Manual

Environmental Protection Act 1994

Manual for assessing consequence categories and hydraulic performance of structures

This Manual for assessing hazard consequence and hydraulic performance of structures (the Manual) sets out the requirements of the administering authority, for consequence category assessment and certification of the design of 'regulated structures', constructed as part of environmentally relevant activities (ERAs) under the Environmental Protection Act 1994 (EP Act).

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Queensland Government

Version history

Version	Effective date	Description of changes
3.00	6 December 2013	Review of manual and guideline to address operational implementation issues.
3.01	13 December 2013	Amendment to Table1. Consequence Category Assessment and footnotes.
4.00	10 April 2014	Amendment to Table1. Consequence Category Assessment, plus other minor grammatical amendments.
5.00	29 March 2016	Amendments to exemptions, definition of regulated structure, levees and Table 2. Publication number change from EM635 to ESR/2016/1933
5.01	29 March 2016	The document template, header and footer have been updated to reflect current Queensland Government corporate identity requirements and comply with the Policy Register.
5.02	29 March 2016	Amendment to references to the Environmental Protection (Water and Wetland Biodiversity) Policy 2019.
5.03	23 February 2024	Document rebranded to align with machinery of government changes.

1 Scope

This *Manual for assessing hazard consequence and hydraulic performance of structures* (the Manual) sets out the requirements of the administering authority, for consequence category assessment and certification of the design of '**regulated structures**', constructed as part of environmentally relevant activities (ERAs) under the *Environmental Protection Act 1994* (EP Act).

The term regulated structures includes land-based containment structures, levees, bunds and voids, but not a tank or container designed and constructed to an Australian Standard that deals with strength and structural integrity. Structures may be assessed using this Manual as being in one of three consequence categories: low, significant or high. Where categorised as a significant or high consequence, the structure is referred to as a regulated structure.

This Manual **does not** provide a detailed methodology for the design of dams, spillways and levee structures. The detailed design of a regulated structure is to be undertaken by a suitably qualified and experienced person[1] with relevant professional experience, and requires appropriate documentation and certification[2].

1.1 Related Guideline and laws

This Manual relates to, and should be read in conjunction with, the guideline *Structures which are dams or levees constructed as part of environmentally relevant activities (ESR/2016/1934[3])* published by the administering authority,

The Manual does not limit, amend or change in any way, any other requirements to be complied with under environmental authority (EA) conditions and/or regulations for the design and operation of a dam[4]. Further, this Manual does not negate any lawful requirements of the EP Act, other Commonwealth, state or local government laws or requirements under relevant standards or agreements.

1.2 Background

Good practice engineering for dams, spillways, and levee structures requires that they be assessed for the consequences associated with 'dam break' and 'failure to contain' scenarios, and that the impacts of such potential failures are identified and considered in their design and operation.

The early identification of the consequence potential of these structures is important in determining the standard of reliability required for design, construction and operation of the structure. The default objective for any structure containing substances (liquid and/or solid material) that could result in environmental harm is that the substances be contained so as to prevent or otherwise minimise harm to the environment.

Whilst this Manual details the hydraulic performance criteria for regulated structures, it does not prescribe site planning standards. Site planning should consider avoiding wherever possible and practicable locating

[1] The term 'suitably qualified and experienced person' is defined in the definitions.
[2] A copy of the certification required can be found at appendix B
[3] This is the publication number, which can be used as a search term to find the latest version of the publication at www.des.qld.gov.au.
[4] An example of other legislative requirements that may be relevant are those relating to referrable dams under the *Water Supply (Safety and Reliability) Act 2008*.

regulated structures in high risk or sensitive locations (e.g. flood plains, above shallow groundwater systems, residential areas, environmentally sensitive areas).

The Manual does not detail operational standards for regulated structures. However, the water management strategy for a site must entail active management (including if relevant, treatment) of contaminated waters in regulated structures so that in the event of an incident, the impact is reduced to as great an extent as possible, (if not avoided altogether). This should include use of pumps and transfer systems of appropriate capacity to effectively manage contaminant water levels in the structure. Water management should also minimise unnecessary generation of contaminated waters by segregating clean catchment flows from contaminated catchment flows. In this context, regulated structures also include flood protection levees to reduce risk of ingress of clean floodwaters into operational areas where they may become contaminated with possible adverse impact on water management operations and containment performance.

Structures that could have significant or high impacts need to be carefully designed and operated.

1.3 Purpose

The purpose of this Manual is to:

1. guide the assessment of the consequence category of all structures constructed as part of activities that require an EA or development approval
2. guide the determination of the structures that require formal documentation; and
3. provide approved methods for specifying the design performance and monitoring requirements for those structures.

This document is structured in three parts:

- **Part 1**—outlines the requirements for consequence assessment
- **Part 2**—outlines the hydraulic performance requirements for dams that are assessed as being regulated structures
- **Part 3—**outlines specific considerations for assessing levees and hydraulic performance requirements for levees that are assessed as regulated structures

2 Assessment requirements

2.1 Initial consequence category assessment

This part provides guidance for undertaking a consequence category assessment for a structure which is a dam or levee.

All structures which are dams or levees associated with the operation of an ERA, must, unless otherwise stated in this Manual, have their consequence category assessed based on the potential environmental harm that would result from the failure event scenarios (Section 1.1) described in this Manual. Specific considerations for levees are included in part 3 of this Manual and consequence category assessments for levees should be conducted in consideration of the information contained in this section.

The consequence category will determine whether the structure is a regulated structure. A structure is only a regulated structure where the consequence category for the structure is ‘significant’ or ‘high’.

The consequence category of a structure is the highest consequence category determined under any of the assessment criteria set out in this part for each failure event scenarios.

2.1.1 Exemptions

Structures are excluded from the requirements of this Manual if they comply with (a) or (bb):

(a) The structure is constructed to:

- i. contain fluids for no longer than 24 months;
- ii. store less than 2.5ML of fluids;
- iii. minimise the site-specific risks of seepage;
- iv. minimise passage of the wetting front; and
- v. allow the structure to be managed in a way that first prevents then minimises the potential of fluids overtopping.

(b) The structure is constructed to:

- i. contain fluids for no longer than 24 months;
- ii. store between 2.5ML and 5ML of fluids;
- iii. minimise the site-specific risks of seepage;
- iv. meet a site-specific or pro-forma certification of a design plan to contain the wetting front; and
- v. allow the structure to be managed in a way that first prevents then minimises the potential of fluids overtopping.

The proforma certification of a design plan would provide the following:

(a) a description of all the documents which constitute the design plan;

(b) a statement of:

- i. the applicable standards including engineering criteria, industry guidelines, relevant legislation and regulatory documents, relied upon in preparing the design plan; and
- ii. all relevant facts and data used in preparing the design plan, including any efforts made to obtain necessary facts and data, and any limitations or assumptions to facts and data used in preparing the design plan;
- iii. setting out the reasoning of the suitably qualified and experienced person who has certified the design plan, as to how the design plan provides the necessary required performance to ensure the stability and structural integrity of the proposed structure.

(c) detailed criteria for the design, operation, maintenance and decommissioning of the regulated structure, including any assumptions.

To be clear, structures used to contain wastewater from stimulation activities (i.e. fracc flowback water) are also exempt if they meet the above requirements AND the structure is certified by a suitably qualified and experienced person as being able to contain the wetting front. As an alternative to the RPEQ certifying the structure as being able to contain the wetting front, a suitably qualified and experienced person may certify a ‘pro forma’ design that will contain the wetting front. The pro forma approach means that individual suitably qualified and experienced person certification for each structure is not required when the design is used.

