

DSC3G

June 2010

GENERAL DAM SAFETY CONSIDERATIONS

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1. INTRODUCTION

The normal requirements of the NSW Dams Safety Committee (DSC) are set out in its guidance sheets with its principal guidance sheet, *DSC Background, Functions and Operations (DSC1A)*, outlining the DSC's general operations and authority.

This guidance sheet is intended to assist owners implementing a new dam, or modifying an existing dam, by listing common design, construction and operational issues, which the DSC considers to be good practice for most situations, but which are sometimes neglected or inadequately covered in submissions to the DSC, and are not covered in detail in other DSC documents. This sheet is not intended to be a comprehensive design manual, or set of guidelines, and the full responsibility for all phase of dam safety management rests with dam owners and their professional advisers. Accordingly, the DSC will carefully consider any well documented case supporting the use of alternative approaches.

It is intended that this document will be updated on a regular basis and modified to reflect further issues that come to notice, and to take account of changing standards in the dams industry.

The DSC Dam Safety Goal and Key Requirements (Section 2) at the start of the sheet are a summary - the whole sheet is to be read for a proper understanding of DSC considerations on a range of dam safety issues.

2. DSC DAM SAFETY GOAL & KEY REQUIREMENTS

2.1 DSC Dam Safety Goal

The DSC's prime goal is to ensure that all prescribed dams in NSW are designed, constructed and operated to a standard where risks to the community are tolerably low. The level of risk is determined by the likelihood and consequences of failure.

The relevant issues for consideration are set out in the following sections of this sheet, generally in the same sequence as the dam life cycle, and aim to provide direction and guidance to assist dam owners in achieving this DSC goal.

2.2 DSC Key Requirements

This section summarises the DSC requirements outlined in this sheet.

3.2 Geology / Geotechnical

A comprehensive geotechnical investigation should be undertaken, and a detailed report prepared, for all Extreme, High and Significant Consequence Category dams. During construction, all excavations forming part of the permanent works, are to be geologically mapped, foundation levels recorded, features photographed and results of water tests and grouting are to systematically recorded. All of this work should be undertaken by suitably qualified personnel.

3.3 Floods

Dam owners are required to carefully consider the DSC's guidance sheet on Acceptable Flood Capacity for Dams (DSC3B).

3.4 Earthworks

Dam owners should ensure that the design of embankment dams (including CRFD) clearly states the basis for design strengths, stability methodology, assumptions on pore pressures and the factors of safety and includes calculated predictions of the settlement behaviour and states the safety against piping.

3.5 Foundation / Abutments

The layout of the dam should avoid any sharp changes in the profile of the foundation with foundation and abutment grouting planned and carried out with the assistance of specialist advice. All exposed foundations and excavations for structures should be logged by a suitably qualified engineering geologist. Special care should be taken in the design of any interface between foundation or concrete structures and earthfill to minimise the piping risks along the interface. The design of all Extreme, High and Significant Consequence Category concrete dams reliant on uplift relief should consider the effectiveness of the uplift relief system and make provision for its accessibility and maintenance.

3.6 Filters / Drains

The DSC is of the opinion that the design of effective drains and filters is highly cost effective in terms of the total safety of embankment dams with all Extreme, High and Significant Consequence Category earthfill and earth core/rockfill dams to have fully intercepting filters. In addition, seepage collection and monitoring is required in all Extreme, High & Significant Consequence Category dams.

3.7 Conduits

Where possible conduits should be embedded in the natural foundation and not located in the embankment and no unencased metal conduits are to be used in any part of the dam. Pressure pipelines, without an airspace separation from the embankment, are to be continuously welded and no rubber ring jointed or bolted flange pipes are to be used in conduits, except for penstocks with an air space separation within a larger conduit.

3.8 Concrete

The DSC requires special consideration of the issue of durability in concrete structures.

3.9 Tendons and Post-Tensioning

Only restressable and monitorable post-tensioning tendons are to be used. Tendons are to be fully encapsulated in protective grout and there is to be an impermeable barrier between the tendon and the rock foundation and one stage grouting of the cable length is required to maximise corrosion resistance. Provision shall be made for the monitoring of anchor head condition.

3.10 Hydraulics

The design of erosion resistance for all discharge channels shall make appropriate allowance for envisaged flow depths and velocities particularly where there may be sudden changes in channel cross-section or direction of flow.

