of the dam to the outlet in the riverbed downstream of the dam. It normally consists of an inlet, conduit spillway, diversion and outlet. A conduit spillway is defined as an ungated spillway or a gated spillway.

Spillways shall be constructed in a safe and appropriate manner. Consideration shall be given to capacity limitations, air requirements, erosion of exposed surfaces, pressure pulsations and the risk of blockage and icing.

Flood diversion shall preferably occur on ungated spillways with a standard spillway shape, specified for design discharge flood. Designs and cross-sectional profiles that are at variance with the ideal can be used if the diversion capacity and stability are adequately documented.

Gated spillways will preferably be used only where the consequences for safety of a malfunction are minor. When the consequences for safety of a malfunction are major and gated spillways are the only possible option, extra safety measures shall be initiated. Flood diversion and drawdown shall be possible without any risk to the dam's safety. The diversion and the re-entry to the downstream riverbed shall be done in a controlled way without any risk of eroding the landscape, the dam foundation and the toe of the dam. Where large amounts of energy are released, special consideration must be given to the

potential for erosion and landslides, and, if necessary, special arrangements must be made for the conversion of this energy.

The consequences for accident loads shall be discussed. When the consequences are unacceptable, structural measures shall be implemented, or extraordinary diversion measures shall be arranged.

Section 4-14. *Other structures and structural components*

a) *Tunnels, shafts and caverns*

Tunnels, shafts and caverns shall be planned, situated and designed so as to be adapted to the topographical and geological conditions in the area. In particular, cover, leakage and stability shall be evaluated.

Enclosed waterways that can be exposed to pressure shall be designed so that air that is entrained in the intake does not give rise to unstable operating conditions, reduce the capacity or cause damage when compressed air is released. Intakes shall be designed with a view to reducing air entrainment.

Openings where uncontrolled releases of compressed air may occur, shall be located and arranged with a view to minimising damage, and, if necessary, special measures shall be taken to counteract and reduce damage.

Concrete plugs for closing water-bearing tunnels shall be watertight and be placed in impermeable and stable bedrock. It shall be documented that the bedrock can withstand the applied forces in the place where the plug is located. Any sealing and stabilisation of the bedrock that is necessary shall be undertaken by injection and the use of necessary safety measures before the plug is built.

Tunnels, shafts and caverns for the transport of water under high pressure shall be designed, located and protected so that damaging leakage and deformations of the surrounding bedrock do not occur. Measures shall be taken to prevent landslides and the falling of blocks of stone into a waterway, which can block or reduce its capacity.

An open structure for equalising pressure shall have a freeboard that protects against overtopping when load pulsation occurs or have defined spillways or diversion works for the diversion of water when overtopping occurs.

Flood tunnels shall be stabilised against landslides and rock falls. It shall be ensured that leakage and seepage of water and snow will not form ice plugs that fully or partly block the tunnel. Flood tunnels shall be operable at all times.

b) *Channels*

Channels must be dimensioned and designed so that their bottom and sides are stable and can resist the effects of erosion from flowing water, and they shall be operable at all times.

It shall be demonstrated that the sides of the channel have sufficient freeboard under all operating conditions. Channels with a water level above ground shall be designed and constructed according to safety requirements similar to those that derive from sections 4-8 - 4-11 for dams of similar materials. These provisions apply insofar as they are appropriate.

c) *Sluices*

Sluice gates shall be dimensioned and designed with requirements similar to those that apply to diversion works, cf. section 4-11. Sluice chambers shall be designed and constructed according to safety requirements similar to those that derive from sections 4-8 - 4-11 for dams of similar materials. These provisions apply insofar as they are appropriate.

Chapter 5. Construction and renewal

Section 5-1. *Work schedule*

NVE may require that a work schedule that specifies all important phases in the construction work be drawn up and submitted. The plan shall be drawn up before the construction work is initiated.

Section 5-2. *Construction and inspection of construction*

Work shall not commence until NVE has given the necessary approval.

An overview of the organisation of the construction project shall be drawn up where the division of responsibility and tasks is specified.

If there are several parties involved in the construction process, the implementation shall be coordinated. This coordination shall be carried out by a qualified person.

There shall be a detailed programme for the implementation of the technical quality control during the construction work. This programme shall be approved by NVE.

In the strictest classes of installations, NVE will normally require an independent inspection. The undertaking that performs the inspection shall be independent of the contractors and the entity responsible for a watercourse structure.

The inspection shall be performed by qualified personnel. NVE may require documentation of the qualifications of those who perform the inspection.

There shall be a programme for the measurements that are performed during construction. NVE may require that the programme be submitted.

Section 5-3. *Reporting*

NVE may require that periodic reports be submitted with results of measurements and tests and the inspector's evaluation of them and of other factors that may be significant for construction.

A final report shall be prepared and submitted to NVE. This report shall contain a summary of the performed inspection with the inspector's evaluation and drawings, which show the completed watercourse structure.

