WATER
CORPORATION

Assets Planning and Delivery Group
Engineering

DESIGN STANDARD DS 61

Water Supply Distribution - Tanks

VERSION 4
REVISION 1

NOVEMBER 2023

FOREWORD

The intent of Design Standards is to specify requirements that assure effective design and delivery of fit for purpose Water Corporation infrastructure assets for best whole-of-life value with least risk to Corporation service standards and safety. Design standards are also intended to promote uniformity of approach by asset designers, drafters and constructors to the design, construction, commissioning and delivery of water infrastructure and to the compatibility of new infrastructure with existing like infrastructure.

Design Standards draw on the asset design, management and field operational experience gained and documented by the Corporation and by the water industry generally over time. They are intended for application by Corporation staff, designers, constructors and land developers to the planning, design, construction and commissioning of Corporation infrastructure including water services provided by land developers for takeover by the Corporation.

Nothing in this Design Standard diminishes the responsibility of designers and constructors for applying the requirements of the Western Australia's Work Health and Safety (General) Regulations 2022 to the delivery of Corporation assets. Information on these statutory requirements may be viewed at the following web site location:

Overview of Western Australia’s Work Health and Safety (General) Regulations 2022 (dmirs.wa.gov.au)

Enquiries relating to the technical content of a Design Standard should be directed to the Senior Principal Engineer, Water Conveyance Section, Engineering. Future Design Standard changes, if any, will be issued to registered Design Standard users as and when published.

Head of Engineering

This document is prepared without the assumption of a duty of care by the Water Corporation. The document is not intended to be nor should it be relied on as a substitute for professional engineering design expertise or any other professional advice.

Users should use and reference the current version of this document.

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Any interpretation of anything in the Standards/Specifications that deviates from specific Water Corporation Project requirements must be referred to, and resolved by, reference to and for determination by the Water Corporation's project manager and/or designer for that particular Project.

REVISION STATUS

The revision status of this standard is shown section by section below:

For Revision status of Versions 1 to 3 refer to Version 3

REVISION STATUS						
SECT.	**VER./ REV.**	**DATE**	**PAGES REVISED**	**REVISION DESCRIPTION (Section, Clause, Sub-Clause)**	**RVWD.**	**APRV.**
1	**4/1**	**8.11.23**		**Design for inspection and condition assessment of all components**	**JD**	**JD**

2	4/0	30.10.17	All	New version	JD	JD

3	4/0	30.10.17	All	New version	JD	JD

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7	**4/1**	**8.11.23**	**7.8.2**	**Project assessment of Equipment hatch in concrete roofs**	**JD**	**JD**

8	**4/1**	**8.11.23**	**8.1.3**	**Concrete strength and Cover to Durability groups recommendations. Columns 60mm**	**JD**	**JD**
	4/1	**8.11.23**	**8.1.7**	**Chloride attack considerations added based on Reservoir 8column review.**	**JD**	**JD**
	4/1	**8.11.23**	**8.5**	**Bolted tanks considerations added**	**JD**	**JD**

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DESIGN STANDARD DS 61

Water Supply Distribution - Tanks

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1 General

1.1 Scope

This Standard provides guidelines for the design of tanks of capacity 100 kL or more that are to be operated or to be taken over by the Water Corporation, and is intended to describe requirements for new tank projects that are components of the water supply distribution system. The requirements are based on operation, safety, maintenance, water quality, durability, and value for money considerations.

The Corporation's regions may have additional or specific requirements for their tanks. These need to be identified on a case-by-case basis. The structural design of tanks is not specifically addressed in this Standard. The structural design is to be in accordance with published Australian and International Standards.

This Standard shall be read in conjunction with Design Standard DS61-02 – Water Supply Distribution - Tank Drawings.

1.2 Description

ADWG	-	Australian Drinking Water Guideline
BPZ	-	Building Protection Zone
ERA	-	Environmental Risk Assessment
TWL	-	Top Water Level

1.2.1 Ground Level Tanks

Ground level tanks are generally cylindrical water storage structures constructed with the floor at ground level.

1.2.2 Elevated Tanks

Elevated water tanks are water storage structures built with the floor above ground level, either supported on a stand or an integral support structure.

1.3 Purpose

Tanks in the Corporation's water supply system provide the storage to balance the difference between inflow and outflow over a sequence of days of high water demand.

Depending on available inflow, economic analysis may determine that tanks are sized to be refilled over the peak day, peak week, peak fortnight or any other economically and operationally justified period.

Tanks may also:

a) Provide reserve storage of water for use during system failures;

b) Break pressure in a main;

c) Store water prior to and after water treatment;

d) Provide water at an elevated level to provide pressure suitable for distribution.

1.4 Philosophy of Design

Designs must not only comply with the requirements explicitly identified in this Standard, they must also conform with the Corporation's design philosophy.

For a design to be deemed compliant, it must comply with the following tenets:

1. prioritise safety.

2. prioritise whole-of-life costs of the asset over just initial construction costs.
3. be accessible and conducive to operational and maintenance activities.
4. yield assets that the people of Western Australia can rely upon for a dependable supply of water and sanitation services.
5. enhance social and environmental benefits as much as practical.
6. consider potential future requirements and make reasonable allowances for them.
7. maximise time to failure and/or replacement. and
8. minimise maintenance.
9. **Allow safe , easy and effective inspection and condition assessment of all components**

Where there is any significant conflict between these tenets that meaningfully influences the design outcome, then advice shall be sought from the Water Corporation Design Manager or Standard Custodian.

1.5 Preferred Tank Size

In many cases, the dimensions and volume of a proposed tank need to be specifically designed to match those of existing tanks, to suit site requirements, or to satisfy the hydraulic requirements of a scheme design.

It is desirable that proposed storage tanks be designed to have volumes in multiples of:

a) 100 kL for tanks up to 1000 kL
b) 500 kL for tanks from 1000 kL up to 10000 kL
c) 1000 kL for tanks larger than 10000 kL.

The number and sizes of tanks to be constructed at a site shall be determined based on Clause 12.8 and the adequacy of water supply to consumers through bypass and alternative supply arrangement during the maintenance period. If adequate supply cannot be maintained during prolonged refurbishment or maintenance period, at least two tanks will be required at the site. Advice from the Asset Planners shall be sought to finalise the requirements.

1.5.1 Wall Height

Tanks wall height is usually based on the top water level requirement and structural efficiency.

Other considerations include aesthetical/environmental requirements and the lifting of equipment to the roof with locally available Corporation equipment. Typically, utility vehicle mounted cranes have a reach of 4.5 m, whereas the reach of truck mounted cranes exceeds 6 m. To enable inspections/ maintenance or repair, the wall/roof height should not exceed the lift capacity of commonly available elevating work platforms. Consideration will be given to the compound access and set-up stability of any external vehicles or equipment required for tank access purposes.

1.5.2 Typical Tank Sizes – Ground Level

The nominal capacities of existing ground level tanks range from 100 kL to 80,000 kL.

1.5.3 Typical Tank Sizes – Elevated

The nominal capacity of existing elevated tanks ranges from 100 kL to 4000 kL.

1.6 Materials of Construction

1.6.1 General

Historical construction materials and ranges of capacities which have been used for tanks operated by the Water Corporation are detailed in Table 1.1 below.

Table 1.1 Historical Types and Capacity of Ground Level Tanks in Service

Type of Tank	Indicative Capacity Range (kL)
Sheet Steel with Liner[1]	100 to 600
Welded Steel Plate	1000 to 50000
Reinforced Concrete	100 to 15000
Pre-stressed Concrete	5000 to 80000

[1] – The Water Corporation is increasingly using robotic tank cleaning. There is limited experience with using these cleaner on a liner and therefore is a concern that robotic tank cleaners may damage the tank liner

The selection of a particular material is generally based on whole of life cost, however the Corporation's Regions may have a preference that has been generated through operations, maintenance, and security factors.

The Corporations experience has proven the construction cost of tanks has varied significantly with the location of the tank and the availability of specialist 'concrete' or 'steel' construction contractors at the time of tender. Hence it is difficult to predict if a certain type of tank is more economical for a certain size.

1.6.2 Elevated Tanks

Elevated tanks of up to 400 kL capacity generally consist of a braced steel frame structure supporting a prefabricated sheet steel or fibre-reinforced plastic tank.

Above 400 kL, elevated tanks generally consist of a constructed tank on an integrated support structure. The material of construction is generally welded steel plate or reinforced concrete but pre-stressed concrete has been used in a few locations. These elevated tanks are often referred to as water towers.

1.7 Storage Components

The **nominal capacity** of a tank is calculated as the volume between the average floor level and the overflow level. The overflow level is the **nominal top water level** (TWL). Note that the **effective top water level** is an operational setting at some distance below the nominal top water level.

The **balancing storage** of a tank is the amount of storage required to balance the difference between inflow and outflow over the determined refill period.

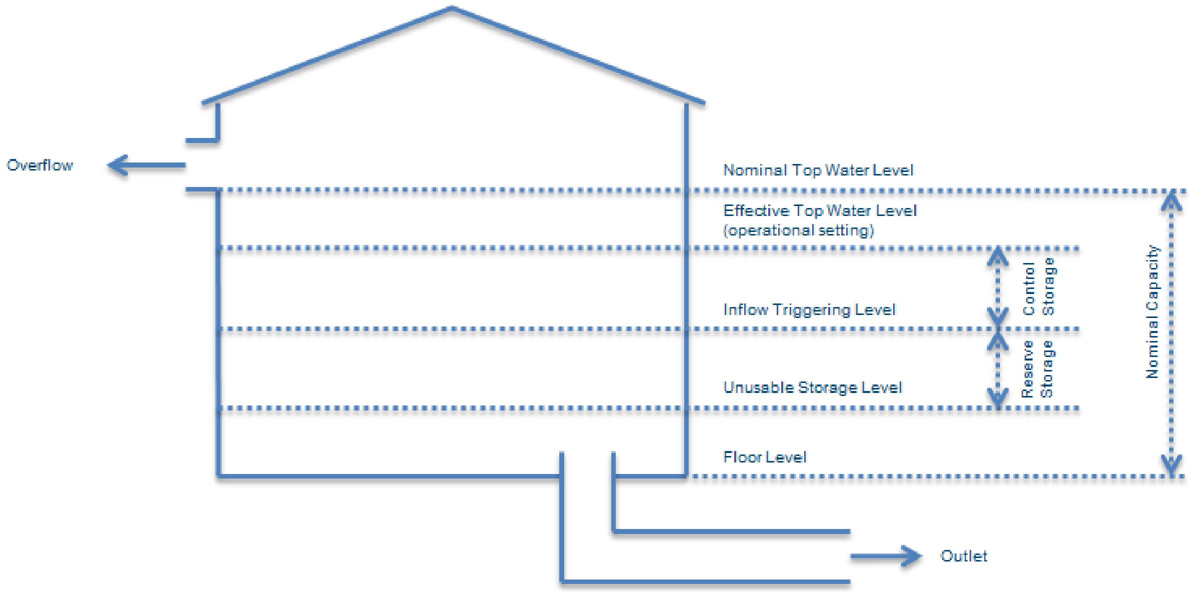
The **control storage** of a tank is the amount of storage from the **effective top water level** to the level at which inflow is first triggered. The **control storage** may be varied seasonally to promote tank water turnover.

The **operating level** of a tank is the water level in the tank at any time, and is generally between the **effective top water level** and the **unusable storage**.

The **reserve storage** of a tank makes provision for scheme failures and inflow interruptions of an assessed duration.

The **unusable storage** in a tank is the bottom layer of water that should not be supplied to customers.

Balancing storage and **reserve storage** provisions normally prevent the **operating level** of the tank from ever reaching the **unusable storage**. The depth of **unusable storage** varies for each tank, however is typically 300 mm, in order to prevent sediments from being drawn into the tank outlet, and to prevent the formation of vortexes and resultant air entrainment in the supply system. Unusable storage is significant in tanks supplying pumping stations, which may have larger unusable storage depth in order to prevent vortexing.



1.8 Hydraulic Requirements

The required inflow rates, outflow rates, storage components and capacities of tanks to be incorporated in the Corporation's supply system will be determined in accordance with the Corporation's current scheme planning report.

The sizes of tank fixtures, such as inlets, outlets, overflows and scours, are determined during the concept or the engineering design phase. Refer to pipework design parameters in Section 12.

1.9 Legislative Requirements

Prerequisites to Works, statutory requirements, environmental and safety considerations shall be fully observed for all tank projects (refer Water Corporation's External approvals Manual and Prerequisites to Works Manual).

1.10 Acceptance of Materials

All materials which will be in contact with drinking water supply shall comply with AS/NZS 4020. Designers and contractors should be aware that certain products are part of a "system" with ancillary items such as primers, adhesives, or injectable grouts. Confirmation should be sought from supplier that the AS4020 certificate covers all items in such a "system" or that the items have individual certification.

In addition, the Corporation may choose not to accept materials that it considers inappropriate for use.