3.11 Mechanical / Electrical

All mechanical / electrical systems essential for dam safety shall have adequate back up provisions including back-up power sources.

3.12 Gates / Valves

A plan should be prepared for formal internal briefing on spillway gate opening practices and procedures to be carried out at regular intervals. The design of gated systems shall include a risk assessment of the potential for gate or control system failures. All

emergency opening and closing devices should have protected access for all emergency conditions. The design of the outlet works shall consider the adequacy for emergency dewatering.

3.13 Design for Dams

Dam design documentation requirements are outlined in the DSC's guidance sheets on *Demonstration of Safety for Dams* (DSC2D) and *Documentation and Information Flow over Dam Life Cycle* (DSC2B). A checklist of pertinent matters to be considered in design submissions to the DSC is included as Appendix A to this sheet.

3.14 Construction for Dams

During dam construction the DSC requires the employment of experienced construction supervisors and the involvement of designers. No changes are to be made to the design without the approval of the designer and a record of all design changes is to be kept. Proper records of construction are to be kept and a Construction Certificate and Construction Report are to be submitted to the DSC upon completion of construction. Work-as-Executed (WAE) drawings are to be prepared and preserved.

3.15 Operations and Maintenance, Instrumentation

All Extreme, High and Significant Consequence Category dams are to have an Operation and Maintenance (O&M) Manual. A plan should be prepared for the training of all operations personnel. All systems shall have formal incident reporting after any incidents. All Extreme and High Consequence Category Dams should have automatic and telemetered monitoring systems for storage level and seepage (where practicable). Provision shall be made for chemical testing of seepage water where the foundations or dam materials are of a soluble or dispersive nature. Planting of trees on, or any vegetation that impairs surveillance of, a prescribed dam is not permitted.

3.16 Documentation

All important design decisions are to be recorded in a formal Design Report for both new dams and modifications of existing dams. Specifications for the construction, or modification, of an Extreme, High or Significant Consequence Category dam are to require that a formal Construction Report, including Work-As Executed drawings, be prepared on completion of the works. Dam owners are to have an effective long term archiving system of all important documentation relating to the dam.

3. DSC DAM SAFETY MANAGEMENT CONSIDERATIONS

3.1 General

The standards of design, construction and operation of dams reflect the level of potential adverse consequences from dam failure and are always subject to revision and updating to reflect new technologies and changing community standards. In this regard, the DSC notes that the ANCOLD 'Guidelines for the Design of Concrete Gravity Dams' (1991) are now being updated. Until this review is completed, the DSC considers that good examples of best practice in this area are the United States Bureau of Reclamation (USBR) Guidelines for new dams and the draft Chapter III of the US Federal Energy Regulatory Commission (FERC) Guidelines for existing dams. Overall, care should be taken by dam owners when referring to any dated guidelines.

To reflect this dynamic nature of dam safety management, the DSC continually reviews and updates its range of requirements that are applied to suit the assessed risk, and encompass the site specific conditions, changing technical and community standards, and

established dams engineering practice. In parallel, the DSC requires dam owners to carefully consider the relevance of any reference used in their dam safety management programs and state these references on any major management decision.

Although dam owners are responsible for ensuring dams meet tolerably low risk levels, the DSC has a responsibility to draw owners' attention to any conceptual or detail issues which are questionable in terms of established standards of good practice or which need to be further supported. The DSC considers the matters set out in this sheet to represent minimum good practice for the subject issues in most situations. It needs to be emphasised that this sheet does not aim to be comprehensive in the treatment of issues affecting the safety of dams. Rather, its aim is to highlight those issues which tend to receive inadequate attention, or which have been a source of difficulty in the DSC's experience.

3.2 Geology / Geotechnical

A comprehensive geotechnical investigation should be undertaken, and a detailed report prepared, for all Extreme, High and Significant Consequence Category dams. As a minimum, the investigation report should include:

- A description of the regional geology and structure;
- A detailed description of the geological conditions at the site, highlighting any geological structure, hazards or potential problem areas;
- Detailed geological sections which allow an interpretation of the stratigraphy and geological structure;
- Detailed data on the permeability, strength, compressibility and erodibility of the foundation, sufficient to allow an assessment of the depth to suitable foundation material for the dam, and the need for any foundation treatment;
- Comments on the stability of batters, crests, cracks and slips;
- Data on the proposed sources and properties of all materials to be used in the construction, including earthfill, rockfill, filters, rip-rap, concrete aggregate;
- Details on the watertightness, erodibility and stability of the reservoir area and rim; and
- Comments on the seismicity of the region.