2.1.2 Consequence category—based on assessment of failure event scenarios

The consequence category of a structure must be assessed by a suitably qualified and experienced person and include:

1. Documentation of the assessment, including the methodology used, of each of the following failure event scenarios:
   (a) **‘Failure to contain – seepage’** – spills or releases to ground and/or groundwater via seepage from the floor and/or sides of the structure;
   (b) **‘Failure to contain** – **overtopping’ –** spills or releases from the structure that result from loss of containment due to overtopping of the structure; and
   (c) **‘Dam break’** – collapse of the structure due to any possible cause.

Assessment of the ‘Failure to contain – seepage’ scenario is only required for new structures and does not apply to structures approved prior to development of this version of the Manual.

Assessment of the ‘Failure to contain – overtopping’ and ‘Dam break’ scenarios are required for both new and pre-approved structures.

In assessing each scenario under item 1, the types of impacts that may occur under the scenario must be identified and considered, and must include any local and regional flooding that may lead to:

   (a) overtopping of the structure[5]; or
   (b) the need for erosion protection of the structure; or
   (c) other structure failure modes[6].

2. Documentation of the assessment, in relation to each of the above scenarios, of the potential for each of the following:
   (a) the failure of a structure placing lives at risk due to dwellings or workplaces being in the failure impact zone;
   (b) downstream consequences, including but not limited to failure of other structures that may be affected by any flooding;
   (c) the consequences of such cascade failure for other structures;
   (d) the impact to both on-site and off-site environmental values;

[5] This includes consideration of overtopping from inside and from outside due to flood ingress over the dam wall
[6] Examples of other dam failure modes may include piping and pump failure

(e) long term potential adverse effects due to release of contaminants to groundwater systems and soil profiles;

(f) potential consequential effects on surface water systems; and

(g) storage releases that may chemically interfere with waters used as sources of drinking water.

3. Despite any exemption that would otherwise have been applicable under the *Water Supply (Safety and Reliability) Act 2008*, a failure impact assessment in accordance with the requirements that would otherwise have applied under that Act if the structure is a dam that is either:

   (a) more than ten metres in height with a storage capacity of more than 1500 Mega litres (ML); or

   (b) more than ten metres in height with a storage capacity of more than 750ML and a catchment area that is, more than three times its maximum surface area at full supply level;

   If the dam exceeds these parameters, the additional assessment must be included in the consequence category assessment, unless valid justification is documented in the consequence category assessment for not doing so.

4. Documentation of any other matter that the suitably qualified and experienced person reasonably considers to be relevant to the assessment, taking into account the guidance at the beginning of this Manual about Scope, Related Guideline and Laws, Background and Purpose.

Upon completion of a consequence category assessment, a structure will have a consequence category identified for each of the scenarios identified under item 2. These consequence categories will be determined by applying Table 1 to the assessment of each failure event scenario.

Consequence categories for each failure scenario are subsequently used to determine the appropriate hydraulic performance criteria in accordance with Part 2 of this Manual.

The consequence category for each failure event scenario may be changed by relocating the structure away from where it could/will affect environmental values, including public amenity and safety. The consequence category for a failure event scenario cannot be changed by adding a design element.

Table 1. Consequence Category Assessment[7]

Environmental harm	Consequence category		
	High	**Significant**	**Low**
Harm to humans	Location such that people are routinely present in the failure path and if present loss of life to greater than 10 people is expected[8]. Note: The requirement to consider the location of people in the failure path is only relevant to the 'dam break' scenario.	Location such that people are routinely present in the failure path and if present loss of life to 1 person or greater but less than 10 people is expected[7]. Note: The requirement to consider the location of people in the failure path is only relevant to the 'dam break' scenario.	Location such that people are not routinely present in the failure path and loss of life is not expected[7]. Note: The requirement to consider the location of people in the failure path is only relevant to the 'dam break' scenario.
	Location such that contamination of waters (surface and/or groundwater[9]) used for human consumption could result in the health of 20 or more people being affected[10].	Location such that contamination of waters (surface and/or groundwater[8]) used for human consumption could result in the health of 10 or more people but less than 20 people being affected[9].	Location such that contamination of waters (surface and/or groundwater[8]) used for human consumption could result in the health of less than 10 people being affected[9].
General environmental harm	Location such that: a) Contaminants may be released to areas of MNES, MSES or HEV waters that are not already authorised to be disturbed to at least the same extent under other conditions of this authority subject to any applicable offset commitment (Significant Values); and	Location such that contaminants may be released so that adverse effects[10] (that are not already authorised to be disturbed to at least the same extent under other conditions of the authority subject to any applicable offset commitment) either: a) Would be likely to be caused to Significant Values but those adverse effects[10]effects[10] would not be likely to meet the thresholds for the High consequence category and instead would be likely to cause at least one of the following:	Location such that either: a) Contaminants are unlikely to be released to areas of Significant Values or Moderate Values; or b) Contaminants are likely to be released to those areas, but would be unlikely to meet any of the minimum thresholds specified for the Significant Consequence Category for adverse effects[10]

[7] To be used for all failure event scenarios

[8].'People routinely present in the failure path' could be considered to be people who occupy buildings or other places of occupation that lie within the failure impact zone. For the purposes of this Manual, this should refer to people other than site personnel engaged by the resource operation and located on the tenements and tenure associated with the resource operation; for other ERAs, it would be the 'premises referred to in the authority'. It should be noted that while this is appropriate for the assessment of consequence categories in accordance with this Manual, adherence to the requirements of this Manual does not limit, amend or change in any way, any other requirements to be complied with under relevant health and safety acts or legislation that requires the safety of site personnel to be considered.

[9] When considering potential impacts on groundwater, it is not envisaged that a full hydrogeological assessment will be required in all cases. Any consideration of potential impacts on groundwater systems should consider the water quality of the potential receiving aquifer as well as the quality of fluid stored in the regulated dam. Existing groundwater drawdown in areas surrounding resource operations (e.g. drawdown as a result of mine pit or underground mine dewatering) can also be considered when assessing the consequence of dam seepage on groundwater systems.

[10] 'An adverse effect on human health means a physiological effect on human health and does not include an impact on the quality of downstream water that merely negatively affects taste and which is unlikely to cause persons to become physically ill.

Environmental harm	Consequence category		
	High	**Significant**	**Low**
	b) Adverse effects[11] on Significant Values are likely; and c) The adverse effects[10] are likely to cause at least one of the following: i) loss or damage or remedial costs greater than $50,000,000; or ii) remediation of damage is likely to take 3 years or more; or iii) permanent alteration to existing ecosystems; or iv) the area of damage (including downstream effects) is likely to be at least 5km^2 .	i) loss or damage or remedial costs greater than $10,000,000 but less than $50,000,000; or ii) remediation of damage is likely to take more than 6 months but less than 3 years; or iii) significant alteration to existing ecosystems; or iv) the area of damage (including downstream effects) is likely to be at least 1km^2 but less than 5km^2. or b) Would be likely to be caused to environmental values classed as slightly or moderately disturbed waters[12], wetland of general ecological significance[13], riverine areas, springs or lakes and associated flora and fauna (Moderate Values), and the adverse effects[10] are likely to cause at least one of the following: i) loss or damage or remedial costs greater than $20,000,000; or ii) remediation of damage is likely to take more than 1 year; or iii) significant alteration to existing ecosystems; or iv) the area of damage (including downstream effects) is likely to be at least 2 km^2	
General economic loss or property damage	Location such that harm (other than a different category of harm as specified above) to third party assets in the failure path would be expected to require $10 million or greater in rehabilitation, compensation, repair or	Location such that harm (other than a different category of harm as specified above) to third party assets in the failure path would be expected to require $1 million and greater but less than $10 million in rehabilitation, compensation, repair or rectification costs[13].	Location such that harm (other than a different category of harm as specified above) to third party assets in the failure path would be expected to require less than $1 million in rehabilitation, compensation, repair or rectification costs[13].