1.11 Lightning Protection

Lightning protection for each tank and associated instrumentation equipment shall be assessed in accordance with AS/NZS 1768 - Lightning Protection. Lightning protection design of power and instrumentation equipment shall be in accordance with the requirements of the DS20 and DS40 series of design standards.

With respect to the tank proper, the philosophy is not to protect the tank from a direct strike but rather guide the lightning surge safely to ground. In this regard, it is important to establish a connection from the air termination to an earthing system with a combined resistance to earth of less than 10 ohms. Depending upon the type of tank construction, this will involve either two down conductors from the air termination or simply a connection from the metallic tank base to the earthing system. Furthermore, the connection to the earthing system shall be via suitably rated DC De-couplers (e.g. DEI SSD Solid State De-coupler) to provide corrosion/cathodic protection isolation.

For the purpose of this section, the air termination is defined as the metallic roof of the tank and a grading ring is defined as a bare copper conductor buried encircling the tank and spaced one metre from the tank wall. The down conductor is defined as an insulated copper conductor from the air termination to the earthing system.

Guidance relating to the minimum earthing requirements outlined above for various types of tank construction is given below:

a. Steel roof of ground level concrete tank. *Two down conductors terminated into an earth system*.

b. Steel roof of ground level steel tank. *Two connection points from the base of the tank to a grading ring*.

c. Concrete roof of ground level concrete tank. *No earthing requirements for the tank.* However, Consideration of the earthing and bonding of any external metallic structure is required.

d. Concrete roof of elevated concrete tank supported on concrete columns or shaft. *Consider earthing and bonding of any internal metallic structure.*

e. Steel roof of elevated concrete tank supported on concrete columns or shaft. *Two down conductors terminated into an earth system. Consider earthing and bonding of any internal metallic structure.*

f. Steel roof of elevated steel tank supported on concrete columns. *Two down conductors terminated into an earth system*.

g. Steel roof of elevated steel tank supported on steel frame. *Two connection points from the base of the tank to a grading ring*.

2 General Design Guidelines

2.1 Engineering Design Process

The Corporation's Engineering Design Process Manual of Requirements shall be used in the design of Water Corporation's engineering assets. The manual describes the roles of the Corporation's Design Manager and Designer in the design process and provides or references:

a) Design process guidance notes

b) Templates for process documents and design outputs

Any submission of design work to the Water Corporation shall be carried out and delivered in accordance with the current Engineering Design Process Manual as agreed with the Water Corporation's design representative. Design work shall not be delegated to equipment suppliers or other contractors. For issue of Engineering Design Process Manual and associated documents, email request to Engineering.StandardsEnquiries@watercorporation.com.au

2.2 Safety in Design

Designers shall provide the client with a written Report (Safety in Design Report) on the OSH aspects of their design work in accordance with the requirements of WA OSH Regulation Clause 3.140 (Responsibilities of Designers) and the National Standard for Construction Work 2008 (Designers, Clients and Contractors). The Water Corporation's "Safety in Design" work instruction, which provides instruction on the compilation of this report, can be found within the Water Corporation's Engineering Design Process and associated documents.

2.3 Design for Inspection, Maintenance, and Repair

The water conveyance network and associated tank function is considered to be required for much longer than individual tank components (such as purlins, tek screws, etc) can achieve. Therefore the designer shall ensure that components are designed with inspection, maintenance, and replacement in mind. Components such columns, roof sheet, purlins, beams, joint seals, etc shall be designed with solution for multiple repairs or replacements in the future.

Anticipated replacements intervals and suggested replacement procedures shall be included in the design report.

2.4 Environmental Assessment

Many of the environmental issues and risks associated with asset creation and operation will have been identified during the planning phase.

An environmental risk assessment (ERA) shall be undertaken throughout design phase, in consultation with the assigned environmental officer, to ensure that all environmental impacts and risks are identified and evaluated so as to avoid or minimise issues.

The ERA provides a means of applying a quantitative indicative risk ranking for the environmental issues and factors associated with a project. It also identifies environmental issues that need to be addressed in environmental management and commitments made to the Department of Environment Regulation. In this regard, the output of the ERA has direct implications for the design and implementation of the project.

The designer must communicate environmental risks to the project manager through the design manager so that the risks can be captured in the project risk register.

2.5 Design Standards

Materials and workmanship shall comply with the latest edition of the relevant Australian Standards, unless otherwise specified. A list of relevant Australian Standards is included at Appendix 1.

In cases where an applicable Australian Standard is not published, the applicable British Standard, European, New Zealand or American Standard shall be used.

In the application of Loading Codes, in addition to the load cases required by AS 1170, the following conditions shall be addressed by the design:

a) Ultimate wind load with the tank empty

b) Earthquake loading with the tank full.

All tanks shall be designed for Importance Level 4, as defined in AS 1170, unless the use of Importance Level 3 can be justified based on

i. Availability of alternative source of supply during post disaster period.

ii. Environmental and safety risks of areas immediately adjacent. Social and environmental consequences within the area of water services during post-disaster period.

Designers shall provide the relevant design parameters on the General Arrangement or similar drawing, including:

1. Wind Design Code and year.
2. Design wind speed, basic and factored.
3. Noting if the roof is for Cyclonic or non-Cyclonic conditions.
4. Earthquake Design Code and year.
5. Earthquake zone and Site factor.
6. Tank Design code and year.
7. Design Crack width for concrete elements.

2.6 Prevention of Falls

Design of new tanks shall meet the requirements of the Water Corporation's Prevention of Falls Standard S151.

Design of new tanks and upgrades should eliminate the need for tasks associated with inspection, operation and maintenance to be performed at height/depths, and all instrumentation shall be located at ground level.

Where this Standard exceeds the control measures set out in S151, this Standard shall take precedence.

In the event of any conflict between S151 and this Standard, Water Corporation's written clarification/confirmation shall be sought.

2.7 Edge Protection

All guardrails, including supports, top rail, mid rail, toe board, self-closing gate and connections shall be designed to comply with the loading requirements for guardrails (not handrails), as specified in AS 1657 and in the S151. Self-closing gate shall open such that it is secure when closed to prevent a person falling from height. Minimum height of guardrails and self-closing gates shall be 1.0 metre.

Provision of edge protection to prevent falls from any part of a platform shall be by installing guardrails.

Although handrails supplied by a few manufacturers satisfy the requirements for guardrails, the Designer shall ensure that all the requirements for guardrails are met before specifying any product.

Self-closing gate shall be to Water Corporation's Drg No. IP76-2-1.

3 Design Life and Durability

3.1 Design Life

Design life is the period assumed in design for which a tank structure or structural elements and associated ancillary elements are required to perform their intended purpose without replacement or major structural repairs and keeping to a scheduled maintenance programme.

The life of tank and tank roof will vary significantly depending on the following factors:

a) the location and the corrosiveness of the environment and the stored water

b) the appropriateness of the design details

c) the suitability and quality of the material and construction

d) the asset maintenance program and implementation

e) residual chlorine concentration of the stored water

f) ventilation of the roof enclosure

g) the extent and concentration of chlorine in the roof enclosure

Design life applicable to a tank could vary dependent on the short-term, medium-term and ultimate planning needs. The planning requirement shall be confirmed and the design life of a tank shall be determined before concept design or engineering design of a tank project is undertaken.

The design life definition herein is obtained from the Australian Standard for bridge design (AS 5100.1-2017, Clause 8.3.3) serviceability limit states that are defined in terms of:

1) Deformation of foundation to give limitation on use or is of public concern.

2) Permanent damage due to corrosion, cracking or fatigue, which significantly reduces the structural strength or useful service life of the structure.

3) Vibration leading to structural damage or justifiable public concern.

4) Flood damage.

Accordingly, with respect to item 2) above, the end of the design life is defined to occur when deterioration progresses to a level that makes the structure unsafe or unserviceable or the maintenance necessary to maintain the functionality of the structure becomes uneconomical. The above design life definition clarification recognises the need for ongoing maintenance to achieve the design life.

Subject to expected maintenance during design life stated in Table 3.2, the minimum design life of a tank that is required to meet ultimate planning requirements shall be 100 years. Where components have a design life of less than 100 years, the replacement cost and loss of service must be included in any tank type comparisons. The expected design life for components of such tank projects shall be as listed in Table 3.1.

Particular care shall be taken to achieve the design life for members of a structure that have limited access or are inaccessible. These members should have a design life of the structure with no maintenance.

Table 3.1: Project Assets/Component Design Life

Assets/Components	Design Life (years)
Unless otherwise stated in this table tanks (concrete & steel plate) and all structures, whether buried, submerged or exposed to air	100
FRP Tanks <80 kL	25
Civil and building assets	100
Earthworks	100
Foundations	100
MSCL Pipeline	100
Interconnecting pipes and fittings	80
Wall construction- Joint Seal and Water stop materials	100
Wall Seating- Joint Grout	100
Wall Seating- Joint Seal Material	25
Concrete Roofs	100
Steel Roof Sheeting & Fasteners	25
Roof Steel Support Beams & Fasteners	50
Steel Roof Purlins, bridgings & Fasteners	25
Aluminium Sheeting & Fasteners	40
Roof Aluminium Support Beams & Fasteners	100
Aluminium Roof Purlins bridgings & Fasteners	30
Galvanised steel sheet tank with membrane liner	20
Liner for galvanised steel tank	10
Protective coatings for steel plate tanks	25
Cathodic protection system	20
Mechanical assets	25
Electrical assets	25
Instrumentation/control assets	15
SCADA assets	15

Table 3.2: Project Assets/Component Expected Maintenance

Materials and Component	Expected Maintenance
Reinforced Concrete Floor Slab (liquid retaining structures)	No maintenance[1] unless leakage or physical damage observed. (refer below for joint maintenance) Inspect when any interior visits undertaken. For tanks, inspect when the tank is emptied
Reinforced Concrete Walls and Columns (liquid retaining structures)	No maintenance[1] unless leakage or physical damage observed. Inspect when any interior visits undertaken. For tanks, inspect above water level when any interior visits and the entire wall when the tank is emptied. Inspect exterior when visiting to inspect other components
Reinforced Concrete Floor Slab, Walls and Columns (non liquid retaining structures & Buildings)	No maintenance[1] unless physical damage observed. Inspect when any interior visits undertaken. For tanks, inspect when the tank is emptied.
Wall & Floor Construction Joint with surface Sealant (liquid retaining structures)	25 years before major joint seal replacement. Inspect wall joints when any interior visits above water level undertaken. Inspect all floor and wall joints when the tank is emptied. Replace sealant when the extent of damage justifies. Material manufacturers will not provide a long-term life expectancy for surface sealant products, with warranty to 10 years available. Service life from 10 to 25 years is primarily influenced by the initial installation and secondly the operational conditions (normally stable in water tanks) Note 1. Fibre-reinforced concrete has been successfully used to minimise the extent of floor joints and subsequently, reduce leakage, sealant repair costs and the whole of life cost. 2. The Corporation is increasingly using robotic tank cleaning. These robots often have a rotating brush and vacuum suction head. The impact of these need to be considered and minimised where possible (e.g. recessed sealant detail)

Wall & Floor Construction Joint with encased Waterstop	100 years with no expected waterstop replacement. No inspection possible with waterstop encased in the concrete. Material manufacturers will not provide a long-term life expectancy for waterstop products. The common products presently, when appropriately installed, are not subject to materials deterioration (e.g. no ultraviolet light to degrade the PE material). Fatigue cycling is not expected to initiate failure in the normally expected environment, and dewatering the tank for operational cleaning will not significantly change the slab base moisture condition.
Steel Roof Sheeting & Fasteners	Coating maintenance at 15 years intervals. 25 years before major replacement. Roof Sheeting manufacturers will not provide a long-term life expectancy, with warranty up to approximately 12 years available. Fasteners inspection at 5 year intervals and inspect other components during this visit
Roof Steel Support Beams & Fasteners	Coating maintenance at 10 years intervals. Major re-coating/maintenance of structural steel and fasteners at 25 years intervals. Replacement at 50 years. Fasteners inspection at 10 years intervals and inspect other components during this visit.
Steel plate tank floor and wall	Inspect the Internal and External of the Tank Walls and Internal of the Floor for evidence of Pitting and Corrosion. Measure Pitting depth and loss of Material Thickness. Frequency of Testing 15 years or earlier if identified by visual inspections
Aluminium Roof Sheeting & Fasteners	No maintenance[1] 40 years before major replacement. Roof Sheeting manufacturers will not provide a long-term life expectancy, with warranty up to approximately 30 years available. Fasteners inspection at 5 year intervals and inspect other components during this visit
Roof Aluminium Support Beams & Fasteners	No maintenance[1]. Fasteners inspection at 10 years intervals and inspect other components during this visit.