The report should be supplemented by the factual outcome of investigations, including:

- Geological mapping;
- Borehole logs and core photographs;
- Foundation / Borrow Area test results (permeability, seismic, SPT, etc);
- Trench and pit logs;
- Laboratory test results (soil, rock);

- Rock strength test results; and
- Petrology results.

Borehole cores should be systematically boxed, photographed, recorded and permanently retained.

During construction, all excavations forming part of the permanent works, are to be geologically mapped. All foundation levels are to be recorded, so that the location of any part of the foundations is permanently known. Extensive photography of the foundations is to be retained permanently. Results of water tests and grouting are to be systematically recorded.

All of this work should be undertaken by suitably qualified personnel (e.g. engineering geologist, geotechnical engineer).

3.3 Floods

The DSC is especially conscious of the rapid pace of change in the methodologies and availability of data in this field. In general, dam owners are required to carefully consider the DSC's guidance sheet on *Acceptable Flood Capacity for Dams (DSC3B)* and collate all hydrologic data in accordance with the DSC's Data Form D6. In addition owners should ensure that:

- All data, assumptions, other inputs, methodologies and outcomes of the hydrology study are explicitly noted and documented;
- Construction flood provisions are nominated and allowed for in the design, and the basis on which the risks are assessed to be tolerable is documented;
- For modifications to existing dams, the normal objective is to be that risks from flood during upgrading are not greater than those existing prior to commencement of upgrading. If this objective cannot be achieved, the owner is to demonstrate that the risks are as low as reasonably practicable;
- A flood frequency curve for the catchment and storage is prepared using the guidelines provided in Australian Rainfall and Runoff;
- Seasonality of flooding is considered where appropriate;
- The design of fuse plug type spillways considers all incremental surge impacts downstream, so as to minimise these impacts where people are at risk; and
- The design of dams with limited spillway capacity includes consideration of long duration flood, or prolonged or seasonal rainfall events, where the critical condition may be based on flood, or long-term rainfall, volume and not the more typical flood peak flow.

3.4 Earthworks

The DSC notes that the available statistical data on dam failures suggest that earthen embankments experience the highest incidence of failure from all causes. Accordingly, the design, or safety review, of all earthfill embankments should be undertaken by dam's engineers or geotechnical engineers experienced in this field. Dam owners should ensure that:

- The design of embankment dams (including CRFD) clearly states the basis for design strengths, stability methodology, assumptions on pore pressures and the factors of safety;
- The design of all Extreme, High and Significant Consequence Category dams includes calculated predictions of the settlement behaviour of the finished structure;
- The design takes into consideration the issue of construction pore pressures; and
- The design of embankment dams includes an assessment of piping failure and states the safety against piping.

3.5 Foundation / Abutments

The DSC places considerable emphasis on the lessons learned from dam failures. In this regard, it is noted that failure initiated through conditions associated with dam foundations has been a commonly recorded feature. Consequently:

- For earth core dams, the dam body should be keyed into the abutments with end slopes, in the direction parallel to the dam axis, flatter than 1.5 (vertical) on 1 (horizontal), unless special provisions have been made for piping control at this interface;
- The batters of core trenches, in the direction normal to the dam axis, should not be steeper than 1 (horizontal) on 1 (vertical);
- The layout of the dam should avoid any sharp changes in the profile of the foundation;
- Foundation and abutment grouting should be planned and carried out with the assistance of specialist advice;
- The design of any permanent sheet piling shall make adequate provision for durability;
- The design should consider the possibility of liquefiable sands in the foundations;
- All exposed foundations and excavations for structures should be logged by a suitably qualified engineering geologist. The resultant geological plans should be included with the WAE drawings or otherwise retained as part of the permanent record;
- The design should include assessment of foundation and foundation interface piping potential and state the safety against piping;
- Special care should be taken in the design of any interface between concrete structures and earthfill to minimise the piping risks along the interface (e.g. appropriate downstream filters, concrete slopes no steeper than rock abutments to maintain high fill pressures); and
- The design of all Extreme, High and Significant Consequence Category concrete dams reliant on uplift relief should consider the effectiveness of the uplift relief system and make provision for its accessibility and maintenance.