[11] Adverse effects includes chronic and acute effects where an acute effect is on living organism/s which results in severe symptoms that develop rapidly, and a chronic effect is an adverse effect on a living organism/s which develops slowly. In some instances, it may be necessary to carry out or reference existing ecological/toxicological studies to assess the impacts of contaminants on living organisms.
[12] See Environmental Protection (Water and Wetland Biodiversity) Policy 2019for definitions
[13] Wetland of general ecological significance' means a wetland shown on a map of referable wetland as a 'general ecologically significant wetland' or 'wetland of other environmental value'.

Environmental harm	Consequence category		
	High	Significant	Low
	rectification costs[14].		

2.2 Hydraulic performance criteria for dams that are regulated structures

The requirements under Part 2 only apply where a dam is assessed to be a regulated structure. The hydraulic performance objectives for dams that are regulated structures are directly related to the assessed consequence category for each failure event scenario:

1. **'Failure to contain – seepage'** – dams that are regulated structures must be designed to ensure appropriate containment of contaminants in accordance with a specified design standard based on the assessed consequence category for the 'failure to contain – seepage' scenario.
2. **'Failure to contain – overtopping**'– dams that are regulated structures must be designed to ensure appropriate containment of contaminants up to a specified probability of exceedance criteria based on the assessed consequence category for the 'failure to contain – overtopping' scenario.
3. **'Dam break'** – spillways of dams that are regulated structures must be designed to ensure that the structure will survive and can successfully pass a flood event up to a specified probability exceedance criteria.

2.2.1 Failure to contain – seepage

The hydraulic performance objectives for dams that are regulated structures in relation to the 'failure to contain – seepage' scenario are to be achieved by:

1. selecting the appropriate design objectives in accordance with Table 2
2. determining appropriate materials, design parameters and construction requirements to achieve the relevant design objective for containment
3. determining appropriate design parameters and construction requirements to meet the design objectives relating to leak detection and rectification.

Table 2. Hydrological design criteria for 'failure to contain – seepage' scenario

Design criteria	Adequate containment and detection measures		
Regulated structure classifications	**Containment**	**Leak detection and/or monitoring**	**Rectification**
High consequence	Designed with a floor and sides of material that will contain the wetting front and any entrained contaminants	Have a system that will detect any passage of the wetting front or entrained	Either be capable of repair to rectify any passage of the wetting front through either the

[14] This does not include the holder's own mine or gas production, on-site industrial or commercial assets, the holder's workers' accommodation, agricultural facilities on the holder's land such as a farm shed or farm dam or infrastructure solely for servicing the holder.

	within the bounds of the containment system during its operational life.	contaminants through either the floor or sides of the dam[15].	floor or sides of the dam, or else be decommissioned and rehabilitated.
Significant consequence	Designed with a floor and sides of material that will minimise (or reduce) seepage to avoid the environmental harm in the significant consequence category in Table 1 and ensure that the environmental harm likely to occur is only as in the low consequence category of that table.	Have a system that is appropriate to demonstrate that significant harm as per table 1 will not occur.	N/A[16]

2.2.1.1 Managing seepage consequences for higher risk contaminant concentrations

For dams assessed as having a 'high' consequence category for the 'failure to contain – seepage' scenario, and also assessed as exceeding, one or both of the thresholds in Table 3, the design criteria in Table 4 will apply to the structure in addition to those controls which are required for a "high" consequence structure in Table 2.

Table 3. Specific contaminant trigger levels Consequences for higher risk dams associated with the 'Failure to contain – seepage' scenario

Contaminant	Limit
pH	pH <5
Electrical conductivity	60 000 µS/cm

Table 4. Additional design criteria for dams determined to meet the requirements of Table 3

Design criteria	Adequate containment and detection measures

[15] Leak detection and/or monitoring requirements will be required by conditions on the environmental authority. Consistent with the requirements of this table, additional monitoring may also be required. For example, groundwater bores may be required to be monitored in the vicinity of some dams ('failure to contain – seepage') if the groundwater systems are identified as potentially at risk, or if there is uncertainty about the impacts from seepage from the regulated dam. Conditions, including conditions about monitoring are imposed under the provisions of the EP Act.

[16] While rectification measures are not a design requirement, this does not remove any subsequent obligations imposed by the administering authority to require rectification or decommissioning of a dam if dam failure is believed to have caused, or about to cause, environmental harm.

Regulated structure classifications	Containment
Dams that are both assessed as having a 'high' consequence category for 'failure to contain – seepage' scenario, and that are assessed as meeting the consequence thresholds identified in Table 3 for the 'failure to contain – seepage' scenario	Constructed with a system for the collection and proper disposal of any contaminants that move beyond the bounds of the containment system

2.2.2 Hydraulic performance criteria for regulated dams that are assessed as 'significant' or 'high' consequence for the overtopping scenario

This section explains the requirements for:

- a design storage allowance (DSA);
- an extreme storm storage (ESS) allowance; and
- a mandatory reporting level (MRL).

The DSA, ESS and MRL requirements in this section must be addressed for only those dams assessed as having a 'significant' or 'high' consequence for the 'failure to contain – overtopping' scenario. If a dam was assessed in the low consequence category for the 'failure to contain – overtopping' scenario, the determinations for a DSA, ESS and MRL are not required even if the dam is otherwise a regulated structure, e.g. if assessed as 'significant' or 'high' consequence for the 'failure to contain – seepage' scenario only.

Definitions for DSA, ESS and MRL are set out in the Guideline. In summary:

(a) The DSA is an available volume provided in a dam as at 1 November each year in order to prevent a discharge from that dam up to a specified annual exceedance probability (AEP).

(b) The ESS means a storm storage allowance determined in accordance with the criteria below.

(c) The MRL is a level at which the dam has a remaining available volume equivalent to the ESS allowance and this must be marked in a clearly visible location [NB this would not be required for 'all' dams if using a linked MRL system].

The DSA, ESS and MRL can be distributed across multiple regulated dams as described in Section 2.2.2.

2.2.2.1 Hydraulic performance objectives for 'failure to contain – overtopping'

In determining the hydraulic performance requirements under this section, the consequence category to be applied is the consequence category determined from the 'failure to contain – overtopping' scenario.

The hydraulic performance objectives for dams that are regulated structures in relation to the 'failure to contain – overtopping' scenario are to be achieved by:

1. selecting an appropriate AEP for adequate wet season containment storage (DSA) from Table 5
2. selecting an appropriate methodology to determine minimum capacity requirements for wet season containment storage (DSA). The suitability of the selected method for ensuring the appropriate mitigation of risk of harm must be substantiated and certified by the suitably qualified and experienced person in the design plan for the dam
3. estimating the ESS/MRL by:
   (a) selecting the highest volume/lowest level required in a regulated dam to contain:
      i. the runoff from the contributing catchment of the particular dam for a 72-hour duration storm at the AEP specified in Table 5, using 100% runoff of rainfall and making documented conservative assumptions regarding the operability of equipment during the event; and
      ii. a wave allowance at that AEP as estimated using a recognised engineering method.
   (b) assuming that diversion bunds and drains remain operative
   (c) measuring ESS/MRL volume with respect to the dam spillway level.

The estimation of an operational DSA and ESS volume must, as a minimum, be undertaken in accordance with this part and take into consideration reasonably foreseeable scenarios including, but not limited to, climatic variability and pump or power failures during wet weather events.

A dam that is a regulated structure must be designed and operated such that:

(a) Sufficient available storage is maintained to accommodate expected inputs and outputs during the year.

(b) The DSA is provided for at the 1 November for the coming wet season.

(c) All reasonable efforts are made to ensure the ESS is provided for at all times.