Steel Access Facilities and Landings	Coating maintenance at 10 years intervals. 25 years before major replacement. Fasteners inspection at 10 year intervals and inspect other components during this visit.
Mild Steel Pipes – interconnecting pipes and inlet & outlet pipes	**Buried Pipes (Sintakote, concrete encased, no CP):** No maintenance[1]. Mass concrete encasement of Grade N25 provides corrosion protection. **Buried Pipes (Sintakote, not concrete encased, no CP):** No maintenance[1]. Fill free of chemical contamination and high soil resistivity provides corrosion protection. **Buried Pipes (Epoxy Coated):** No maintenance[1]. Bed and backfill free of chemical contamination and high soil resistivity provides corrosion protection. **Above Ground Pipeline (Sintakote/IZS):** Coating maintenance of external pipeline surfaces at 10 years intervals. Major re-coating/maintenance of external pipeline surfaces at 25 years intervals. **Above Ground Pipes (Epoxy Coated):** Coating maintenance of external pipeline surfaces at 10 years intervals. Major re-coating/maintenance of external pipeline surfaces at 25 years intervals. **Tank Water Pipes (Epoxy Coated):** Coating maintenance of external pipeline surfaces at 5 years intervals. Major re-coating/maintenance of external pipeline surfaces at 25 years intervals. **All Pipelines: Cement Mortar Liner (CML).** Reasonable internal inspections and maintenance will be required to minimise the risk of premature failure from soft water attack after 60+ years for pipes from the dam to the stabilisation position, with interval based on prior inspection as per ACA.

Mild Steel Pipes – inlet and outlet pipes	Grade S40 floor and wall concrete and proprietary shrinkage compensating grout at tank internal edge of pipe provides corrosion protection. Inspect proprietary shrinkage compensating grout at tank internal edge of pipe at 5 year intervals and localised repair completed if damage justified. Inspections completed when operational internal access available and not access only for this inspection.
Mild Steel Pipelines	Buried Pipes (majority of pipes) Nil. Above Ground Pipes (small portion of pipes) Major refurbishment/replacement at 50+ year intervals due to potential UV damage for PE pipes (with UV resistant outer layer complying AS 4130 or protected from direct sunlight exposure) & uPVC pipes.
Cathodic protection system	Maintenance at 4 week interval where not remotely monitored and once yearly where remotely monitored. Further maintenance and replacement as per DS95
Notes: 1. Because tanks are considered to be required for a period beyond any reasonable design life and because not all failure modes can be anticipated, "No expected maintenance" does not take away the need to design tanks for maintainability and reparability. 2. Condition assessment methodologies for concrete and steel structures are available in Nexus document #11573252 and #11118245 for concrete and steel respectively.	

3.2 Durability Assessment for Large Tanks

A Durability Assessment Report (DAR) shall be produced by a recognised durability consultant for all tanks of capacity 5.0 ML and larger.

For tanks of capacity less than 5.0 ML excluding liner tanks, DAR shall be produced for tanks:

a) constructed under design and construct contracts;

b) located in aggressive external environment;

c) that store water of aggressive quality outside the normal range (Refer to Section 8.1.4); and

d) are considered as critical assets based on long-term need and importance.

Durability assessment shall be carried out following the recommended practice in Concrete Durability Series published by the Concrete Institute of Australia.

Inspection standard for concrete (Document number 11573252) and steel (Document number 11118245) structures provide information on inspection, testing procedures and life expectancy. For external consultant, these documents are available from the water corporation design manager.

4 Site Selection and Layout

4.1 Tank Site Investigations

Prospective tank sites shall be thoroughly investigated. The following aspects shall be considered.

4.1.1 Site Selection

The selection of the location of the tank site is largely influenced by the outcome of the Environmental Risk Assessment, but as a minimum the following shall be undertaken in the definition or concept design phase:

a) Discuss the proposal with stakeholders, such as the local authority, native title claimants, adjacent and nearby property owners etc.

b) Locate the tank so as to not change the skyline from significant viewpoints, if possible.

c) Utilise significant existing vegetation (if available) to provide screening for the tank subject to meeting the requirements for Building Protection Zone-Refer section 4.3.

d) Alternatively, provide for landscaping with indigenous species to provide screening for the tank.

e) Select the colour of the tank walls, roof and fascia to complement the surrounding environment (the walls of a steel tank are painted for corrosion protection; however the walls of a concrete tank are not normally coloured.

f) Site selection to suit the system hydraulics.

g) Site selection based on minimizing costs and risks.

h) Site selection based on foundation suitability.

4.1.2 Site Layout

The layout of the tank site shall consider:

a) dimensions of the tank site to accommodate all anticipated future works, including scour and overflow sump;

b) location of ancillary structures on the tank site away from major viewpoints;

c) locating the security fence as close as practical to the cleared tank site, allowing for Building Protection Zone specified in section 4.3 black or dark green security fencing has less visual impact;

d) designing access tracks so as to not provide a direct line of sight to the tank site;

e) routing pipes to the tank along the access track in order to minimise clearing of vegetation and increasing distance away from fire fuel load;

f) designing tank site earthworks to blend with natural contours;

g) control and discharge of stormwater;

h) rehabilitation of the site upon completion of the work; and

i) maintenance and operational access for the primary asset (Tank) and general site related access for major inspections i.e. trucks, scaffold, cranes need to be considered when looking at the overall site footprint and location.

If rehabilitation includes landscaping, fire retardant vegetation as detailed on web site "http://www.ozbreed.com.au/download/fire_retardant_plants.pdf," should be used.

4.2 Security

A tank site shall be provided with a security system in accordance with the Water Corporation Design Standard DS62 – Standard for Site Security Treatments. Security against unauthorised access is vital to the protection of water quality and continuity of supply. Security measures shall be assessed for each particular site and shall take into account previous history of unauthorised access and likelihood of future unauthorised acts. All security requirements shall be discussed with Water Corporation's Security Program Manager.

For Category A and B sites as detailed in DS62, these assessments and designs shall be carried out by a licensed security consultant from the Water Corporation's Security Panel.

4.3 Building Protection Zone

Known as Building Protection Zone (BPZ), this area is provided to ensure that there will be no direct flame contact on the building from a bush fire.

All tanks and associated critical structures shall be surrounded by a BPZ that meets the following requirements:

a) The minimum width of the BPZ shall be 20 metres measured from external wall of tank/asset.

b) The location of BPZ shall be within the boundaries of the lot on which the tank/asset is situated unless it can be confirmed that minimum width of BPZ would be available at all times during the life of the tank.

Any proposal to reduce the BPZ shall be presented to the Water Corporation. Any agreement shall be documented in the design report and in the Safety in Design report.

4.4 Hardstand around the Tank

The design of the tank site shall allow for material and equipment access to the roof perimeter using a crane and to the wall using mobile work platforms.

To allow unobstructed EWP operation, a minimum, a 6.0 m width of clear and level hard stand is required around the full perimeter of the tank.

The area required for crane access shall be specifically assessed. Dedicated crane pads around the tank can be considered.

To prevent erosion from roof runoff, a minimum 1.0 metre wide concrete or bitumen paving is required around the perimeter of a tank of height less than 3.0 metres to direct runoff away from tank foundation and towards the site drainage. For tanks of height greater than 3 metres, concrete paving of at least 2 m width shall be provided.

The remainder of the hardstand may be an unsealed gravel or limestone pavement. Bitumen or concrete pavement could be used for this section of the hardstand if better quality access around a tank is required.

To enable the use of vehicles with mobile anchor points, clear access for a typical 6 wheel truck with outriggers shall be provided.

Due to the difficulty and safety issues associated with maintaining equipment located in pits, the use of pits around the tank is not preferred. However, where pits are required, they should preferably be located outside the 'access hardstand' and protected with bollards. Where pits within the 'access hardstand' cannot be avoided, the pit and cover shall be class D rated.

4.5 Storm Water Drainage

Stormwater drainage system for a tank site shall be designed to generally meet the requirements of AS 3500:3.

The system shall be designed to contain stormwater within surface drains, pipe drains or formed flow paths, for minor storm events with an average recurrence interval of 10 years (min). The system shall also be designed to ensure overflows- in major storm events with an average recurrence interval of 100 years- do not present a hazard to people and vehicles or cause any damage to tank foundation and significant damage to adjacent areas and properties.

Appropriate average recurrence interval for minor storm event shall be derived based on a risk assessment.

All surface and subsurface flows, any stormwater discharge from adjacent land, flows from sub-soil drains provided to protect tank foundation (Appendix 2 – Assessment of Underdrainage Requirements for Tanks), tank overflow and scour discharges shall be considered. Erosion protection of all surfaces, including cut or fill slopes, shall be considered.

5 Geotechnical Investigations and Foundation

5.1 Geotechnical Investigation

A geotechnical investigation shall be undertaken to address as a minimum the following:

a) quality of the in-situ soil;

b) recommended foundation preparation;

c) design of site fill to achieve acceptable bearing pressures;

d) aggressiveness of the soil in relation to the floor of a steel plate tank;

e) local geology and the possibility of rock pinnacles and sink holes;

f) consolidation and settlement of the tank foundation;

g) slope stability (local & global);

h) surface drainage requirements, including surface water courses, tank overflows and scouring, and rainfall storm runoff;

i) sub-surface drainage requirements, including groundwater and tank leakage collection;

j) risk of foundation damage (eg. dissolution, softening, piping etc.) by leakage or other water flows; and

k) Permeability assessment of soil to help determine location and size of sumps.

5.2 Foundations

All tank sites with more than 200 kL storage shall be referred to a professional geotechnical engineer for geotechnical investigation and recommendations. The professional geotechnical engineer shall assess the stability of the foundation materials for the tank structure. It may be necessary to carry out a detailed foundation risk assessment if the foundation or its stability can be compromised by leakage or other water flows (For example, Soluble limestone, shrink-swell clay, granite sheet joint, piping in dispersive clay etc.).

Foundation preparation shall be in accordance with the geotechnical recommendations, subject to the following minimum requirements:

a) On all sites, a 200 mm minimum layer of topsoil shall be stripped over the tank foundation and appurtenance area to remove all organic material.

b) The topsoil shall be stockpiled and re-spread on embankment slopes or disposed of as required.

c) The undisturbed sub-grade shall be proof compacted by at least 6 passes of a 450 kg static mass vibrating plate compactor or at least 6 passes of a smooth drum vibrating roller of not less than 6 tonne drum mass.

d) Fill material shall be sand or selected gravel compacted in layers to achieve a minimum of 95% modified maximum dry density or minimum 70% Density Index, whichever is higher.

e) The tank wall footings shall be founded on a 300 mm minimum thickness of compacted sand or gravel layer, which shall extend over the tank foundation area.

5.3 Assessment of Underdrainage Requirements

A risk-based assessment of underdrainage requirements shall be carried out based on the information and recommendations in the memo in Appendix 2.

5.4 Settlement Measurement Pins

For tanks larger than 5000 kL and where foundations are susceptible to movement, stainless steel settlement measurement pins (DN20) shall be cast into reinforced concrete tank footings or welded to the wall plate just above the annular plate of steel tanks at suitable intervals. The minimum number of pins shall be 4 for tanks of capacity less than 5000 kL, and 8 for larger tanks.

6 General Operational Requirements

6.1 General

Each of the Corporation's regions may have specific operational requirements for a proposed tank. Regional requirements shall be investigated during the definition or concept design phase and be resolved before commencing engineering design.

6.2 Overflow/Scour

Tanks shall have a suitable means of scouring unusable water and also the control of unintended overflow.

6.3 Overflow Sump

An overflow sump is required on tank sites where there is no suitable alternative for emergency overflow discharge. Alternatives may include long contour drains in permanently undeveloped land or a piped drainage system.

Sump capacity shall be subject to a risk assessment that considers the following factors:

a) time to detect an overflow, taking into consideration the alarms and telemetry and their reliability;

b) likely time required to rectify the overflow condition; and

c) consequences of a sump overflow.

Historically, overflow sumps were sized to hold not less than 3 hours of overflow at the maximum inflow rate. In the design of new facilities and taking into account the risks and consequences of overflow, reasons must exist to allow a sump capacity of less than the "3 hour" size.

Sump capacity shall include provision for roof and tank site stormwater runoff. The sump embankments or walls shall be designed and constructed to be stable under all loading conditions. The sump floor shall be unlined to allow water to infiltrate into the ground.

A stable emergency overflow shall be provided in the sump embankment as a safety measure. (A controlled discharge into a street drain would be preferable to uncontrolled failure of the sump). The sump overflow and spillway shall have a capacity 2 times greater than the tanks ultimate inflow rate.

Sumps shall have access for cleaning by earthmoving plant such as a front end loader or a skid-steer loader. Sumps should be enclosed by a safety fence. It can be the site fence.

Where the construction of a sump is impractical, alternative measures shall be determined on a case-by-case basis. In some cases, drainage of overflow water has been directed into the local drainage system with the agreement of the local authority after meeting environmental requirements.

6.4 Scour Sump

A scour sump shall be provided where an overflow sump is not available or there is no environmentally acceptable discharge location. The material to be discharged could be floor sludge.