3.6 Filters / Drains

The DSC is of the opinion that the design of effective drains and filters is highly cost effective in terms of the total safety of embankment dams. The DSC has noted in recent years that this issue is sometimes not given adequate consideration by dam designers. This has resulted in time-consuming correspondence with owners to achieve necessary amendments to the submitted designs. Important issues to consider are:

- Slotted drain pipes, or pipes of any sort, should not be used for drainage under embankments, except where they are readily accessible for maintenance or replacement (for example, in toe drains running just inside the bank, with inspection pits);
- Seepage collection and monitoring is required in all Extreme, High & Significant Consequence Category dams;
- Finger drains, as an alternative to blanket layers of filter media, generally do not provide adequate seepage discharge capacity to prevent local or general saturation of the downstream shell of earth dams. In this situation, such drains are generally unacceptable to the DSC. Where their use is proposed, the owner is to demonstrate by calculation, using the recognised high factors of safety for seepage discharge capacity, that there will be no local or general saturation of the downstream shell;
- In assessing the required discharge capacity of filter systems generally, consideration is to be given to the risk of cracking in earth cores, or other impermeable elements, due to such causes as earthquake shaking or differential settlement;
- The treatment of foundation surfaces under blanket filters shall be such as will promote flow of foundation seepage into the filter;
- Special care is required when filter media are won from natural deposits of sand and gravel, since the gradation and quality of material in such deposits can be highly variable. Frequent sampling and testing, along with vigilant inspection by supervision personnel, is needed in such cases;
- Geotextile filter cloth is generally not acceptable as an alternative to a sand filter. In this regard, the DSC's policy is that geosynthetics should only be used where they are not critical to the performance of the dam, and generally where they can be repaired or replaced if necessary;
- All Extreme, High and Significant (relating to non-itinerant PAR only) Consequence Category earthfill and earth core/rockfill dams are to have fully intercepting filters;
- The design of concrete lined spillways shall consider the need for drainage under the spillway slabs; and
- Designers shall consider the need for upstream filters in narrow earth core dams as a "crack stopper" or to retain fines if rapid dewatering is a likely load case.

3.7 Conduits

Outdated practices for the design and construction of conduits have been a major contributing factor in the piping failure of embankment dams. There are numerous dams in operation with aging pressure conduits, often unencased metal, which present a significant safety risk. The DSC requires that these outdated practices are eliminated in all new and modified dams. The following issues should be considered in the detail design of conduits:

- No unencased metal conduits are to be used in any part of the dam, unless separated from the embankment fill by an air space (for example, a small diameter pressure penstock within a large diameter concrete conduit or tunnel);
- Pressure pipelines, without an airspace separation from the embankment, are to be continuously welded, fully concrete encased, and normally of cement-lined steel construction. The encasement is to be reinforced so as to carry the full static and dynamic head, without reliance on the contribution of the steel pipe. The steel, or other, liner is to be checked against buckling due to the external water pressure;
- No rubber ring jointed or bolted flange pipes are to be used in conduits, except for penstocks with an air space separation within a larger conduit;
- Where possible conduits should be embedded in the natural foundation and not located in the embankment. Conduits, which project into the embankment fill, particularly the earth core, promote low fill pressures adjacent to the conduit, with risk of hydraulic fracture or other forms of piping;
- If HDPE conduits are specified they should be concrete encased and checked to ensure they can withstand external water pressures. They would normally only be considered suitable on small dams with low failure consequences; and
- A downstream filter type collar, with large discharge capacity, is generally considered a more effective protection against piping than a concrete cut-off collar. For new dams, the DSC will look for means of protection against piping that are more effective than cut-off collars.

3.8 Concrete

The DSC requires special consideration of the issue of durability in concrete structures. Dams are considered to have a 'monumental' design life, that is, with effective lives well in excess of 100 years. Earth and rockfill have an indefinitely long life, as evidenced by dams thousands of years old. The concrete elements are generally the controlling factor in the longevity of a dam structure. The design of the concrete mix and the concrete detailing should reflect this reality. Consequently:

- The concrete mix design should give due consideration to the durability of the concrete, especially if Roller Compacted Concrete (RCC) is proposed;

- Those RCC dams so far constructed in Australia have exhibited much higher permeability than is normal for conventional concrete dams. Also, the cementitious content is typically lower than for conventional concrete. Consequently, the DSC has some concerns regarding the durability of RCC where dams of that material are to have along service life. In such cases, the owner needs to demonstrate that the RCC will have the desired durability;
- The susceptibility of the concrete to Alkali Aggregate Reaction should be determined and reported to the DSC;
- The cover to flexural steel reinforcement should be more generous than for normal building construction;
- Careful attention must be given to the durability and performance record of water stops used for sealing joints in concrete water retaining structures; and
- The specification should carefully consider and detail appropriate repair methodologies for defects in the concrete.