Table 5. Hydrological design criteria for ‘failure to contain – overtopping’ scenario

Design criteria	Adequate containment storage	
Consequence category for ‘failure to contain – overtopping’	**Wet season containment (DSA)**	**Storm event containment (ESS)**
Containment dams - high consequence	1:100 AEP	1:100 AEP 72 hr duration
Containment dams - significant consequence	1:20 AEP	1:10 AEP 72 hr duration

2.2.2.2 Managing design storage allowance and extreme storm storage in integrated water management systems

1. For sites with interconnected regulated dams functioning as an integrated containment system, the DSA and/or ESS volume calculated for the entire containment system catchment may be shared across a number of regulated dams comprising the containment system.
2. Where this approach is taken, the design and operating rules for the system as a whole must be documented in a system design plan that is certified by a suitably qualified and experienced person.
3. The system design plan must contain the design plans, the 'as constructed' plans, the operational rules for each individual regulated dam that forms part of the system, the standards of serviceability and accessibility of water transfer equipment or structures, and the operational rules for the system as a whole.

   Note: An acceptable system design should have demonstrable resilience in the event of failure in any component of the system and provision for redundancy. For example, fixed plant and equipment, and automatic operation are features that would add resilience.

4. The system design plan must state what DSA and/or ESS volume is to be located in each regulated dam that forms part of the system on the 1 November prior to the next wet season.
5. Where DSA and/or ESS is to be distributed across a containment system, the design and operation must consider and allow for the practical limitations of being able to redistribute stored volumes across the containment system (including operability of equipment under extreme weather conditions).
6. A methodology for accurately identifying the MRL for the water management system (i.e. when the total remaining available free volume in the water management system is equal to the ESS) must be specified in the design plan and identified by a physical marker (or marker's) in a clearly visible location wherever possible. Where the ESS is to be shared across multiple storages in an integrated system, the methodology for determining when MRL for the entire system is reached and how it is to be managed must be documented in the design plan.
7. The transfer capacity of redistribution systems must consider the possible need to transfer large volumes of water within short timeframes (i.e. not use average wet season accumulation to determine required transfer capacity).
8. The overall objective of the system design must remain the minimisation of the potential for harm that could occur from a failure to contain contaminants.
9. If there is complexity or diverse constraints in the way that transfer systems can be operated to effectively redistribute accumulating waters during the wet season, this must be considered by the suitably qualified and experienced person in selecting the methodology used as the basis for calculating the DSA and/or ESS requirements.

2.2.2.3 Estimating the design storage allowance

The certification required as part of the regulated structures approval must specifically certify that the chosen method for estimating DSA is considered suitable, by the suitably qualified and experience person, to be relied upon for the mitigation of risk or harm associated with the 'failure to contain – overtopping' scenario. This must be substantiated and certified in the design plan for the dam. This requirement for certification also applies to any methodology that may be used to estimate the DSA in situations where a significant proportion of expected inflows into the structure are likely to be as a result of pumping or other means of transfer.

Notwithstanding the above, Appendix A details two example methods for estimating the DSA that could potentially be used. This appendix is provided as guidance only and is not intended to limit the ability of the suitably qualified and experienced person to select a method that best suits the available data and individual circumstances for the dam in question.

2.2.3 Failure to contain – dam break

2.2.3.1 Hydraulic performance objectives for 'failure to contain – dam break'

In determining the hydraulic performance requirements under this section, the consequence category to be applied is the consequence category determined from the 'dam break' scenario.

The hydraulic performance objectives for dams that are regulated structures in relation to the 'dam break' scenario are to be achieved by selecting an appropriate design AEP for spillway capacity in accordance with Table 6. Table 6 provides a range of design events for spillways. A designer should select and document a conservative capacity from the nominated range based on expected dam break consequences.

When determining the spillway capacity, it must be assumed that the dam commences full at the spillway crest level; and that diversion works designed to restrict the contributing catchment are not effective, unless those diversion works are included specifically in the certified design plan and designed to the same hydraulic performance criterion as the spillway. Appropriate freeboard and wave allowance above the peak design flood level in the dam should be provided and documented.

Table 6. Hydrological design criteria for 'dam break' scenario

Design criteria	Flood passage	Flood ingress prevention
Consequence Category for 'dam break'[17]	**Spillway capacity[18]**	**Flood level for embankment crest levels[19]**
Containment dams high consequence	1:1 000 AEP To 1:100 000 AEP	Spillway design flood peak level + wave run-up allowance for 1:10 AEP wind

[17] The design criteria identified in this table are relevant to a dam break scenario that is caused by failure of the spillway to pass a flood of the identified probability or where flood ingress over the tops of the banks occurs. As such, they are not relevant to dam break failure modes where no inflows exist to the dam, such as failure caused by piping. Consideration by the suitably qualified and experienced person may need to be given to the appropriateness of the consequence category for the 'dam break' scenario and the correct application of the design criteria in this table if there is a significant difference in consequence between the different failure modes.
[18] Spillway capacity selected by the certifier with rationale.
[19] If spillway design flood is PMF, no wave run-up is required. Part of safety bunds of embankments may be used for waver run-ups if supported by a risk assessment.

Containment dams significant consequence	1:100 AEP To 1:1000 AEP	Spillway design flood peak level + wave run-up allowance for 1:10 AEP wind

2.3 Specific considerations for levees and associated hydraulic performance criteria.

2.3.1 Consequence assessment for levees

Levees may differ from most dams containing contaminants, where the consequence category can be readily determined for 'failure to contain' and 'dam break' scenarios in accordance with Table 1 and appendix B.

For flood protection levees or diversion levees, the suitably qualified and experienced person conducting and certifying the assessment needs to consider the function of the levee in relation to the broader operations and management of contaminants at the site, including functions to protect the integrity of contaminant storages. The following situations should be considered for consequence assessment of levees.

1. Levee designed for the diversion of contaminated waters or protection of the structural integrity of a dam

Where a levee is designed to divert contaminated waters into a containment dam (which also means designed to prevent release of contaminants), or as part of the protection of the structural integrity of a containment dam, the levee should be considered a key design element of the relevant dam.

The consequence assessment is then to be undertaken for 'failure to contain - overtopping' and 'dam break scenarios' (as outlined in Table 1 and appendix B) from the perspective that the levee is an integral part of the dam performance and failure of the levee could result in either failure to contain contaminants, and/or result in dam break failure of the dam.

2. Levee designed to prevent the ingress of clean flood water

Where a levee is designed to prevent ingress of non-mine affected flood water into an operational area, or catchment of a containment system, the suitably qualified and experienced person conducting and certifying the assessment and construction would declare that the levee is a regulated structure where the flood modelling shows that the pit would be encroached by a flood event with a probability more likely than or equal to 1:1000 AEP. The design and construction of the levee is to meet the criteria in Table 7 scenarios.

Where the flood modelling shows that an operational area or catchment of a containment system would be encroached by a flood event with a probability less likely than 1:1000 AEP, a cost benefit analysis should be undertaken to decide if a levee is to be constructed to provide protection against such an event.

For levees determined to be regulated structures based on their function primarily to exclude flood water, design criteria are defined in Table 7 of this Manual.

The consequence assessment for both situations must include sufficient documentation of the context of the levee in relation to site containment systems and surrounding waterways and catchments (with maps and quantified data on catchments within and outside the containment system) to substantiate the classification determined to be appropriate by the suitably qualified and experienced person conducting and certifying the assessment.

In the above situations, if the consequence of 'failure to contain' and 'dam break' of the levee has been incorporated into the relevant dam assessment, there does not have to be an individual consequence assessment of the levee separate to the dam assessment.

There is no requirement for a consequence assessment for the ‘failure to contain – seepage’ scenario to be conducted for levees.