The capacity of scour sump for a tank should be adequate to accommodate the following:

a) The unusable water;
b) A volume equivalent to the volume in the tank to a height of 300 mm above the outlet pipe level; or
c) As agreed with asset manager and environmental representative, based on cleaning process to be adopted.

If the depth of the sump is greater than 300 mm, the need for safety fence and access for cleaning shall be assessed and provided in accordance with Standard S151.

7 Operational Access and Instrumentation

7.1 General

Each tank must have facilities which provide a safe access system for:

(i) Cleaning inside a tank;

(ii) Condition inspection;

(iii) The provision, reading and repair of instrumentation;

(iv) The return to ground level, outside the tank, of an injured person;

(v) If required, dosing and sampling.

(vi) Repair and maintenance of the tank;

Ideally, the facilities and system should allow items (i) to (v) of the above activities to be undertaken from ground level.

The facilities provided should also:

a) Minimise or eliminate where possible, the need to access the roof.

b) Unless justified on a whole of life costing, minimise the need for equipment that is infrequently used but requires costly and frequent inspection or certification.

c) Provide multiple ways to achieve the same objective, which will allow operators the freedom to select their preferred method, and may better allow for future changes in OH&S requirements or changes in 'best practice.'

d) Not compromise the ability to maintain continuous water supply to customers.

The safe access system for each tank should be described and endorsed in the design report, prior to commencing the tank detailed design.

7.2 Tank Roof Access

The tank design should aim to eliminate the need to access the roof outside of the guarded platform area.

Where practical, the tank design should also aim to minimize or eliminate the need to access the roof guarded platform area. If so the platform area may not be required.

If access to the tank roof is required for any of the following:

a) inspection and maintenance of the roof;

b) maintenance of roof mounted tank accessories;

c) emergency rescue and recovery;

d) diver access into tank for cleaning / inspection

Then roof access facilities are required.

Roof access facilities shall be provided in the following order of priority:

1) Permanent Stairs,

2) Permanent Ladders (height <3m), or

3) Temporary but fixed in position ladders.

Scaffolds or mobile fall arrest anchor point (registered crane) is not a primary method for normal access for new tanks, but reserved for backup cases as required.

Any roof access facility shall include the relevant fall arrest and security barrier features and shall be compliant with AS 1657 and section 7.7.

Where all items in Section 7.1 are satisfactorily addressed without requiring roof access, the provision of roof access facilities is not required. For example, small poly tanks within a tank farm can be arranged to not require roof access facilities, so there is no roof hatch, no ladders, no roof platform or guardrails.

Roof features that may require maintenance and repair should wherever possible be mounted more than 2m plus space required for maintenance to limit the reliance on a guard rail.

7.3 Tank Interior Access

Access into the tank interior is required for:

1. inspection and maintenance (either in a drained condition or using divers);
2. tank cleaning (either in a drained condition or using divers);
3. initial disinfection of the interior of the tank;
4. refurbishment of internal coatings in welded steel plate tanks;
5. repair or replacement of tank liners in sheet steel tanks;
6. repair of interior wall; and
7. emergency rescue and recovery.

The usual access to the tank interior in a drained condition is via a ground level entry. Refer to FW65-30-27 for typical wall hatch details.

7.4 Examples of Access Systems

The access facilities must be agreed prior to completion of concept design. The following are examples of access facilities.

7.4.1 Multiple small prefabricated tanks in a group

CLEANING

1. A ground level entry (GLE) is provided to allow the interior to be cleaned by pressure washer and drained via a scour located at the lowest point. The washer operator remains outside the tank to avoid confined space entry.
2. A less desirable alternative is to only provide multiple portholes to allow the interior to be pressure washed and drained via a scour at the lowest point. The washer operator remains outside the tank.

INSPECTION

3. Provide sufficient hardstand around the tank to allow inspection and minor repair of the wall and overflow from a EWP or scaffold. Also allows visual inspection of the roof from the perimeter
4. The roof material, either FRP/poly or concrete is durable and not expected to need routine inspection

REPAIR AND MAINTENENCE

5. As the tanks are replaceable items, when major repair is required, the whole tank is isolated and replaced.
6. Minor repairs may be undertaken with the correct OH&S procedures and with the use of temporary facilities, such as an EWP, temporary scaffold, temporary anchor points or temporary

guardrails to enable minor external repairs. Should a minor internal repair be required, the GLE may allow, with the correct OH&S procedures, internal tank entry.

INSTRUMENTATION

7. All instrumentation, and any required dosing or sampling points, are positioned to enable access from ground level.

MINIMISE ROOF ACCESS

8. No facilities or instruments are installed on the roof. The roof material, either FRP/poly or concrete is durable and not expected to need routine inspection, The roof is not normally accessed and no permanent ladders, stairs, prevention of fall barriers, anchor points or davit bases are provided.

CONTINUOUS WATER SUPPLY

9. Provide suitable valves, instrument locations and pipework to allow a single tank to be isolated while storage and supply continue to be provided by the other tanks within the farm. Or

10. A reliable bypass system is in place

THE RETURN TO GROUND LEVEL OF AN INJURED PERSON

11. External, not required as roof access is not normally required or permitted.

12. Internal access is not normally required or permitted.

13. For unexpected minor repairs, temporary access is required to be installed, to a safety plan including the rescue capability.

7.4.2 Large Concrete Wall Tank with a Concrete, Steel or Aluminum Roof

ACCESS FOR CLEANING, INSPECTION AND REPAIR

1. A ground level entry (GLE) is provided to allow access to the interior of the empty tank.
2. Roof access hatch and internal ladder is provided to allow access into a full tank by divers. The hatch has a guardrail surround. To allow for multiple ways to achieve fall restraint, the tank should have multiple options:
    a) A large hardstand area for parking of a specialised vehicle capable of providing an anchor point above the hatch, and
    b) The platform is suitable for the erection of a tripod fall arrest system.
    c) Where the ongoing inspection procedure and high frequency usage has been acknowledged by the operator, a permanent davit base may be installed. This is the least preferred option due to the ongoing requirement for inspection of the davit base.

       Or
    d) Design for and identify a designated clear position on the roof or wall for the future installation of a davit base.
3. Provide external stairs to the roof work platform area.
4. Provide sufficient hardstand around the tank to allow inspection and repair of the wall and overflow from a EWP or scaffold.
5. The roof work platform area is guard railed.
6. The remaining roof will need future inspection and or repair. The frequency of inspection is most for a steel roof for item such as tek replacement, damaged ventilators and is least for a concrete roof (no teks, less vents and preferably no vents within 2 m of an edge). For tanks >3 m height and with

a steel or aluminum roof, it is considered appropriate to include a full perimeter guardrail. For concrete roof >3 m height, with no facilities outside of the guardrailed working area, or only a limited number of vents and none within 2 m of the edge, the use of a central anchor point may be provided as an alternative to a full perimeter guardrail. The anchor point may be permanent or temporary. For all other cases, the fall prevention system shall be considered on an individual basis. The use of permanent anchor points on steel or aluminum roofs is not preferred due to the inability to inspect the portion of the anchor located under the roof sheeting (in the most corrosive location).

INSTRUMENTATION

7. All instrumentation, and any required dosing or sampling points, are positioned on the ground level pipework.

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8. From inside a full tank, utilise the winch and harness, already in place as a prerequisite for confined space entry.
9. From inside an empty tank, return to ground level via the ground level entry.
10. From the roof, the provision of multiple options is required. The design should allow.
    a) External wide stairs and wide landings of sufficient size to allow the use of stretchers. Permanent stairs are the preferred solution.
    b) Davit positioned to allow lowering outside the tank (Preferably the same davit base will be positioned to serve for both hatch entry and lowering outside the tank.) A davit base introduces more risk during installation and use, also the ongoing burden of inspections. Davit bases are a last resort.
    c) Use of an EWP in emergencies only.
    d) Using FESA or similar agency, where proven to be capable and available.

7.5 Confined Space

Access to the interior of the tank will be subject to a local job safety environment analysis (JSEA) and will be undertaken according to current occupational safety and health requirements.

7.6 Hatches & Hoisting Equipment

7.6.1 Ground Level Entry/Wall Hatch

A ground level entry/wall hatch shall be provided for ground level tanks of wall height equal to or greater than 3 metres, for all elevated tanks and all other tanks where a GLE forms part of the access system for the purpose of removing an injured person on a stretcher or for inspection or maintenance work.

The entry shall be of a manhole or porthole type with minimum clear dimension 1000 mm, and shall consider ease of personnel access in its design. The entry door shall be hinged. Typical details of floor level entry/wall hatch are shown in tank type drawings.

All ground level tanks of nominal diameter 25 metres and greater shall be provided with a second wall hatch diametrically opposite to the first wall hatch. Where a wall hatch is provided to a tank of diameter less than or equal to 20 metres, the personnel hatch on roof should be located diametrically opposite the wall hatch.

For ground level tanks of wall height less than 3 metres, a floor level entry/wall hatch shall be provided where it is possible to eliminate entry through the roof.

7.6.2 Personnel Access Hatch

Where required as part of the access system, a roof mounted personnel hatch, located within the working platform on the roof, shall be provided for all new tanks and existing tanks that are being refurbished.

The personnel access hatch shall be located over the tank's internal ladder system, and shall have a minimum opening of 900 mm x 1100 mm. The top edge of the upstand shall have a tubular rubber seal that is totally covered by the hatch cover. The hatch cover shall have concealed hinges and be of aluminium construction. An "ADI" lockable mechanism, or similar, shall be located under a protective cover. An internal brace shall be provided to prevent the hatch from slamming shut. Details of the hatch are provided in the tank type drawings listed in DS61.02.

Where part of the access system, a permanent davit base for a portable hoisting system May be located adjacent to a personnel hatch to enable a person to be tethered while entering or lifted out of interior of the tank from roof and lowered down to ground from the roof. (Note the davit arrangement is a non-preferred system)

Personnel hatch shall be provided with edge protection including guardrail, mid-rail and self-closing gate as shown on tank type drawings. The layout shall also be suitable for the use of portable tripod frames.

7.6.3 Hoisting Equipment

Where part of the access system, a permanent davit base shall be fitted for use with a portable davit and winch arrangement. Note the davit arrangement is a non-preferred system. The need for a davit is expected to be very rare.

Davit and winch arrangement shall be specifically rated for single person fall arrest as per AS 1891.

The winch shall be installed at a height above any opening (including open covers) that allows easy movement of an attached person such that the attached person does not interfere with the tank infrastructure and when being moved from over the hatch opening or tank perimeter guardrail.

Requirements for design, installation and testing of portable davit system used by the Water Corporation are provided in Appendix 3 – Design, Installation and Testing of Portable Davit System.

"Pro-Man" hoisting system is not acceptable for use on tank roofs as its radial movement is limited to only 600 mm. At least 1200 mm radial movement is required to have adequate clearance from tank wall during a rescue operation.

All structural connections of a fall arrest system including the floor mount connection shall be visible for inspection from outside the tank and shall not protrude into tank to avoid exposure to corrosive environment inside the tank.

7.7 Roof Platform and Edge Protection

7.7.1 Platform

Where roof hatches are part of the access system, a working platform shall be provided on the tank roof to provide:

a) a safe working area;

b) access to the personnel hatch, and ventilation hatch (where fitted);

c) a safe area to conduct a rescue

The dimensions of the platform are to be assessed on a case-by-case basis, and shall consider the type of work to be undertaken on the roof. The platform shall be designed to load requirements but not less than that specified in AS 1657.

For steel or aluminium roof, the platform shall be of aluminium chequer plate construction fully sealed mounted directly onto roof supporting members. For steel roofs, the platform shall be insulated against galvanic corrosion. Adjoining roof sheets shall overlap the chequer plate by 200 mm and be appropriately sealed. Guardrails, mid-rails and toe boards shall be provided on the perimeter of the working platform with gates. Aluminium guardrail shall be welded to the chequer plate around the perimeter of the working platform with a gate on the tank roof side of the platform.

Details of the platforms are provided in the tank type drawings.

7.8 Other Roof Hatches

Roof hatches including personnel hatch shall be of the concealed hinge type as shown in the tank type drawings. Sliding hatches may be used at the top of the dry access towers of elevated water tanks. During a tank survey carried out in the year 2001, sliding hatches on tank roofs were found to be not providing an adequate barrier seal to meet the requirements of ADWG.

7.8.1 Ventilation Hatch

A single hatch has traditionally been installed on tank roofs, located opposite to the access hatch, to allow light and cross ventilation into the tank while personnel were inside.

In line with reducing the number of roof mounted facilities and hence the need to inspect or maintain the facilities, a vent/light hatch is no longer required on new roofs. Torches and forced ventilation will be required when personnel entry is required.

The walkway that was sometimes provided to access the vent hatch is also no longer required.

7.8.2 Equipment Hatch

Equipment hatches have been used on large tanks (>10 ML) to facilitate lowering of large equipment for maintenance/repair purposes.

These hatches are not **always** required on new tanks.