3.9 Tendons and Post-Tensioning

The stabilisation of dams using post-tensioning technology has been widely adopted over the past few decades because of its cost effectiveness. This technology has developed significantly over this period, and the design of some older anchors is now considered unsuitable for use in dam construction. The current requirements of the DSC are:

- Only restressable and monitorable post-tensioning tendons are to be used;
- Tendons are to be fully encapsulated in protective grout and there is to be an impermeable barrier between the tendon and the rock foundation;
- Access and monitoring requirements for post-tensioning are to be assessed and stated;
- All tendon top anchorages shall be checked for bursting and spalling stresses;
- One stage grouting of the cable length is required to maximise corrosion resistance;
- Provision shall be made for the monitoring of anchor head condition, and replacing of the grease in the top anchorage of tendons, at periods not exceeding two years;
- All anchors are to be proof tested during installation and records kept of anchorage installation and stressing details;
- The first Surveillance Report after anchor installation is to outline the results of recent load testing of ALL anchors, comparing performance against installation conditions and recommending future monitoring arrangements (e.g. number of tendons to be checked, frequency); and

- After this initial testing, the DSC requires a proportion of anchors to be tested at five yearly intervals and reported in the next Surveillance Report for the dam along with recommendations for future monitoring. As a minimum, the DSC requires the following progressive sampling of anchors at five yearly intervals:
 - Extreme Consequence Category Dams 50%
 - High Consequence Category Dams 33%
 - Other Dams 10%

3.10 Hydraulics

The DSC has noted instances in recent years of designs that have not adequately considered the dynamic forces arising from spillway, channel and outlet works flows and their implications for dam safety. The DSC now requires that:

- The design of erosion resistance for all discharge channels shall make appropriate allowance for envisaged flow depths and velocities particularly where there may be sudden changes in channel cross-section or direction of flow;
- The design shall investigate and consider standing wave patterns in open and natural channels;
- In the design of major dams the designer should consider the value of physical spillway modelling in addition to modern numerical modelling technology; and
- For embankment dams particularly, adequate protection is to be provided from spillway outlet flows to the dam toe and groins. This is best achieved by a separation between the dam structure and the spillway, with a positive substantial barrier of natural ground between the two elements.

3.11 Mechanical / Electrical

A current issue before the DSC is the emergency preparedness of dams reliant on electrical and mechanical systems for dam safety. This includes flood warning systems, gated spillways and automated outlet works, including the associated monitoring and control systems. In this regard, designers shall ensure that:

- All mechanical/electrical systems essential for dam safety shall have adequate back up provisions including back-up power sources;
- The design of monitoring and control systems is to consider the availability to the owner, throughout the life of the dam, of electronic and other components, and of specialist technicians. It is essential that such systems can be maintained in an “as new” condition of effectiveness indefinitely. Complex systems should be avoided if the supply of needed components in the future is doubtful or if suitably trained people will not be available to maintain the system;
- The need to consider the safety of operating personnel should not compromise the safety of the dam. For this reason, as an example, it would generally be preferable that spillway gates or emergency release controls, can be operated from a safe

location not on the dam structure, the safety of which may be questionable in an extreme flood event or following a severe earthquake; and

- The design should make adequate provision for night lighting for access to all essential systems at the dam.

3.12 Gates / Valves

As noted above, the design of all dams reliant on mechanical flow control devices should place due emphasis on the design for, and planning of, operational issues. To this end:

- A plan should be prepared for formal internal briefing on spillway gate opening practices and procedures to be carried out at regular intervals;
- The design of gated systems shall include a risk assessment of the potential for gate or control system failures, including failure of multiple gates, and the impact of the time required for opening, especially during extreme loading events. Such an assessment should include human factors, such as the predicted effectiveness of communication and decision systems, the availability of specialists such as electricians, the training status of personnel, and the likelihood of operator error;
- All emergency opening and closing devices should have protected access for all emergency conditions; and
- The design of the outlet works shall consider the adequacy for emergency dewatering, and, if practicable, conform to the USBR Criteria set out in '*Criteria and Guidelines for Evacuating Storage Reservoirs and Sizing Low-Level Outlet Works*', US Department of the Interior, ACER Technical Memorandum No. 3, 1982.