2.3.2 Hydraulic performance criteria for levees that are regulated structures

The requirements under this section only apply where a levee is assessed to be a regulated structure in accordance with Part 1 and section 3.1 of this Manual.

In determining the hydraulic performance requirements under this section, the consequence category to be applied is the consequence category determined from the ‘dam break’ scenario.

The hydraulic performance objectives for levees in relation to the ‘dam break’ scenario are to be achieved by designing and maintaining each levee so that:

(a) it isolates and diverts the peak flow from a design storm of critical duration for the contributing catchment relevant to the zone to be protected by the levee, at an AEP specified in Table 7; or

(b) it can adequately accommodate the estimated level and flow rate of a release of flowable materials that may result from failure of other works or infrastructure; and

(c) in at least one place in the levee crest, there is a restricted length of low crest, limiting the freeboard at that point, such that a flood exceeding the design protection level of the levee will be directed to a planned area or areas within the zone to be protected.

Table 7. Hydrological design criteria for levees

Consequence category for levee[20]	Design criteria - flood level for embankment crest levels*
Levee determined to be regulated structures[21]	1: 1000 AEP

*Note: crest level should include a suitably designed freeboard.

[20] The design criteria identified in this table are relevant to section 2.3.1 – Consequence assessment for levees. As such, they are not relevant to dam break failure modes where no overtopping occurs, such as failure caused by piping. Consideration by the suitably qualified and experienced person may need to be given to the appropriateness of the consequence category for the ‘dam break’ scenario and the correct application of the design criteria in this table if there is a significant difference in consequence between the different failure modes.

[21] Refer definition of a levee. Table 1 consequence assessments are not necessarily used to assign a consequence category to a levee; refer to the Appendix for further guidance. All regulated levees are required to provide a minimum of 1:1000 AEP flood protection.

3 Definitions

Note: Definitions of terms in this document are provided in the guideline *Structures which are dams or levees constructed as part of environmentally relevant activities (ESR/2016/1934[22]).*

4 References

1. *Downstream Hazard Classification Guidelines,* ACER Technical Memorandum No. 11, U.S. Department of the Interior, Bureau of Reclamation 1988.
2. *Guidelines on Dam Safety Management,* Australian National Committee on Large Dams (ANCOLD) August 2003.
3. *Guidelines on the Consequence Categories for Dams.* Australian National Committee on Large Dams (ANCOLD) October 2012.
4. *Guidelines on Tailings Dams.* Australian National Committee on Large Dams (ANCOLD) May 2012
5. *Queensland Dam Safety Management Guidelines*. Queensland Department of Natural Resources and Mines February 2002
6. *Guideline for Failure Impact Assessment of Water Dams*. Queensland Department of Natural Resources, Mines and Energy 2018.
7. *Guidelines on Acceptable Flood Capacity for Dams*. Queensland Department of Natural Resources and Water February 2007.
8. *Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland*. Queensland Department of Minerals and Energy January 1995.
9. *Dam Safety Course Notes*. Queensland Government Dam Safety Group DPI Water Resources March 1994.
10. *Guidelines on Selection of Acceptable Flood Capacity for Dams,* Australian National Committee on Large Dams (ANCOLD) March 2000.
11. *Guidelines on Prevention of Water Pollution from Cyanide Use in Gold Ore Processing*, Queensland Government Department of Environment and Heritage, January 1990.

[22] This is the publication number, which can be used as a search term to find the latest version of the publication at www.des.qld.gov.au.

Appendix A—Example methods for estimating the design storage allowance

A.1 Estimating the design storage allowance using the method of deciles for volumetric containment

Background

Rainfall data is available for most localities throughout Queensland from the Bureau of Meteorology. Studies of this data indicate that:

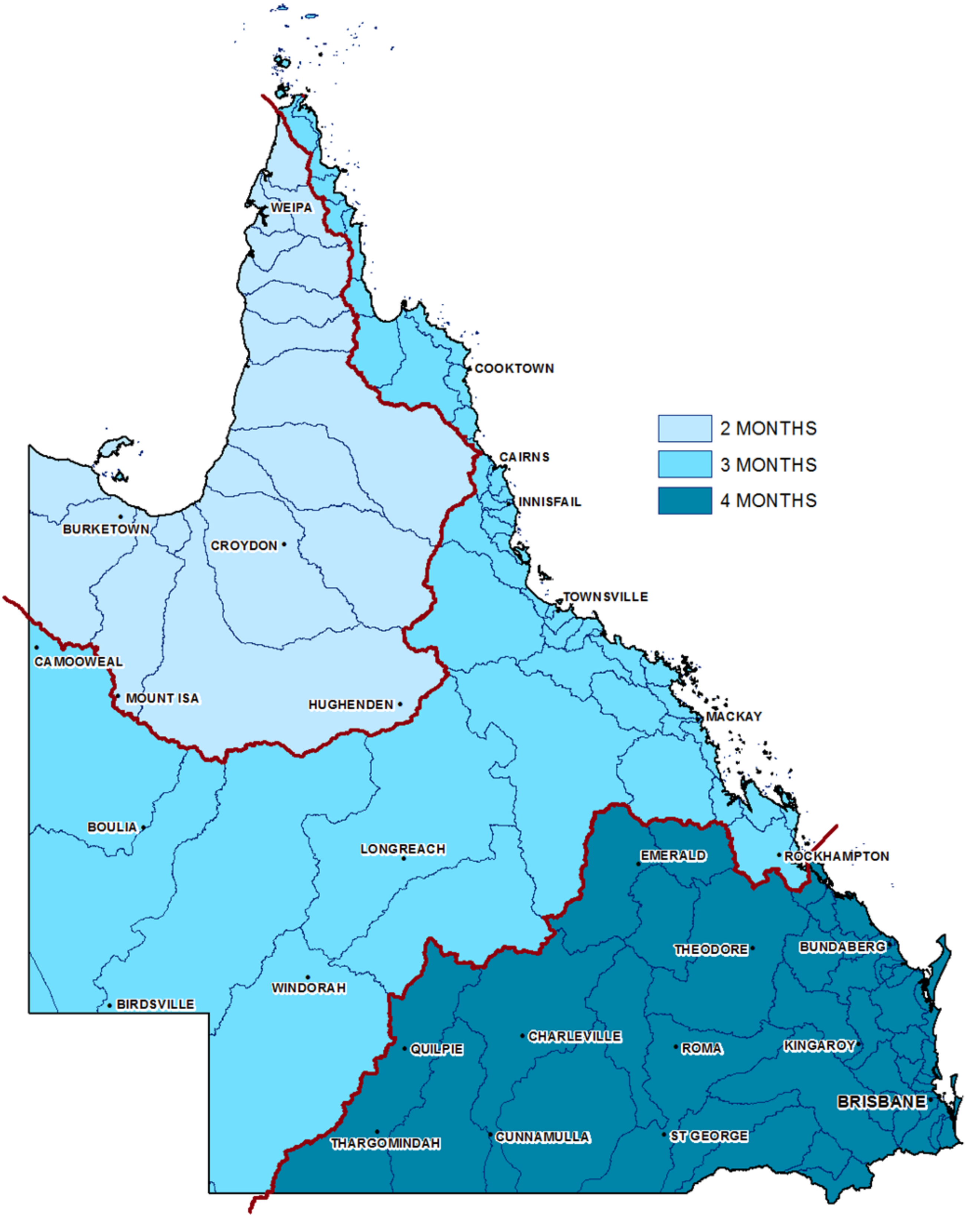
1. Queensland is subject to tropical/sub-tropical wet seasons typically caused by monsoonal/tropical lows and cyclones.
2. Consistently for locations in the river basins depicted in Figure 1, an average of up to 70% of total annual rainfall occurs during the periods of months as indicated in that figure.
3. Cumulative wet season rainfall for a series of storms generally exceeds that of a rare event storm.
4. Extreme storms are most likely to occur during the wet season.
5. Extreme wet events are often followed by more storms.