Chapter 6. Commissioning

Section 6-1. *Programme*

During the commissioning of a new installation and after the reconstruction of existing ones, a programme shall be drawn up for the initial impounding and commissioning of a dam and waterway with diversion works. This programme shall specify the speed of impounding and the scope and methods for inspection, measurement and testing activities. A course of action shall be indicated for interrupting and reversing the commissioning, if necessary. The programme shall designate a person who is professionally responsible for the commissioning. NVE may require that the programme be submitted.

Section 6-2. *Reporting*

A record of the commissioning shall be kept, based on the programme and activities registered in the log.

NVE may require that the record be submitted.

Chapter 7. Operations

Section7-1. *Operational procedures*

There shall be operational procedures for watercourse structures. These procedures shall also indicate the routines for dealing with operating conditions and situations that are at variance with the normal ones so that hazardous situations can be avoided to the greatest possible extent.

If the operation of installation components may entail a risk to people, the environment and property, and the risk can be reduced by manual surveillance, provisions relating to this kind of surveillance shall be included in the procedures.

NVE may require that the procedures be submitted. The procedures shall be familiar to all involved parties.

Section 7-2. *Inspection*

There shall be a programme for the inspection of watercourse structures. This programme shall specify competency requirements for personnel, time periods, extent of inspections and reporting at various levels of inspection. Damage and accident reporting shall be included in the programme. The responsible entity shall take care of updating and implementing the programme. As a basis for the inspection, there shall always be up to date documentation of the watercourse structure.

NVE may require that the inspection programme and the reports from implemented inspections be submitted.

Section 7-3. *Reassessment*

Reassessment is a thorough examination and review of an established watercourse structure that shall determine whether the installation meets the safety requirements that have been specified in the Water Resources Act and in these and subsidiary regulations.

The reassessment shall be based on a structural condition analysis and experience with the installation during the time that it has been in operation.

Reassessment shall be performed regularly and otherwise when the need arises. It shall be performed by an approved firm that does not have any organisational affiliation with the responsible entity for the installation.

The reassessment shall be documented and submitted to NVE with the information and conditions that are necessary for NVE's control and approval.

Section 7-4. *Programme for testing diversion works*

A programme shall be created for testing diversion works. NVE may require that the programme and the results of conducted tests be submitted.

Section 7-5. *Reconstruction or rehabilitation of watercourse structures*

Prior to the reconstruction or rehabilitation of a watercourse structure, NVE may require that a reassessment of the existing installation be carried out, cf. section 7-3.

Chapter 8. Measures in serious hazardous situations

Section 8-1. *Orders to the developer*

When the conditions in a watercourse create a special and extraordinary hazard to people, the environment or property, the watercourse authorities can order any developer to conduct his operations so as to reduce the hazard pursuant to section 40 of the Water Resources Act.

Chapter 9. Decommissioning of watercourse structures

Section 9-1. *Decommissioning*

The decommissioning of a watercourse structure can first occur after a permit has been granted on the basis of an application to decommission the installation pursuant to section 41 of the Water Resources Act.

Section 9-2. *Transfer to new owner*

If an application has been submitted to decommission an installation, the watercourse authorities may transfer it to a new owner pursuant to section 42 of the Water Resources Act.

Chapter 10. Implementation and penalties

Section 10-1. *Coercive fines*

Pursuant to section 60 of the Water Resources Act, NVE may impose a coercive fine to be paid to the Norwegian state on the entity responsible for the installation so as to ensure that resolutions pursuant to these and subsidiary regulations are implemented. Pursuant to section 61 of the Water Resources Act, NVE may see that work is carried out at the responsible entity's expense if it does not comply with an order issued pursuant to these and subsidiary regulations.

Section 10-2. *Penalties*

Wilful or negligent violation of obligations that derive from these and subsidiary regulations or from orders issued pursuant to these and subsidiary regulations, will be punished with fines or imprisonment of up to three months, cf. section 63 litra e of the Water Resources Act, cf. section 63 paragraph 3.

Section 10-3. *Fees*

NVE may collect fees to cover the costs of NVE's inspection, control and approval pursuant to these and subsidiary regulations.

Chapter 11. Final provisions

Section 11-1. *Subsidiary regulations*

NVE may issue subsidiary regulations to implement and supplement these regulations to the extent that they apply to:

- classification, cf. section 36 of the Water Resources Act
- contingency plan, cf. section 38
- competence, cf. section 39 of the Water Resources Act
- internal quality control, cf. section 54 of the Water Resources Act
- fees, cf. section 58 of the Water Resources Act

Section 11-2. *The regulations' entry into force*

These regulations enter into force on 1 January 2001. On the same date, regulations no. 4165 of 14 November 1980 relating to planning and construction, etc. of dams and regulations no. 595 of 2 April 1982 relating to the inspection of dams in watercourses and the delegation of authority will be repealed.