If the tank has a metal roof, lowering of equipment could be achieved by removal and replacement of roof sheets **and purlins** to agreed specification and following local Job Safety Environment Analysis (JSEA).

The need for and size of hatch is to be assessed for each tank project with a concrete roof. Keeping in mind the hatch itself will be a maintenance item with limited life that will incur cost to inspect, maintain and replace. In the absence of a hatch, how will the equipment required to allow the inspection and condition assessment of the internal roof be brought into the tank.

7.9 Ladders, Stairs, Landing, Platforms and Hatches

Ladders, stairs, landings and platforms shall comply to Standard S151 and be designed in accordance with standard AS 1657, subject to requirements in this Standard taking precedence. In addition, the ladders shall be provided with non-slip rungs.

7.9.1 External ladders, Stairs and Landings

Means of access to the roof of a tank based on height (distance from ground level to the roof) shall be:

i. By a staged stairway where height is 3.0 m or greater, however, where space restrictions prevent installation of a stairway, a vertical staged ladder shall be fitted with landings at flights not more than 3.0 metres.

ii. Height less than 3.0 metres shall be by an inclined ladder unless risk assessment results in the need for a stairway or space restrictions permit only the installation of a vertical ladder.

All structural connections shall be visible for inspection from outside the tank and shall not protrude into tank to avoid exposure to corrosive environment inside the tank.

Where external stairs are provided:

a) stairway can be straight flights or curved;
b) all steel construction shall be hot dip galvanised;
c) guardrail system including top rail, mid rail and toe board shall be provided to the stairs;
d) landings shall be provided with guardrails and toe boards;
e) the landing surface shall be banded Webforge grating or equivalent;
f) stair treads shall be chequer plate or banded Webforge grating or equivalent;
g) The stairs shall be large enough to allow the use of stretchers; the minimum clear width shall be not less than 1000 mm. Landing shall be large enough to accommodate the use of a 2.2 m length by 800 mm wide stretcher;
h) Subject to requirements of Section 4.2, all stairways are to be fitted with a door/gate and other accessories in accordance with the Guide to Selection of Security Barriers Drawing No. GX54-7-0.

Attachment of steel sections to external concrete shall be with hot dip galvanised chemical anchors.

Details of external ladders are shown in the tank type drawings.

Where external ladders are provided:

a) Inclination to horizontal of inclined ladders shall be 750;
b) all steel construction shall be hot dip galvanised;
c) ladder rungs shall be slip resistant and may be manufactured from DN20 deformed reinforcing bar;
d) landings shall be provided at equal spacing not exceeding 3 m;
e) landings shall be provided with guardrail system including top rail, mid rail and toe board;
f) the landing surface shall be banded Webforge grating or equivalent;
g) ladder stiles shall extend 1.0 metre above the exit level at top;
h) exposed rungs of a ladder from ground level to a height of 2.2 metres (maximum) shall be covered with a ladder security cover as shown on type drawings;
i) ladder climbing systems shall be provided to:

- fixed ladders 3.0 metres or greater in height;
- fixed ladders less than 3.0 metres high from which a potential fall is 3.0 metres or greater;
- fixed ladders less than 3.0 metres high if the need is determined by risk assessment.

j) Where practical, the ladders and landing shall be configured so avoid the need for a ladder climbing system. This avoids to ongoing inspection requirement for the system.
k) Ladder climbing system shall comply with the requirements in Prevention of Falls Standard S151 and AS 1891;
l) Ladder cages are not required where ladder climbing systems are provided.

7.9.2 Internal Ladders, Landings and Guard Rails

The access to a tank interior shall consist of a fixed rung ladder vertically oriented and fixed to the wall beneath the personnel hatch. This hatch is used for personnel access, delivery of equipment as required and rescue operation. The vertical ladder arrangement shall always be provided with a fall prevention arrangement. Entry into the tank requires the use of a harness/fall arrestor attached to the fall prevention equipment.

Details of internal ladders, ladder extensions, landing platforms are shown in the tank type drawings.

Requirements for internal ladders:

a) internal ladders shall be fabricated from fibre-reinforced plastic (FRP);
b) Ladder rungs shall be manufactured from pultruded DN38 x 6.4* (wall thickness) FRP round tube. Rungs shall be mechanically fixed to the stiles and shall have a bonded non-skid surface;
c) ladder stiles shall be from pultruded 50 x 6.4* (wall thickness) FRP square tubes;
d) all cut surfaces of FRP sections shall be sealed with a potable water approved resin;
e) Fasteners shall be as required in Section 7.9.3 of this Standard;
f) Aluminium ladder stile extensions shall be provided on the working platform outside the access hatch cover as appropriate.

*Note: Member sizing is not verified and dependent on ladder geometry. Designer shall ensure correct dimensions are specified

7.9.3 Fasteners

The requirements for fasteners are as follows.

7.9.3.1 Carbon/Mild Steel Fasteners

Bolt, nuts and washers inside tank above top water level and external to tank shall be hot dip galvanised.

7.9.3.2 Stainless Steel Fasteners

7.9.3.3 Bolts, nuts and washers inside tank below top water level shall be Grade 316 stainless steel. Other Fasteners

FRP fasteners may be used for connections between FRP members.

7.10 Inflow Control

Inflows to tanks are usually controlled by:

a) Pressure measurement (hydrostatic pressure of liquid head) linked to an actuated valve and/or pump;
b) Limit Pressure switches linked to an actuated valve and/or pump;

The valve may be hydraulically or electrically actuated.

Electronic measurements of levels shall be linked to the actuated valve through an approved device for control; typically this will be an RTU or PLC.

7.11 Level Measurement

Tank water levels should be measured using pressure sensors with transmitters and pressure switches.

Pressure transmitters and switches should be installed in still water to effectively measure the tank level; they measure the head of liquid so are a bottom up configuration. They are normally installed on the scour pipework, upstream of the scour valve. It is preferable to provide a large measuring surface area such as a flush-faced measuring diaphragm or a large diameter impulse line to avoid blockages, contamination or air entrapment. The pressure element should be mounted below or as close to the bottom of the tank as possible so as to offer measurement of the full height of the tank level.

Consideration should be given to the criticality and consequences of measurement failure, duplication of the pressure transmitter or a backup measurement type (such as pressure switches) shall be used to provide security of the measurement if it is deemed required for the measurement/control point.

Instrumentation and any associated equipment valves should be accessible at ground level.

Typically, level measurement systems are linked into the SCADA or telemetry system.

Typical level measurement arrangements and instrumentation are shown on the LP12 set of drawings listed as reference drawings in DS61-02. Arrangement appropriate to the type of tank shall be used.

8 Ground Level Tanks

8.1 Reinforced Concrete and Pre-stressed Concrete Tanks

The minimum design requirements for reinforced concrete and pre-stressed concrete tanks are as follows. Typical arrangements for ground level reinforced concrete and pre-stressed tanks are shown in the tank type drawings.

8.1.1 Standards

Concrete tanks shall comply with all the requirements of AS 3600, AS 3735, AS 5100.5 and recommended practice in Concrete Durability Series published by the Concrete Institute of Australia. The onerous requirements of above documents shall be adopted to develop design and specification for a reinforced and pre-stressed concrete tank project considering the design life required.

8.1.2 Dimensions

Nominal heights and diameters for reinforced concrete circular tanks are shown in Table 8.1 below.

Table 8.1: Nominal Dimensions of Reinforced Concrete Ground Tanks

Volume (kL)	Height (m)	Diameter (m)
1000	4.0	17.8
2500	4.5 – 6.0	26.6 – 23.0
5000	4.5 – 6.0	37.6 – 32.6
10000	4.5 – 6.0	53.2 – 46.0

8.1.3 Concrete Mix Design

a) Concrete mix design shall be developed to achieve a design life of 100 years (minimum) for the finished concrete unless a lower design life is specified.

b) Initial selection of concrete mix shall be based on:

1. Ability of premix supplier to successfully deliver required volume and quantity;
2. sources of appropriate fine and coarse aggregates;
3. source of suitable water;
4. environment in which a tank is to be located;
5. reinforcement spacing and compaction requirements;
6. cover to reinforcement;
7. potential adverse effects due to excessive drying;
8. alkali-aggregate reactions;
9. soluble salts;
10. thermal cracking.

c) Concrete mix shall comply with the requirements in **Error! Reference source not found.**.

Table 8.2: Concrete Mix Characteristics

Element	Concrete Grade	Min binder (cementitious) content (kg/m^3)	Max binder (cementitious) content (kg/m^3)	Max w/c ratio	Min w/c ratio	Max Aggregate size (mm)	Slump (mm)	Max. Shrinkage Strain (microstrain)	
								21 days	56 days
Floor slab, Ring beam and Footing	S40	320	400	0.45	0.40	20	100 ± 20	430	600
In-situ Walls (reinforced)	S50	400	450	0.45	0.40	20	120 ± 20	430	600
Precast Walls (post-tensioned)	S50	400	480	0.40	0.35	20	100 ± 20	430	600
Infill panels in post-tensioned walls (stitch joints)	S50	400	500	0.40	0.35	14	150 ± 30	320	450
Columns	S60	420	500	0.40	0.35	20	100 ± 20	430	600
Roof precast Beams and planks	S50	400	450	0.45	0.40	20	100 ± 20	430	600
Precast hollow core planks	S60	400	520	0.35	0.30	14	0 (zero)	320	450
In-situ Roof topping	S40	320	400	0.45	0.40	20	100 ± 20	430	600

Note 3: Concrete made with blended cement must contain a minimum of 220kg/m^3 of GP cement.

Note 5: AS1478 Type MWR or HWR admixtures may be used in accordance with manufacturer's recommendations to achieve desired consistency for placing and compacting concrete with a slump after admixture addition of 120 ± 20 mm,. Use of Type MWR or HWR admixtures must consider all other admixtures in the mix design to evaluate the impact on workability, segregation, bleed, and setting time, and assess the benefit of using the admixture.

Note 8: The concrete mix for infill panels (stitch joints) and for columns shall have integral waterproofing admixture such as crystalline growth admixture and corrosion inhibitors (e.g Xypex C5000 or equivalent) to the mix at a rate of 0.5% to 0.6% by weight of cement or as appropriate.

Note 9: The infill panels shall have shrinkage compensating admixture to reduce shrinkage to approximately 450 microstrain at 56 days.

Note 10: Floor slab, Ring beam and Footing (Post-tensioned) can have early strength gaining admixture or higher grade concrete (e.g. S50) as required by the stressing of the floor elements. Larger pour may require shrinkage compensating admixture to reduce shrinkage to approximately 450 microstrain at 56 days if required by durability consultant.

Note 11: **Durability section Nexus document 156099726 has background on the performance of existing tanks and new tank strength and cover recommendations.**

d) Admixtures shall be free of calcium chloride and conform to AS 4020 and AS 1478.1.

Where two or more admixtures are proposed for incorporation into a concrete mix, their compatibility must be certified by the manufacturers.

e) Aggregate used for the concrete mix shall not exhibit any tendency of alkali reactivity or other adverse interaction with the cement. Each aggregate from each source used in the concrete mix to be incorporated into the Works must be:

i) petrographically examined in accordance with ASTM C 295; and

ii) assessed and classified for AAR using the accelerated mortar bar test method RTA T363.

For aggregates classified as non-reactive by RTA T363 available at website http://www.rms.nsw.gov.au/business-industry/partners-suppliers/specifications/volume-1-materials-test-methods.html , no action for control of potential AAR is required. Where any of the aggregates in a mix are classified as slowly reactive or reactive by RTA T363, actions taken for control of potential AAR in the concrete shall be in accordance with Table 8.3.

Table 8.3: Action for Control of Potential AAR

Mortar bar expansion (%) in 1 M NaOH (80°C) at 21 days		Actions Required
Coarse aggregate	Fine aggregate	
≥ 0.10, < 0.40	≥ 0.15, < 0.45	Use blended cement
≥ 0.40 or <0.10	No limits	Use an alternative aggregate; or Use blended cement and assess aggregate reactivity in the concrete mix using RTA T364
No limits	≥ 0.45 or <0.15	Use an alternative aggregate; or Use blended cement and assess aggregate reactivity in the concrete mix using RTA T364

a) When determined in accordance with AS 1012.20, the average mass of acid soluble chloride ion per unit volume of ground samples of hardened concrete shall not exceed 0.3 kg/m^3.

The sulphate content of ground samples of hardened concrete, determined by calculation and expressed as percentage by mass of acid soluble SO_3 to cement, shall not exceed 3% for heat accelerated cured concrete or 5% otherwise.

b) The thermal cracking may be controlled by using blended cement containing fly ash or blast furnace slag. Chilling the mix water and insulating the concrete member are other methods to control thermal cracking. Thermal cracking is usually aggravated with large volume concrete elements.

The effects arising from temperature increases as a result of cement hydration during production and curing of the concrete element shall be modelled and measured to prevent thermal cracking shall be identified.