Queensland is subject to tropical/sub-tropical wet seasons typically caused by monsoonal/tropical lows and cyclones.

Pre-wetting of land increases the proportion of rainfall that reports as runoff. When land is saturated a large portion of rainfall becomes surface runoff. This situation can occur commonly during wet seasons experienced in Queensland.

In consideration of the above, and for the purposes of this Manual, the Method of Deciles analysis should be applied on the basis of the conservative assumptions including 100% runoff and no evaporation during seasonal rainfall periods. It should also be assumed that all diversion drains and bunds remain operative.

Figure 1. Critical wet periods for method of deciles analysis relative to river basins.



RIVER BASINS

Method of calculation

This method of estimating DSA is based on rainfall deciles. It uses records from a Bureau of Meteorology daily rainfall station with similar meteorology and sufficient length of record, at a location sufficiently close to the site to enable conservative estimation of wet season rainfall runoff volume reporting to a dam.

To be suitable for this analysis, the nearby rainfall station must:

1. have at least 50 years of usable record
2. for any particular year, the record in that year must include the wet season for that year; and
3. be located within the same basin as the site where the dam is/is proposed to be constructed or operated. In large river basins the rainfall station should, as a minimum, be located in the catchment of tributary rivers.
4. If no suitable daily rainfall station records exist, then Silo Data Drill for a point within the site of the proposed dam may be used.
5. The duration of a critical wet period should be determined from Figure 1, based on the physical location of the site relative to river basins in Queensland.
6. The annual maxima wet season rainfall for the critical wet period is to be determined by sampling from the station or silo rainfall data. Sampling to create the critical wet period should be based on contiguous periods for the critical wet period.
7. The maximum rainfall for the critical wet period must then be sampled for each available wet season (within the period from November in one year to May in the following year inclusive) in the station record. A plotting position formula is to be applied to the resulting statistical series, and a 'best fit' trend made to the data.
8. Rainfall depths for relevant AEPs are interpolated or extrapolated as necessary, from the statistical analysis.
9. The DSA volume is calculated assuming:
   (a) 100% of the rainfall on contributing catchments is assumed to report to the dam combined with process inputs to the dam over the critical wet period
   (b) the sum of net daily process inputs are to include process water, tailings, and other water disposed of or stored in the regulated dam, and runoff and seepage waters captured outside the contributing catchment of the regulated dam and pumped into the regulated dam or its catchment during the wet season
   (c) net daily process inputs cannot be a negative value for the purposes of estimating process inputs in the DSA calculation
   (d) no evaporation losses are allowed during the wet season.
10. The DSA volume must be calculated for either:

(a) individual regulated dams corresponding to the catchment of that dam and be made available within each individual regulated dam at the start of each wet season; or

(b) an integrated containment system distributed across a number of regulated dams corresponding to the catchment of all dams and be made available within the system at the start of each wet season.

11. The documentation of the DSA method of deciles must include:

(a) rainfall data sources; statistical analyses; and determined AEP wet season rainfall depths

(b) catchments including maps, quantified areas, and assumptions of catchment diversion works

(c) basis of process inputs into the DSA calculation including necessary procedures or operations to ensure that process inputs do not exceed the allowance in the DSA volume estimate

(d) where relevant, assumptions, constraints, operations, and procedures relied upon to distribute DSA allowance for an integrated containment system across a number of regulated dams.

A.2 Estimating the design storage allowance using the method of operational simulation for performance based containment

General

This method for estimating DSA can be used at the discretion of a suitably qualified and experienced person where there is local historical monitoring data for a sufficient period to form a basis for robust validation of modelling methods and assumptions.

It involves:

1. Establishing a time based operational simulation model of the site's water management system.
2. Demonstrating satisfactory model performance through comparison between metered and simulated data.
3. Provision of documentation to meet with the requirements of independent technical review and substantiation. The completeness of documentation should be sufficient to allow independent replication of the modelling by a suitably qualified and experienced person.
4. Quantification of simulation accuracy and selection of an appropriate design simulation margin (DSM) for the purposes of DSA estimation.
5. Calculation of the required DSA estimate, being:

   (a) the simulated maximum increase in the stored water inventory within the regulated dam (or entire containment system comprising several regulated dams) over the wet season subsequent to 1 November each year, as determined from plotting position analysis of operational simulation outcomes for the selected design AEP, plus

   (b) an additional volume equal to the DSM times the volume calculated in 5 (a) above.
6. Items A through to, and including, H that follow define the minimum essential requirements and considerations for any operational simulation modelling application and related methods, that are to be

used to assess system performance in mitigating environmental hazards, including the calculation of design storage capacity of regulated dams.

Documentation

Comprehensive documentation of the whole modelling process and results is required sufficient to enable independent replication of the model representation and assessed performance outcomes. This should include:

(a) purpose of the modelling

(b) substantiation that the modelling application is suitable for the purpose

(c) available data

(d) catchment maps (with topography sufficient to demonstrate drainage patterns within the system, upstream and downstream)

(e) system configuration plans (all key infrastructure comprising the containment system, including works intended to exclude clean waters)

(f) model schematisation assumptions and diagrams

(g) all assumptions and relevant associated data (or reference to data sources) to support model parameterisation

(h) validation methods, data, and results

(i) operating assumptions and relevant risk assessments to demonstrate operability

(j) relevant mine and waste facility plans and other matters that affect model processes (i.e. source and loss rates of waters and/or contaminants)

(k) period and reliability of climate data (rainfall and evaporation)

(l) model time-step and resolution

(m) quality checks (e.g. net balance check of inputs – outputs)

(n) software utilised for the modelling

(o) method of interpreting model results to characterise system performance outcomes; and statement of limitations for the purpose and where relevant limitations in the model use for alternative purposes

(p) relevant recommendations for monitoring and/or model improvement to maintain or improve validity of the assessed system performance outcomes.

Other matters may also need to be documented where they are deemed by the relevant suitably qualified and experienced person, certifier, or other stakeholders involved in the review of the methods or outcomes, to be of significance for the model representation, or purpose of the assessment. The requirements of the certifier are to take precedence.

Model continuity and net balance check

Modelling should be mass conservative for water volumes and, where relevant, mass of contaminants.

The checking of model results and documentation should demonstrate a net balance check of water (and mass of contaminants where applied) for:

(a) every storage or significant conveyance element (e.g. upstream and downstream watercourse reaches); and

(b) the system as a whole across the period of the model simulations.

Climate data used in modelling

Climate inputs to the model (rainfall and evaporation) must be representative of the historical variability and sequences for the specific site. The period of climate data should be as long as possible to adequately represent the extremes of climate and climate sequences that can occur at a site.

Rainfall inputs to modelling must include a sequence of at least 100 years of real data (infilled as necessary from nearby stations) to deliver output for performance analysis and benchmarking against other model inputs. Such a rainfall sequence can be produced from, in order of preference:

(a) the 'patch point dataset' for a nearby station; or

(b) 'datadrill' (both from silo enhanced meteorological data, published on the web); or

(c) independently created using nearby Bureau of Meteorology rainfall stations in the region—where this can be demonstrated to be robust and consistent with conditions on the site.

Stochastically derived rainfall data may only be used for modelling of containment systems where it is demonstrated that application of the data to continuous time-series simulation of rainfall-runoff processes satisfactorily replicates observed runoff characteristics. For modelling of containment systems where there is reasonable possibility of substantial carry-over water volumes from a wet season well into the next year's wet season, care is required to ensure that the possibility of sequential wet seasons evident in historical climate records is properly represented by the applied climate data.