3.13 Design for Dams

Dam design documentation requirements are outlined in the DSC's guidance sheets on *Demonstration of Safety for Dams (DSC2D)* and *Documentation and Information Flow over Dam Life Cycle (DSC2B)*. A checklist of pertinent matters to be considered in design submissions to the DSC is included as Appendix A to this sheet.

In particular, independent peer reviews are to be undertaken of the designs (and concept designs for major dams) for all Extreme and High Consequence Category dams, with details required relating to the nature of the works to be undertaken and the Consequence Category of the dam (see also section 6.6 of DSC2D for similar peer review requirements of dam safety reviews). Peer reviewers must be recognised as at least equal in experience and technical ability to the designers/ report authors, and comment on the designs/reports relative to the current state of knowledge. The reviewer's role is to check assumptions and concepts, design methods, overall accuracy and the conclusions drawn in the designs/reports. Reviewers are to be independently appointed by dam owners to work closely with designers/authors in a context of trust and respect for intellectual property to ensure all objectives and assumptions are included in the review. The reviewer is to report to the owner, with a copy to the designer/author for consideration, comment and any necessary action. The owner is to provide a copy of the reviewer's report,

together with a report on any outcomes from the reviewer's report, together with the design report to the DSC for its consideration.

3.14 Construction for Dams

To assist in the achievement of safe dams, and to facilitate their maintenance, repair or upgrading during their long life, the DSC requires the following:

- The employment of experienced construction supervisors who will ensure faithful adherence to the design or will recognise the need for consultation with the designers;
- The involvement of the designer during construction, including periodic inspections of the works by the designer;
- That no changes are made to the design without the approval of the designer;
- That a record of all design changes is kept;
- That a construction certificate, in the form specified by the DSC, is submitted upon completion of construction (see DSC2B);
- That proper records of construction are kept, including a photographic record with date and time and a log of all significant events (e.g. date, time and location of concrete pours);
- That the location, date, time and results of all grouting activities and all embankment testing (e.g. compaction, concrete strength) are kept;
- That the final foundation configurations are recorded (see Sub-section 3.2);
- That geological mapping of excavations is prepared and preserved (see Sub-section 3.2);
- That all design drawings are preserved;
- That Work-as-Executed (WAE) drawings are prepared and preserved; and
- That Construction Reports be prepared for all new and modified Significant, High and Extreme Consequence Category dams with their comprehensiveness related to the dam's consequence category. The DSC recommends that basic construction reports be prepared for other dams.

The Construction Report should include the following items:

- Details, including photographs, of the foundation, abutments and reservoir floor conditions exposed during construction;
- Details of treatments for the above areas;
- Summaries of the data collected on the sourcing, properties and placement of construction materials;
- A set of relevant photographs recording construction progress;
- Detailed comments on the nature of any significant incidents during construction (e.g. floods, construction stoppages, earthquakes, extreme weather events or vandalism);

- Explanation of the nature, reasons for, and the endorsement of any variations to the design; and
- Any incidents noted in the commissioning process relevant to dam safety management.

3.15 Operations and Maintenance, Instrumentation

The DSC considers that effective operation and maintenance procedures, in conjunction with appropriate instrumentation, and monitoring and surveillance procedures, can significantly reduce the risks posed by dams. Some of the aspects, which the DSC considers important, are listed below.