8.1.4 Internal Exposure

AS 3735 requires an assessment of how aggressive the stored water will be on the interior of concrete tank. The water characteristics are defined by the Langelier Saturation Index and pH.

Some of the water in the Perth Metropolitan Water supply has a negative Langelier Saturation Index, meaning the water has a demand for $CaCO_3$ resulting in a more aggressive exposure classification being applied under Section 4 of AS 3735.

Some metropolitan hills sources have water with a pH of less than 6.5, whereas the water from groundwater treatment plants and service reservoirs has a pH in the range of 6.5 to 7.5.

In the absence of specific water quality data for the water to be stored in the tank, cover for an internal exposure classification of B2 under Section 4 of AS 3735 or 50 mm- whichever is greater- shall be used for design.

8.1.5 Crack Control

8.1.5.1 General

Reinforced tank elements shall be designed to control the crack widths as follows.

(i) Flexure – 0.15 mm

(ii) Direct tension – 0.10 mm

To ensure cracks are minimized in a concrete tank, the requirements in the following sub clauses shall be adopted to develop the design and to specify construction requirements.

8.1.5.2 Thermal and Shrinkage cracks

Early age thermal behaviour and imposed restraint of all concrete elements shall be evaluated to determine the risk of cracking and potential loss of compression strength. Those elements of particular risk include: thick concrete sections, walls cast onto mass foundations and slabs butted against prior cast slabs.

Early age and long term shrinkage of all concrete elements shall be evaluated to determine the risk of cracking and durable surface finish, and appropriate curing for the environmental conditions.

An Early Age Thermal and Early/Long Term Shrinkage Control Method Statement (included in the Durability Plan) for concrete elements deemed to be a potential risk shall be adopted covering the following issues as appropriate:

i) Mix proportions, particularly cementitious content;

ii) Use of cementitious content with a low heat of hydration (e.g. LH cement);

iii) Use of any shrinkage reducing admixtures;

iv) Use of synthetic fibre reinforcement

v) Strain development and tensile strain capacity;

vi) Concrete heat development and cooling;

vii) Batching and placing concrete temperature;

viii) Ambient and ground temperature;

ix) Thermal properties of ground, formwork and adjacent concrete elements, and the need for insulation;

x) Seasonal and diurnal temperature variations and thermal shock cooling;

xi) Construction sequence, particularly in relation with adjacent concrete elements to minimise restraint;

xii) Heat of hydration of the cementitious components;

xiii) Adiabatic temperature for the concrete mix. Where information is not available for the concrete a 1 m^3 thermal block shall be cast with timber formwork, 100 mm polystyrene insulation, vibrating wire strain gauges (2 nos.), thermocouples (4 nos.), monitoring until temperature returns to the ambient and assessment completed of the test data to interpolate the adiabatic temperature;

xiv) Concrete thermal expansion and contraction coefficients, which can be interpolated from the 1 m^3 thermal block;

xv) Imposed restraint from internal and external factors;

xvi) Compaction appropriate for concrete rheology;

xvii) Curing for environmental conditions inclusive of form stripping time, wet curing including a detailed curing methodology such as the design of water curing reticulation pipework, use of evaporation retarders, curing compounds, etc.;

xviii) Location, frequency and duration of monitoring for concrete elements using thermocouples and vibrating wire strain gauges; and

xix) Summary tables in the plan shall give cement content and type; concrete element thickness, length and width, element type (slab base, wall, slab roof, etc.), element restraint, concrete casting temperature, concrete strain, concrete shrinkage and reinforcement ratios, diameter and spacing. This summary information will be used as a design guide for all reinforced concrete structures.

8.1.5.3 Plastic Shrinkage Cracking

Plastic shrinkage cracking shall be controlled in accordance with Cement Concrete & Aggregate Australia. Appropriate measures to restrict the evaporation of water from the concrete surface must be taken. Technical Procedures for the restriction of the evaporation rates to less that 1 $kg/m^2/hour$ must be submitted. If an evaporation retarder is used to restrict the evaporation of water, its application must be a fine uniform spray.

8.1.6 Design Requirements

8.1.6.1 Concrete Tanks

The minimum design requirements for concrete tanks in general are as follows:

a) unless architectural finishes are specified, the finishes of formed concrete surfaces shall be in accordance with the applicable requirements of AS 3610;

b) The formwork finish class for concrete wall surfaces shall be class 2X. All surface finish qualities (Table 3.4.2 AS 3610) shall be to class 2, whereas a relaxation to class 3 for 'face step' is allowed;

c) Finish for the exposed floor slab shall be unformed U3 surface finish. To achieve U3 finish, the procedure shall consist of steel trowelling work which shall commence only after the moisture film and shine have disappeared from the concrete surface and after the concrete has hardened sufficiently to prevent an excess of fine materials and water from being drawn to the surface. Steel trowelling shall produce a dense uniform surface free from visible blemishes and trowel marks with a tolerance of 5 mm in 3 m;

d) surfaces that will be permanently concealed (buried), shall be Class 5, as defined in AS 3610, Part 1;

e) surfaces of other structures (e.g. valve pit) shall be of Formed Finish Class 3, AS 3610;

f) concrete colour control in accordance with AS 3610, Part 1 shall be Class B;

g) floors shall be poured with the surface flat except a localised dip at the scour outlet as shown on type drawings;

h) Column footings shall be located underneath the slab to provide a flat floor surface suitable for robotic cleaning.

i) floor construction joints shall be located such that the floor is broken into manageable concrete pours;

j) Aggregates used for the manufacture of concrete shall not exhibit any tendency of alkali reactivity or other adverse interaction with the cement. Chert shall not be used as concrete aggregate;

k) all concrete ingredients shall be compatible with potable water application;

l) the concrete cover to internal and external surfaces shall be determined considering the exposure conditions but shall not be less than **60mm for columns** and 50mm internal wall and all other surfaces, with no negative tolerances. **Durability section Nexus document 156099726 has background on the performance of existing tanks and cover recommendations, recommends 60mm cover for columns.**

m) fresh concrete placed in position shall be water cured for at least the first 7 days after casting followed with a further 3 days minimum in a moist-curing environment;

n) isolate any embedded metallic pipework from contact with the tank reinforcing steel to prevent galvanic corrosion;

o) coating of external surfaces should be considered for concrete tanks exposed to a coastal or a more severe environment;

p) the centre-to-centre bar spacing in the top steel of reinforced concrete floor/footing/roof shall not be greater than 180 mm;

q) the minimum thickness of cast in-situ walls with reinforcement on each face shall be 300 mm;

r) Material of floor level/wall hatch of concrete tanks shall be grade 316L stainless steel.

8.1.6.2 Pre-stressed Concrete Tanks

The minimum design requirements for pre-stressed concrete tanks in addition to those in Section 8.1.6.1 are as follows:

a) pre-stressed concrete tanks shall be the post-tensioned type;

b) pre-stressed concrete tanks shall be designed and constructed to the relevant Australian Standards with no residual tension in the tank wall under all loading conditions;

c) steel pre-stressing materials shall comply with the requirements of AS/NZS 4672 Parts 1 & 2;

d) steel tendons shall be 7-wire stress relieved steel strand;

e) Sheathing that forms the ducts shall be of corrugated galvanized steel. The sheathing shall have a maximum curvature coefficient of 0.25;

f) anchorages shall comply with the requirements of AS/NZS 1314;

g) pre-stressing cables shall be protected against corrosion through the pressure-injection of cementitious grout into the cable ducts;

h) a pre-tension system for circular tank walls is not acceptable;

i) where a post-tensioned tank is constructed of precast concrete wall panels, special attention shall be given to treatment of the joints to achieve water tightness at the joints (Refer to clause 8.1.10);

j) Precast member manufacture and acceptance shall be in accordance with the Concrete Institute of Australia publication, “Precast Concrete handbook (2002).”Maximum temperature of concrete during accelerated curing of precast manufacture shall not exceed 70°C for cement type GP and 80°C for cement type LH;

k) Tank floor slab for a post-tensioned tank may be of either pre-tensioned or reinforced concrete;

    i. Where slab is not prestressed, column footings shall be located underneath the slab to provide a flat floor surface suitable for robotic cleaning.

ii. Where slab is prestressed, Column pedestals shall be of dimensions suitable for robotic tank cleaning or alternatively be of conical shape to prevent sediment buildup.(Some robots come equipped with "boom" type cleaning heads that can reach onto the pedestal if it is not to high and wide)

l) Special attention shall be given to treatment of the wall to floor joints to allow for the effect of relative displacement and/or deflection in order to achieve water tightness;

m) Footings and slabs on ground shall be poured on a waterproof membrane. Use of two layers of 0.3 mm polythene building film to allow movement during floor tensioning, and at least one layer is required to prevent mortar loss may be considered

n) The waterproof membrane should be laid on a minimum 50 mm layer of sand or 100 mm layer of no fines concrete as appropriate.

8.1.7 Chloride Induced Corrosion

Design of water tanks and reservoirs is to consider the chloride induced reinforcement corrosion risk just above the water level primarily due to capillary rise/evaporation cycle mechanism that can deposit chlorides into the concrete from relatively low chloride concentrations in water (e.g. chloride in Perth water normal maximum 200 mg/L with up to 250 mg/L when bore water sources are used). Risk assessment is to be based on the expected chemistry of the stored water, in particular the chloride concentration. This mechanism affects all internal surfaces and should be design assessed however, columns have significantly earlier corrosion damage due to the bi-axial chloride deposition at corners.

The above was recommendation of a study into the degradation of Perth Reservoir, 'Reservoir Columns Investigation, March 2019' by GHD. NEXUS ID 20816423

8.1.8 Painting of Concrete Tanks

Concrete tanks are generally not painted due to the ongoing maintenance required and to minimise the contrast of the chosen colour against the white coloured calcification and leaching at cracks and constructions joints that is likely to occur.

If external coating is required on walls for aesthetic reasons, then the surfaces shall be prepared in accordance with Water Corporation specification A5 - Surface Preparation for the Application of Protective Coating on Concrete followed by coating in accordance with Water Corporation coating specification J2 - Anti-Graffiti Coating on New and Old Concrete Structures.

If painting is required, light colours are preferred.

8.1.9 Reinforcement Spacers, Bar Chairs and Form Ties

All reinforcement spacers, bar chairs, wall form tie tubes and cones shall be of the extruded fibre-reinforced mortar type. Plastic elements shall not be used as reinforcement spacers, bar chairs or wall form ties.

Spacers shall be Max Frank or approved equivalent.

Acceptable typical arrangement and system configuration of wall form ties based on proprietary systems available in the market are provided in Appendix 4 - Wall Form Ties.

8.1.10 Concrete Joints

8.1.10.1 General Requirements

The design approach of concrete joints shall provide:

i) At least 2 different seals or leakage barriers, in order to provide levels of redundancy and backup where necessary. Typical barriers include a rearguard waterstop, central waterstop, hydrotite or surface sealant. Note that epoxy fixed surface bandages are considered a repair technique and shall not be an allowable as a barrier during initial construction.

ii) Access to all vulnerable areas.

iii) Ability to return and treat leaks by injecting re-injectable tubing where provided.

iv) Ability to return and drill and grout leaks with polyurethane or other approved methods.

v) Water stops, sealants and coatings shall be approved for use by the Water Corporation and Durability Consultant.

8.1.10.2 Durability and Proven Systems

The design of joints between concrete elements is critical to the long term performance of a tank. Attention shall be given to deterioration of elements which cannot be easily accessed for maintenance or repair. The design of such elements shall ensure that the durability of the elements and the minimum design life applicable to the whole structure are attained without maintenance.

For other elements guarantees from the supplier of the products used to seal any joints shall be available for a minimum of 15 years before the first maintenance.

Where a joint system that in the opinion of the Water Corporation deviates from standard practice such joint system shall have proven to have been used in similar designs elsewhere and evidence of this shall be available together with a third party review of the joint design.

8.1.10.3 Minimum Requirements

i) All construction and expansion joints (if present) shall be watertight.

ii) Vertical and horizontal joints in precast walls panels shall have at least two lines of continuous barrier against water penetration, such as a hydrophilic and re-injectable grout hose type central waterstop and a sealant on the internal face of the joint.

iii) Vertical joints shall not be permitted in cast-in-situ walls.

iv) Horizontal joints in cast-in-situ wall panels shall have at least two lines of continuous barrier against water penetration, such as a hydrophilic and re-injectable grout hose type central water stop and a sealant on the internal face of the joint.

v) Transverse joints in floor slabs shall have at least two lines of continuous barrier against water penetration, including rearguard waterstops.

vi) Surface sealants on horizontal surfaces shall be slightly recessed to prevent damage due to robotic cleaning of tanks (these robots often employ a rotating brush head).

vii) The horizontal joints at external wall base shall have at least two lines of continuous barrier against water penetration. These joints shall be provided with grout injection tubes to facilitate repeated retroactive joint sealing.

viii) At all other perimeter or circumferential construction joints, waterstop shall also be of the hydrophilic and re-injectable grout hose type. Particular care must be taken with the fixing in place of waterstops to ensure that they remain in position square to the joint, without folding, when concrete is placed and vibrated around them. *Site* jointing of waterstops must be limited to simple butt joints which must be made in accordance with the manufacturer's instructions.

ix) All joint sealing systems shall be installed in accordance with the manufacturer's recommendations, including cover requirements for water stop to prevent spalling damage to concrete if the swelling component is activated (minimum 100 mm cover required based on material manufacturer often stating 50 mm minimum and extra construction allowance);

x) Typical joints for in-situ and precast concrete sections are shown on drawing FW65-30-7.1 and FW65-30-7.2.