Evaporation estimates used may need to be adjusted for any local limitations due to expected water quality (e.g. salinity, low pH), and location (e.g. water surface below surrounding land and low surface air flow) where relevant to ensure reasonably conservative outcomes of the assessment.

The suitably qualified and experienced person must document the basis upon which it is expected that the climate data has been used conservatively for the purpose of the assessment.

Hydrological processes and water management operations

Modelling methods/assumptions of hydrological processes and water management operations should be utilised and substantiated to a sufficient degree to ensure that the water balance model adequately represents the system performance response to climate variability.

The use of annual averages of rainfall and evaporation in modelling storage volume outcomes is not acceptable.

The simulation time-step must be no longer than one day.

Conservative assumption of no seepage losses or transmission losses

An assessment of system performance risks to the environment (particularly overflows from dams and adequacy of storage capacity), must assume that there are no seepage losses from dams and no transmission losses from open channel systems used to transfer water. This assumption is intended to be conservative from the perspective of containment performance but may not be conservative for other outcomes of operational simulation modelling (such as water supply reliability).

Runoff processes

The processes represented to transform rainfall onto a catchment to runoff rates/volumes must replicate the catchment responses to a full range of climatic conditions including, but not limited to, conditions during wet seasons.

As a minimum requirement, an established and properly calibrated 'watershed' element of the water balance model that accounts for antecedent catchment conditions must be used.

Where outcomes going into a wet season are being assessed using a water balance model, the watershed calibration must be demonstrated to be appropriate for wet season conditions.

Model calibration and validation

For existing operations where historical operations and/or monitoring data is available, that data must be used to calibrate and validate the models based on comparison of simulated and historical water inventory (storage volumes) over time sequences of wet and dry climate periods (seasonal fluctuations).

Professional care and judgement must be applied to ensure the accuracy of storage curves for dams in making these comparisons. Discrepancies between simulated and historical observed data may be acceptable providing that the differences can be adequately explained and justification made that the model representation maintains conservative assumptions relative to the specific purpose of the assessment.

A best estimate approach shall be applied to those situations where there is insufficient historical data for calibration, including:

- substantiating that runoff parameters are appropriate for catchment conditions including runoff estimates for disturbed lands
- direct rainfall to all open water surfaces
- no losses associated with seepage, transmission, etc
- estimates of process water consumption rates should be conservatively low.

For combined water and contaminant balance models, validation needs to extend to validating the water quality results from the model against historical water quality data. Professional care and judgement must be exercised in the validation methods used and adequate substantiation and explanation provided on the significance of the validation results relative to the specific purpose of the assessment.

Estimates of potential contaminant concentrations on any release must be based on a validated water balance model together with conservative estimates of contaminant concentrations likely to be in relevant dams at the time of any release.

Accounting for model inaccuracy and lack of calibration data

A properly constructed and calibrated operational simulation water balance model will provide a best estimate time series site water balance, without undue imposed bias.

However, the application of simulation outcomes to containment system design and operation requires the addition of appropriate margins to conservatively compensate for observed deficiencies in simulation accuracy or lack of calibration data.

For the purposes of this Manual, model accuracy may be defined with respect to the Seasonal Simulation Margin (SSM), which is to be derived when adequate calibration data is available. SSM is calculated as the numerical difference between recorded and simulated storage inventory maxima for each water year of simulation, expressed as a percentage of the simulated storage inventory maxima, for the particular storage under consideration. SSM is a positive value when recorded inventory volumes are greater than simulated containment system inventory volumes and set to zero otherwise. SSM can never be a negative value. A design simulation margin (DSM) is to be applied to simulation outcomes to provide conservative compensation for model inaccuracy.

DSM is the volume weighted average SSM:

$$DSM = \Sigma(SSM_i \times V_i) / \Sigma(V_i)$$

where: i ranges from 1 to number of annual SSM values, and V_i is the associated simulation volume,

When there is inadequate data for model calibration a minimum DSM value of not less than 50% shall be applied

The required conservative margin is then calculated by multiplying the volume of interest by the DSM.

Appendix B—Notes on consequence assessment based on failure event scenarios

This appendix sets out information that is to be used to guide the assessment and documentation of consequence categories for regulated structures.

Flooding considerations for consequence assessment

The degree of immunity to regional and local flooding, the upstream and downstream effects of the dam on such flood events, and potential erosion of the dam or the general environment; must be addressed in the consequence assessment, design, operation and decommissioning of dams.

Failure to contain consequence

'Failure to contain' consequences are those potential dam failures that are typically non-flood producing, but the release of contaminants could endanger environmental values including human life. Examples of events include:

- release of contaminated waters from a spillway during stormwater inflow events;
- punctured or lifted membrane discharging contaminated process water or tailings;
- releases due to pipe bursts in tailings or process water circuits associated with the dam;
- piping (localised failure) of containment banks or bunds;
- excessive foundation seepage;
- overtopping of tailings dams by superelevation of tailings beaches or blockage of drainage;
- inundation by floodwaters;
- erosion of containment structures around mining waste (decommissioned tailings dams, waste heaps etc); and
- dust and gas emissions.

Evaluation of the consequence potential on release requires information on the probable chemical nature of the stored material, including rates, volume and concentrations at the time of a possible release. Acidity and metal ions in solutions due to prolonged contact with ore bodies or stored material must be considered.

Contaminant concentrations at discharge must be estimated based on the contaminant concentration in the dam, and design parameters such as available storage volume. Operational water balance models may also be used to estimate likely instances of volumes and concentrations at discharge.

Conservative assumptions should be made to estimate outcomes of the worst case contaminant release or collapse of the structure. Assessments must always consider the potential interaction of failure of one dam with any other dams on site.

Assessment of progress of wetting fronts through dams with liners must be informed by proper materials testing (note: in-situ testing is not required as part of this assessment), knowledge of the design sizing and likely driving head during operation, the underlying hydrogeological conditions, and the potential impacts on underlying land and groundwater.

Dam break flood consequence

The prerequisites for a dam break consequence are the existence, either permanently or temporarily, of a large body of water or other flowable substances (slimes, tailings, etc); and environmental values, including stock, human life or property, that are susceptible to harm should a dam break occur.

While not required for the purposes of this Manual, good design and consequence assessment is likely to require that employees and persons associated with the operations for which the holder of an authority is responsible that are likely to be located in the failure path are considered. The requirement to appropriately consider site personnel safety is not removed by adherence to the requirements of this Manual.

The estimated extent of the flood at a particular probability level is called the 'failure impact zone'. The potential for losses to humans and stock must be considered. A high consequence for humans on a flood plain or elsewhere is associated with water depths occurring in excess of 300 millimetres (0.3 metre).

If the 'failure impact zone' is contaminated by the dam break flood, the environmental harm and potential for consequent harm from contaminants including access by stock or humans to the contaminants, must also be fully considered. Clean up in the general environment can involve substantial costs that would fall within the meaning of 'environmental harm' in the Act.

Fundamental consequence evaluation data

Applications that involve the construction and operation of any containment structure, must include relevant information on which an initial consequence assessment by the applicant has been undertaken.

Dam owners are likely to have much of the information already available. The minimum information is:

- maps showing the location of the proposed project in relation to surrounding land use and watercourses—including the general topography and contours at a suitable scale
- details of environmentally sensitive areas, rare and endangered species and human habitation and infrastructure developments in the near vicinity or general area and particularly downstream
- details of watercourses and groundwater aquifers that are or might be used as water resources
- engineering sketch drawings, in accordance with good professional practice and sufficient to fully define the layout, structure, volume and proposed means of construction of all aspects of operations associated with the proposal
- details of quantities and concentrations of all raw materials, products, by-products and waste products produced in operations associated with the proposal; and
- details of all studies conducted to assess requirements for storage and strength of all structures associated with the project—such as hydrological and geotechnical data.