- All Extreme, High and Significant Consequence Category dams are to have an Operation and Maintenance (O&M) Manual (see DSC2F);
- A plan should be prepared for the training of all operations personnel;
- All systems shall have formal incident reporting after any incidents. This process shall be internal and to the DSC;
- Significant scour of abutments and toe shall be monitored and reported internally and to the DSC;
- All Extreme and High Consequence Category Dams should have automatic and telemetered monitoring systems for storage level and seepage (where practicable);
- Provision shall be made for chemical testing of seepage water where the foundations or dam materials are of a soluble or dispersive nature;
- The selection of transducers should be carefully considered to suit the specific conditions of the site and operating procedures including appropriate lightning protection; and
- Due to the extensive evidence world-wide of the deleterious effects of trees on embankment dams, including several dam failures, the DSC's policy is that planting of trees on, or any vegetation that impairs the effective surveillance of, a prescribed dam is not permitted. The degree of vegetation cover on a dam is to be determined by the owner consistent with the DSC's policy and in consideration of the dam's Consequence Category and vulnerability to piping. If existing dams do not meet this DSC requirement, owners must act expeditiously to remove trees and vegetation and maintain the dam to achieve effective surveillance. Where trees on an existing dam have a high social value, the DSC may consider a case by the owner for their progressive removal involving consideration of the dam's Consequence Category, its structural nature, the criticality of different areas of the dam and whether it is a dry retarding basin.

3.16 Documentation

The DSC is concerned that, with the rapid pace of organisational change, documentation and archiving may not be given adequate priority and resources. The DSC is of the opinion that access to design, construction, O&M and surveillance data is an essential feature of the duty of care of dam owners and requires that:

- All important design decisions are to be recorded in a formal Design Report for both new dams and modifications of existing dams. The report shall include, as a minimum, the factual results of investigations, the interpretations made from those results, the assessed input values, the analysis methodologies used and the output values, and the justification of decisions (see Sub-section 3.13 and Appendix A);
- Specifications for the construction, or modification, of an Extreme, High or Significant Consequence Category dam are to require that a formal Construction Report, including Work-As Executed drawings, be prepared on completion of the works; and
- Dam owners are to have an effective long term archiving system of all important documentation relating to the dam, including reports, geotechnical data, inspection check sheets, monitoring results, operation and maintenance records, and design and construction drawings.

APPENDIX A - DSC DESIGN CHECKLIST

The following list is intended to assist proponents of new and modified dams in ensuring that their design submissions to the DSC provide satisfactory project coverage. Dam owners are referred to other DSC guidance sheets (e.g. DSC2B,& DSC2D) to assist in their submission.

1. Consequence Category	Failure Modes (piping, overtopping etc.)	<input type="checkbox"/>
	Dambreak estimates (extent, depth, timing)	<input type="checkbox"/>
2. Stability	Dam and valley geometry	<input type="checkbox"/>
	Static load cases (after construction, FSL, rapid draw down)	<input type="checkbox"/>
	Seismic load case	<input type="checkbox"/>
	Flood load case	<input type="checkbox"/>
3. Foundation Treatments	Excavation requirements	<input type="checkbox"/>
	Cut off's	<input type="checkbox"/>
	Grouting extent and type	<input type="checkbox"/>
	Clean up	<input type="checkbox"/>
	Abutment treatment(s)	<input type="checkbox"/>
	Drains	<input type="checkbox"/>
4. Structure	Concrete (incl. RCC)	
	Cross Section and Dimensions	<input type="checkbox"/>
	Mix and Placement	<input type="checkbox"/>
	Joint Design	<input type="checkbox"/>
	Post Tensioning	<input type="checkbox"/>
	Embankment (incl. CFRD)	
	Cross Section and Dimensions	<input type="checkbox"/>
	Piping Protection	<input type="checkbox"/>
	Filters	<input type="checkbox"/>
	Scour Protection-upstream and downstream slopes	<input type="checkbox"/>
	Material choice and placement	<input type="checkbox"/>
	Tailings	
	Cross Sections and Dimensions	<input type="checkbox"/>
Floods provisions	<input type="checkbox"/>	
Operating issues	<input type="checkbox"/>	
Drainage – Filters and Piping	<input type="checkbox"/>	
Raising issues	<input type="checkbox"/>	
Decommissioning	<input type="checkbox"/>	
5. Spillways	Hydrology	<input type="checkbox"/>
	Capacity	<input type="checkbox"/>
	Type	<input type="checkbox"/>
	Hydraulic Profile	<input type="checkbox"/>
	Protection	<input type="checkbox"/>
6. Peer Review		<input type="checkbox"/>
7. O and M	Manual	<input type="checkbox"/>
	Monitoring / Surveillance	<input type="checkbox"/>
	Outlet works	<input type="checkbox"/>
	Access	<input type="checkbox"/>
	DSEP	<input type="checkbox"/>

This Guidance Sheet is one of a series available from our Website at:

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