8.1.11 Advantages and Disadvantages of Concrete Tanks

The advantages and disadvantages of concrete tanks are presented in Table 8.4 below.

Table 8.4: Advantage and Disadvantages of Concrete Tanks

Advantages	Disadvantages
• If well-constructed, no corrosion problems. Maintenance costs will be minimal. • Concrete walls provide good heat insulation. • Asset has long life, when constructed correctly, in suitable conditions. • Autogenous healing of fine cracks. • Resistant to malicious damage. • Pre-stressed concrete construction can provide material savings and increased quality control through the use of precast panels of thinner wall sections.	• Leak free joints cannot be guaranteed. • Prone to cracking and white calcifications at resultant leaks. • Joint sealants will require periodic replacement. • Specialist repairs required if reinforcement corrodes and concrete spalls. • Low pH water can attack concrete. • Cannot be maintained in perpetuity. • Pre-stressed concrete construction requires increased technical and construction skills.

8.2 Welded Steel Plate Tanks

The minimum design requirements for welded steel plate tanks are as follows. A typical arrangement for a ground level welded steel plate tank is shown in the tank type drawings.

8.2.1 Dimensions

The Corporation has welded steel plate ground level tanks in service in sizes ranging from 700 kL to 60,000 kL. Elevated welded steel plate tanks in service range in size from 120 kL to 2250 kL.

8.2.2 Design Standards

The design of welded steel plate tanks shall be to:

a) AWWA D100-96 – American Water Works Association Standard for welded steel tanks for water storage;

For requirements on design details not specifically given or shown in the above document, the following standards may be used:

i. British Standard BS 2654 - Manufacture of Vertical Steel Welded Non-refrigerated Storage Tanks with Butt-welded Shells for the Petroleum Industry;

ii. American Standard API Standard 650 – Welded Steel Tanks for Oil Storage.

Design based on the combined use of the two standards is not acceptable.

8.2.3 Design Requirements

The minimum design requirements for welded steel plate tanks are as follows:

a) wall thickness shall be structurally adequate to meet strength and durability requirements;

b) no corrosion allowance for the shell thickness is necessary but the theoretical shell thickness shall be rounded up to match the next higher standard plate thickness;

c) Corrosion allowance provided for the floor shall be designed based upon the corrosiveness of the foundation soil and occurrence of groundwater. The minimum plate thickness for tank floors shall be 8 mm;

d) tank wall exterior shall be surface shall be prepared in accordance with Water Corporation specification A1- Surface Preparation for the Application of Protective Coating on Steel or Cast Iron and coated in accordance with Corporation's coating specification C2 - Zinc Rich Epoxy Primer, Epoxy Mastic Coat, Polyurethane Top Coat on Steel or Cast Iron. Refer to DS 95 (Standard for the Selection, Preparation, Application, Inspection and Testing of Protective Coatings on Water Corporation Assets) for additional information and/or clarification;

e) Tank wall interior surface shall be prepared in accordance with Water Corporation specification A1- Surface Preparation for the Application of Protective Coating on Steel or Cast Iron and coated in accordance with Corporation's coating specification D1 – High Build Epoxy Coating on Steel or Cast Iron. Refer to DS 95 (Standard for the Selection, Preparation, Application, Inspection and Testing of Protective Coatings on Water Corporation Assets) for additional information and/or clarification;

f) Submerged portion of the tank interior shall be protected with an impressed current cathodic protection system Refer to DS 91 – Cathodic Protection Standard for the Selection, Design and Monitoring of Cathodic Protection (CP) Systems. Any fittings relating to the Cathodic Protection system shall be installed prior to painting;

g) Australian Standard AS 2832 – Cathodic Protection of Metals shall be used for the design of the cathodic protection system and shall be acceptable to the Water Corporation;

h) area of the tank foundation pad in contact with the tank steel floor shall be covered with a 50 mm (+15-0) thickness of compacted bitumen, sand mix where cathodic protection system for underside of floor plate is not provided;

i) In areas of aggressive soils, or areas subject to water inundation, the underside of the floor plate shall be protected with an impressed current cathodic protection system. The floor plate shall rest on plain sand where a cathodic protection system for underside of floor plate is in place;

j) All welding personnel and welding equipment shall be qualified and acceptable to the Corporation. Refer to Design Standard WS-1, Welding Specification Metal Arc Welding for more information;

k) welding sequence shall be specified to eliminate local buckling of the wall and floor plates;

l) all welds, including that for the wind girders and roof support system, shall be structural sealed welds to prevent the ingress of moisture into the welded joints;

m) Abrasive blasting of the tank interior shall be carried out before installation of the tank roof. Dust control is of paramount importance in the application of the coating system;

n) use of stays/wires as part of the tank roofing system is not acceptable;

o) support brackets for roof beams shall be above the tank top water level;

p) use of gusset plates for the purpose of providing rigidity at base of columns supporting roof beams is not acceptable;

q) Material of floor level/wall hatch of steel plate tanks shall be grade mild steel coated internally and externally as specified for the tank.

r) Column footings shall be located underneath the floor plate to provide a flat floor surface suitable for robotic cleaning.

8.2.4 Advantages and disadvantages of steel plate tanks

The advantages and disadvantages of steel plate tanks are presented in Table 8.5 below.

Table 8.5: Advantages and Disadvantages of Steel Plate Tanks

Advantages	Disadvantages
• No cracks or weeps • Suitable for large capacities (100000 kL tank built in NSW) • Welded tanks have no joint sealant leakage problems • Pipework easily modified or enlarged • Surface is hard and smooth, not subject to scouring, does not attract or harbour organisms such as algae • No leach or weep stains and can be painted for aesthetic reasons	• Requires periodic coating inspection and repair • Stored water may be subject to slight temperature rise • Welded plate tanks require a high level of welding skill • Underside of floor is difficult to protect from corrosion

8.3 Fibre-Reinforced Plastic Tanks (FRP) and Polyethylene Tanks

8.3.1 General

FRP and polyethylene tanks of capacities less than 100 kL are outside the scope of this section. FRP ground level tanks have been successfully used by the Corporation in sizes up to 120 kL. FRP tanks are more suited to shorter term installations of around 15 - 30 years, for example, where it may be desirable to stage storage requirements for a subdivision development.

8.3.2 Design Requirements

The minimum requirements for FRP tanks are as follows:

a) FRP tanks shall comply with the Corporation's Technical Specification FRP, including design and construction in accordance with BS4994. Pipework that is an integral component of an FRP tank system shall be designed and constructed in accordance with BS6464 and BS7159 up to its designated point of interconnection with general process and buried pipework. Where conflict between the requirements of nominated standards arises, the requirements of Technical Specification FRP/GRP - Fibre-Reinforced Plastics or Glass-Reinforced Plastics shall prevail.

b) all reinforcing fibres in the finished product shall be protected from exposure to the liquid contained in the tank;

c) The resin and fibres used in the tank construction shall be suitable for potable water application in regards to compliance with AS 4020 and compatible with the properties of the liquid contained, such as water of high pH.

8.3.3 Advantages and Disadvantages of Fibre Reinforced Plastic Tanks

The advantages and disadvantages of fibre-reinforced plastic tanks are presented in Table 8.6 below.

Table 8.6: Advantages and Disadvantages of FRP Tanks

Advantages	Disadvantages
• High corrosion resistance • Relatively lightweight • Leak free • Shop fabricated – transported to site in rolled panels or complete tanks • Simple, fast to erect	• Limited to small sizes • Subject to UV degradation • Can be damaged by impact • Susceptible to vandalism, particularly bullets

8.4 Galvanised Sheet Steel with a Membrane or Coated Liner

The minimum design requirements for sheet steel tanks with liner are as follows. A typical arrangement for sheet steel tank with liner is shown in the tank type drawings.

8.4.1 Application

Sheet steel tanks with liner are suitable for relatively short term installations. They are easy and fast to erect and have a life span of 10 to 20 years depending on the conditions.

Typically liners need to be replaced at 10 year intervals. Provision for supply alternatives during liner replacement shall be considered in the design stage. Refer Section 12.8.

The size range in use by the Corporation is up to around 600 kL for ground level tanks and up to 200 kL for elevated tanks.

Due to the various choices of manufacturers and liner types, selection of the tank and liner is based in part on the warranty the manufacturer is prepared to offer.

8.4.2 Design Requirements

The minimum design requirements for sheet steel tanks with liner are as follows:

a) a tank manufacturer's warranty against the perforation of roof and wall sheeting by the action of internal condensation or the effects of weather, for a period of 20 years, shall be obtained;

b) a tank manufacturer's warranty against perforation of the tank liner through the action of filling/draining, water quality, chlorinated water, temperature effects, chemical degradation etc., for a period of 10 years, shall be obtained;

c) the liner shall be fabricated from a heavy duty approved no-toxic food grade material such as PVC, polyethylene, polypropylene or combination of such materials, complying with AS 4020;

d) the liner material shall have sufficient strength/fatigue properties that it can withstand two complete emptying and fill cycles of the tank per day;

e) The liner material of sufficient robustness and construction shall limit the amount of folds to prevent damage by a robotic tank cleaning regime;

f) the liner shall be UV stabilised on both sides;

g) the liner shall be installed to enable it to be replaced without removal of the tank roof and in a manner to prevent water ingress between the membrane and the tank wall; the manufacturer's details shall be submitted to IDB for review;

h) the liner shall be adequately fixed to the tank wall and supported around the full tank perimeter;

i) To prevent "piping" failure under the ring beam similar to the failure of the tank at Fitzroy Crossing, the tank foundation shall comprise a concrete ring beam to support and fix the wall and cement stabilised sand floor. The floor shall have recessed drainage to collect and discharge leakage to a monitoring standpipe;

j) a suitable geotextile fabric shall be installed between the liner and the floor;

k) If a finish colour has been specified for the tank wall and roof that is not available as pre-coated Colorbond, then galvanised sheeting shall be used. The tank surface may be prepared and painted in accordance with the Surface preparation standard A3 – Surface Preparation for the Application of Protective Coating on Galvanised Steel followed by coating application of E4 - Epoxy Mastic, Polyurethane Top Coat on Galvanised Steel after the tank has been erected with the approval of the Corporation;

l) Over-the-top inlet pipework shall be arranged so as to avoid discharge onto roof members.

8.4.3 Advantages and Disadvantages of Galvanised Sheet Steel Lined Tanks

The advantages and disadvantages of galvanised sheet steel lined tanks are presented in Table 8.7 below.

Table 8.7: Advantages and Disadvantages of Galvanised Sheet Steel Lined Tanks

Advantages	Disadvantages
• Leak free • Lightweight • Shop fabricated • Easily assembled • Can be relocated	• Limited to small sizes • Tank can be damaged by impact. Susceptible to vandalism, particularly bullets. Liner susceptible to damage by foot traffic. • Limited life • The liner can be degraded by UV if unprotected

8.5 Bolted Panel Tanks

This section refers to bolted panel tanks that are factory produced with a glass fused steel plate panels and imported / transported to site.

These type of tanks may have a life around 20 to 30 years. So they are tanks that need allowance to be periodically decommissioned and replaced. Site design must allow for either duty/ standby tanks, provide for a new duty tank to be constructed prior to the tank life or allow for long term bypassing.

Concerns with panel tanks include:

- **Panels can be damaged during transport, construction or in service. Inspection and repair techniques need to be suitable and in place. If made overseas, additional potential for damage arises.**
- **Potential difficulty in repair of glass coating and/or confidence in quality of repair (when construction defects are found later or new damage found).**
- **Longevity of the sealant between panels**
- **As compared to welded steel tanks, cannot use cathodic protection as the panels are separated by glass and sealant**

- **Large quantity of bolts to assemble, for large steel tanks welding is automatic and potentially cost effective.**
- **Warranty claim issues if manufacturer and installer are separate entities.**
- **Cost varies wildly on exchange rate, local contractor availability etc**

Fully welded tank can be inspected and repaired indefinitely, also can have CP on the walls. Concrete tanks have a longer life, so unless much more expensive, for large tanks, fully welded or concrete tanks are preferred.

Small tanks < 250kl, are treated as throw away and replace. Bolted steel would be compared to liner or multiple plastic tank farm.

Other than within treatment plants, bolted steel plate tanks have not been commonly used in the wider network.