Inspection of site or desktop analysis

Whether or not a site inspection is required for a particular dam as part of a consequence assessment is a matter for consideration by the suitably qualified and experienced person concerned. However, that person must be satisfied that all relevant aspects have been otherwise researched and documented to enable a reliable consequence assessment in each case.

Any assessment must include areas in the potential failure path or downstream of the dam that could be impacted by collapse or failure of the dam. Relevant matters include (but are not limited to):

- environmentally significant sites and species located in potential impact areas
- infrastructure including human habitation, worker accommodation and site offices, road crossings
- recreation facilities (parks and known local camping spots, etc) along watercourses
- raw (fresh water) storages on the same watercourse
- presence of stock, irrigation and domestic water supply pumps, and water holes
- downstream storage containments—such as tailings dams and process water dams
- mine adits (entrances to underground mining) and/or open cuts (voids)—current or proposed
- catchment modification works (diversion drains, bunds etc)—current or proposed.

Collation and assessment of data

A consequence category based on 'dam break' or 'failure to contain' scenarios, must be assessed based on the most adverse environmental harm that can arise from the range of all possible scenarios. The consequence category is based on the consequences of failure, not on the perceived probability of the failure occurring.

The following aspects of possible adverse scenarios should be carefully considered:

- A suitable range of rainfall scenarios will need to be considered in order to cover all potential harm and the required performance contained in tables 5 and 6.
- Where potential harm is by release of a contaminant, account should be taken of the potential dilution by clean runoff entering the dam prior to release and potential dilution in receiving waters.
- For an earth dam or bund wall, a 'sunny day' failure can also occur due to loss of structural integrity of the wall, such as piping failure or weakness in zones of the wall (various causes).

Of course, the probability of piping and similar mechanisms occurring are reduced by good design and construction practices, and regular inspections by informed operators and qualified professionals. The purpose of a consequence assessment is to identify dams that require more care and attention in that regard.

Appendix C—Minimum requirements of certification/certification report

Certification should take the form of a declaration made by the person giving the certificate, and when taken together with any attached or appended documents (including subsidiary certifications of specialist components) referenced in the certificate, all of the following aspects are addressed and are sufficient to allow an independent audit at any time:

Notes on scope of certification:

(a) the certification must be stated in the terms required by any condition that is referenced;

(b) **for consequence assessment report**: provides an assessment of the consequence category of the dam/structure/facility in accordance with the *Manual* published by the administering authority;

(c) **for design and design plan**:

  i. the design has been prepared in accordance with good engineering practice and the design/dam is also consistent with the standards required for structures of the assessed consequence category as set out in the Manual published by the administering authority

  ii. provided the structure is constructed or modified (in consultation with the designer) in the manner specified and the facility is operated and maintained as recommended, the dam/structure/facility is capable of delivering the performance stated in the attached report so as to be compliant with relevant conditions of the environmental authority.

(d) **for 'as constructed' drawings**: the documentation has been prepared based upon appropriate methodology and assumptions, inspections at specified hold points and the attached report addresses relevant aspects;

(e) **for construction report**: the structure has been constructed in accordance with the design drawings and specifications (or as modified in consultation with the designer); as constructed drawings; construction control test results and other relevant data; or

(f) **for annual inspection report**: identify details of inspection of the current condition of the facility; assessment of the hydraulic capacity of the facility; assessment of the physical condition and performance with respect to design intent; whether operation has been undertaken in accordance with the operational plan. The certification report should also reference the operational plan on which a regulated structure performance relies, together with information about the extent to which the regulated structure has been operated in accordance with the operation plan over the last year. The certification report should include any potential implications of non conformance with the operation plan.

Note: minor variation may be made to the wording of the form where it is necessary to ensure that the information provided is accurate and complete, for example, where it is necessary for a suitably qualified and experienced person to rely on subsidiary certifications from someone in the same area of specialisation.

Form of certification (consequence assessment/design plan)

Name of Registered Professional Engineer providing certification:

____

Address of Registered Professional Engineer providing certification:

____

Statement of relevant experience

I hereby state that I am a Registered Professional Engineer of Queensland and meet the requirements of the definition of 'suitably qualified and experienced person'.

Statement of certification

All relevant material relied upon by me, including subsidiary certifications of specialist components, where required by the environmental authority, is provided in the attached report(s) <report name/ref> dated <date>.

I hereby certify that the <consequence assessment/design plan/construction report/as constructed drawings/annual inspection report> entitled <report name/ref> and dated <date> for the <name of dam/structure/facility>:

Refer to the Manual for guidance on the nature of the certification statements that should be included here.

Note: the following is a guide to the minimum information required. Further information may be necessary as part of the certification to comply with all conditions of the environmental authority.

- <identify which regulated structure(s) is the subject of the certification>
- <identify the relevant condition which is the subject of the certification>
- <identify, where appropriate, what is not included in the certification—including information about any limitations, restrictions or exclusions that apply to the certification>

- <identify where the certification relates to an inspection or design>
- <identify if the certification was under supervision, the extent of the supervision>.

I <full name of person making the declaration>, declare that the information provided as part of this certification is true to the best of my knowledge. I acknowledge that it is an offence under section 480 of the *Environmental Protection Act 1994* to give the administering authority a document containing information that I know is false, misleading or incomplete in a material particular.

Signed: ___________________________________

[Signature of Certifier/including Registered Professional Engineer reference number(s)]

Date: ______________________________________

Form of certification (annual inspection report)[23]

Name of Registered Professional Engineer providing certification:

____

Address of Registered Professional Engineer providing certification:

____

Statement of relevant experience

I hereby state that I am a Registered Professional Engineer of Queensland and meet the requirements of the definition of ‘suitably qualified and experienced person’.

Statement of certification

All relevant material relied upon by me, including subsidiary certifications of specialist components, where required by the environmental authority, is provided in the attached report(s) <report name/ref>dated <date>.

I hereby certify that the <annual inspection report> entitled <report name/ref>and dated <date> for the <name of dam/structure/facility>:

Note: the following sets out the minimum information required.

1. Identifies which regulated structure(s) is the subject of the certification;
2. Identifies the relevant environmental authority condition which is the subject of the certification;
3. Identifies details of the inspection of the current condition of the facility;
4. Provides an assessment of the hydraulic capacity of the facility;
5. Provides an assessment of the physical condition and performance with respect to design intent;
6. Identifies whether operation has been undertaken in accordance with the operational plan;

[23] This certification for the annual inspection report sets out the minimum requirements. It has been provided as a guide but its use is not mandated. Other forms of certification will be accepted for the annual inspection report as long as they contain the minimum requirements outlined in manual and guideline.

7. References the operational plan on which a regulated structure performance relies, together with information about the extent to which the regulated structure has been operated in accordance with the operational plan over the last year;
8. Includes any potential implications of non-conformance with the operational plan;
9. Identifies, where appropriate, what is not included in the certification—including information about any limitations, restrictions or exclusions that apply to the certification;
10. Identifies where the certification relates to an inspection or design;
11. Identifies if the certification was under supervision, the extent of the supervision;
12. <Include further statements as necessary to comply with all conditions of the environmental authority and the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures ESR/2016/1933*>.

I <full name of person making the declaration>, declare that the information provided as part of this certification is true to the best of my knowledge. I acknowledge that it is an offence under section 480 of the *Environmental Protection Act 1994* to give the administering authority a document containing information that I know is false, misleading or incomplete in a material particular.

Signed: ___________________________________

[Signature of Certifier/including Registered Professional Engineer reference number(s)]

Date: ______________________________________