9 Tank Farm Guidelines

9.1 General

This section intends to address where multiple and small FRP/Poly tanks are used in combination. Individual tanks shall be designed according to the relevant parts of DS61 unless modified by this section. Propriety tanks may be used with project specific acceptance. These may be designed to the manufacturers own standards, providing a warranty is provided for at least 20 years. Individual tank size up to 60 kL.

9.2 Minimum Requirements

The minimum general design requirements for tanks part of a tank farm are as follows:

a) Each tank shall be supplied with flanged offtakes with AS/NZS 4087 compatible flanges. Offtakes are required for:
   1. Inlet Pipework
   2. Outlet Pipework
   3. Overflow Pipework
   4. Scour Pipework
   5. Common manifold for single set of instruments
   6. One spare

b) All offtakes, except the overflow, shall have an isolation valve fitted at the offtake. The offtake pipework should be a flexible type to avoid placing strain onto the tank offtake.

c) All tank inlets shall be connected to a common inlet manifold and all tank outlets shall be connected to a common outlet manifold.

d) Inlet and outlet manifold should be designed to ensure turnover in each tank is similar

e) Each individual tank should be able to be taken out of service (for cleaning, flushing, inspection, repair or replacement) without affecting other tanks or the overall operation of the tank farm.

f) The overflow may be used as a breather. All breathers or overflows shall be protected from ingress of rainwater, birds and insects.

Drawing GL49-2-1 shows a pipework layout.

9.3 Roof access

Roof access is not permitted. All equipment shall be located at ground level and no roof hatches will be provided.

9.4 Side access

An opening shall be provided at ground level to enable inspection of the tank and to allow for cleaning. It is intended the hatch provides sufficient access for pressure washing (cleaning) the tank without personnel entry. To facilitate washing, the scour is ideally located in the floor of the tank, as close as possible to the wall, and opposite the wall hatch.

The hatch is not necessarily required for personnel entry. However, where practical, a hatch large enough for entry should be provided, as it may, with the appropriate OH&S for isolation and entry, allow minor internal repairs.

10 Elevated Tanks

10.1 General

Elevated tanks are incorporated in a water supply system to provide the required pressure to serve an area if the required minimum pressure cannot be achieved with a ground level tank.

The types of elevated tanks can be as follows.

a) Tanks on Stands
   (i) Fabricated steel tank supported on steel framework.
   (ii) Fabricated steel tank supported on concrete columns.
   (iii) Concrete tank supported on concrete columns.

b) Water Towers
   (i) Concrete tank supported on concrete shaft.
   (ii) Steel tank supported steel shaft.

10.2 Tank on Stands

10.2.1 Tank Stands

Tank stands referred to in this section are of the braced steel frame structure type supporting a prefabricated sheet steel or fibre reinforced plastic tank. Minimum design requirements for tank stands are as follows:

a) tank stands shall be designed for a service life exceeding that of the tank and not less than 50 years, so that the prefabricated tank, at the end of its service life, can be replaced on the existing stand;

b) structure shall be designed so that member geometry installation will promote self-drainage to minimise the risks of corrosion;

c) ladders and landings to access the platform decking shall be to the requirements of AS 1657, DS100 and Sections 7.7 and 7.9 of this Standard;

d) bolted connections are preferred to site welding wherever practicable;

e) Each fastener projection and nut shall be fitted with ‘Radolid’ cap filled with ‘Denso 305 Primer’ or Lanotec Type A Grease.

Reference shall be made to Water Corporation’s Design Standard DS 95 for minimum corrosion protection standards for tank stand, ladders and landings, platforms, and deckings.

10.2.2 Tank Stand Platforms

Platforms, walkways and ladders shall comply with AS 1657, except where the following provisions require a larger platform.

a) platform shall be sized to allow a minimum clear width of 600 mm around the tank;

b) Platform width at the base of a ladder (to the tank roof) shall be not less than 1200 mm measured from the base of the ladder to the guardrail. Alternatively, the width may be reduced to 900 mm (the code minimum) provided a guard is provided between the fixed guardrail and the bottom of the ladder cage;

c) sufficient platform width shall be provided below the tank emergency entry to safely carry out a rescue;

d) Access and lifting requirements shall be determined with the client Region for each particular tank. Consideration shall be given to the compatibility of the equipment to be specified with existing Regional equipment and work practices. Typically, the hoisting equipment may be disassembled and carried to the tank roof. Alternatively, the equipment may be raised to the platform using a truck mounted crane or may be permanently fixed. Each tank shall be considered on a case-by-case basis;

e) guardrails and toe boards shall be provided for the full perimeter of the platform;

f) Nuts shall be prevented from loosening under the load fluctuations induced by wind loading.

10.2.3 Decking

The minimum design requirements for decking are as follows:

a) the decking shall provide a uniform bearing surface for the prefabricated tank floor;

b) the decking shall be non-slip;

c) The decking material shall be durable hardwood or hot dip galvanised steel. Hardwood has a limited life expectancy of about 10 years in the north of Western Australia. If it is to be used, it should be installed ‘heartwood down’ which may double its service life;

d) the decking shall be structurally connected to its supporting structure and the tank stand;

e) the decking shall provide a structural connection to the tank it supports;

f) To prevent crevice corrosion, the deck shall be free draining and the interface between a galvanised tank and galvanised deck shall be coated with ‘International Interline 876’ or approved similar bituminous paint. Also, refer to Water Corporation technical specification H2 - Galvanised Coating of Steel Structures. For more information on coating, references shall be made to Water Corporation Design Standard DS 95.

10.3 Water Towers

The access towers referred to in this section are the integral supporting structure of an elevated tank. Minimum design requirements for access towers are as follows:

a) access tower shall be of the same material of construction as the tank and shall be subject to the same design requirements as the tank it supports;

b) lighting shall be provided within the access tower;

c) access tower shall be sized to accommodate:

   i. pipework

   ii. access stairs and landings

   iii. cable and cable trays

   iv. lifting of maintenance cleaning tools and equipment

   v. emergency rescue operations from within the tower

d) Access tower shall provide access from ground level to the tank roof through the tank interior via a ‘dry shaft.’ The dry shaft shall remain water tight during the service life of the tank;

e) Access tower shall be provided with a lockable standard size external doorway resistant to vandal action. The lock shall be capable of accepting the Corporation’s Bilock keying system;

f) Working platforms shall be provided at suitable levels relative to the positions of the internal pipework and valves to enable access for maintenance.

g) Lighting is not to be mounted more than 2.1 m from platform floor and shall be accessible for repairs without overhanging the guardrail

11 Tank Roofs

11.1 General

To ensure the quality of stored water, the Water Corporation requires that storages containing treated water, or water that is suitable for distribution, be roofed to prevent the entry of contaminants.

11.2 General Design Criteria

Roofs for ground level and elevated tanks shall be designed and constructed to comply with the following general criteria:

a) the roof shall be watertight and shall prevent the entry of stormwater, debris and other contaminants;

b) roof hatches and fittings shall be designed to prevent the entry of stormwater, debris and contaminants;

c) the roof shall prevent the entry of insects (mosquitoes, flies and larger), birds and animals;

d) roof shall be sufficiently secured against unauthorised entry;

e) roof shall drain outward.- internally draining roofs present the risk of overflow of the drainage system into the stored water and are not preferred;

f) water shall not pond on the roof;

g) roof shall be structurally sound and fit for purpose throughout its operational life;

h) Roof shall be designed to allow inspection and maintenance. The roof shall be able to carry load as specified in AS/NZS 1170 over the entire roof area.

11.3 Steel Roofs

The minimum design requirements for steel roofs are as follows. Typical arrangements for steel roofs (on concrete tanks) are shown on the type drawings.

11.3.1 Application

Steel framed and sheeted roofs are the most widely used roof type for tanks, for the reasons of cost, strength and service life. The prevention of corrosion of members in a chlorinated environment and the prevention of the entry of contaminants are of major concerns. The design shall take into account the measures detailed in the design criteria below.

11.3.2 Design Criteria

a) roof and all fittings shall not leak;

b) roof geometry and colour finish shall be designed to satisfy visual and environmental requirements including aspects of light reflection and glare;

c) roof slope shall not be less than 3° or the manufacturer's recommended minimum slope, whichever is greater in order to prevent ponding;

d) roof slope shall not exceed 5°, considered the maximum safe slope for maintenance purposes;

e) Roof system shall be designed to allow for expected thermal movement. Previous designs have allowed for thermal movement between the roof and wall for medium and large diameter tanks and allowed for movement joints in long runs of roof sheeting;

f) Roof structural layout shall minimise the amount of bridging required. Bridging has tended to be more prone to corrosion than other roof members and is expensive to install and replace;

g) design of the sheeting, flashings and closures shall consider the possibility of the flow of water up-slope in strong winds;

h) Steel closures shall be used to seal the sheeting profile where required. The closures shall be hand cut where necessary to match the sheeting profile;

i) foam closures strips are generally not suitable or acceptable because of their deterioration due to exposure to the sun or heat, their dislodgment from the intended positions, attack by birds and rodents, and generally short service life;

j) Roof flashings around protrusions shall be designed and detailed to prevent the entry of stormwater and debris into the tank. Cut sheeting ribs shall be closed off and sealed. Side laps parallel with the protrusion shall also be sealed;

k) sealant type shall be compatible with the roof material, equivalent to Sikaflex 11FC;

l) Ventilation of the roof sheeting comprising a vent area at least 0.2% of the total roof area shall be provided. The locations of the ventilators shall be agreed with the roof sheeting manufacturer to secure the required warranty but should be locate at least 2m plus clearance for access away from the roof edge. Ventilators on wall will not be permitted;

m) ventilation shall be sufficient to cope with the rate of change of water levels due to normal tank operation, and the total ventilation capacity shall exceed the maximum water inflow and outflow rates from the tank;

n) Vents shall be fixed type and be able to prevent the entry of contaminants, including liquids. Wind powered rotary ventilators are not permitted;

o) vents shall be adequately supported, using trimmers where necessary;

p) all roof frame members shall be clear of the water and shall not protrude into the lower half the tank freeboard provision;

q) the interface between all roof components, including:

- all steel structural members,
- cleats and purlins,
- purlins and roof sheeting,
- purlins and working platform, and
- sheeting and working platform

shall be liberally coated, prior to assembly, with an approved bituminous paint (International “Interline 876” or similar) to completely eliminate moisture collecting in the crevice, and to provide some insulation between dissimilar metals.

Interfaces between end laps and side laps of sheeting shall not be coated. If end laps are used they shall be installed and treated as recommended by the manufacturer;

r) A roof sheeting manufacturer’s warranty of 20 years against perforation by weathering in natural elements, and against perforation due to condensation on the underside of the sheeting, should be obtained. The warranty is subject to the conditions set by Bluescope Steel Limited (BSL). The warranty shall not be less than 12 years under any conditions;

s) In the case where BSL will not provide a warranty for prefabricated tanks, a warranty equal in conditions to that of BSL shall be obtained from the tank manufacturer.

11.3.3 Steel Roof Materials

11.3.3.1 Steel Purlins and Bridging

Steel purlins and bridging shall be designed and detailed to comply with the following:

a) The thickness of cold formed structural members (purlins, bridging, mounting brackets) shall be greater than 1.2 mm. The members shall be of grade G450 steel to AS/NZS 4600 and hot-dip zinc coated to Z450 (450 g/m^2 minimum coating mass) complying with AS 1397. The product designation of the members to be AS1397/G450 Z450;

b) Main roof purlins shall be Z-section purlins with a down turned lip to the bottom flange for water shedding purposes. Purlins shall be installed to be self-draining;

c) Bridging shall be constructed from C-section purlins. In this application they are self-draining as they are aligned with the roof slope. Alternatively, channel bridging and bolted brackets may be used provided they are hot dip galvanised through a process such as 'Permagalv';

d) Bridging shall be bolted at both ends to the purlins. Rivetted, spot welded, clinched or hook type systems shall not be used, as they have proven to be prone to corrosion in the tank environment;

e) after removal of all sharp edges and surface irregularities, all punched, drilled and cut edges of purlins, bridging and brackets are to be painted with an Australian Paint Approval Scheme approved organic zinc rich coating such as 'Jotun Barrier' or approved similar, in accordance with AS/NZS 4680;

f) in specifying roof purlins and bridging, uniformity of size and thickness throughout the tank roof shall be considered in order to ensure efficient ordering and use of rolls by the purlin manufacturer;

g) All bolts, nuts and washers for purlin and bridging connections shall be hot dip galvanised in accordance with AS/NZS 4680.

11.3.3.2 Steel Roof Work

Steel roof work shall be designed and detailed to comply with the following:

a) all steelwork shall comply with AS 4100 and shall be hot dip galvanised to Water Corporation Technical Specification H1 – Repair of Galvanised Coating and AS/NZS 4680 after fabrication;

b) any damage to the galvanising shall be repaired in accordance with Water Corporation technical specification H1 - Repair of Galvanised Coating;

c) all bolts, nuts and washers for structural steel connections shall be hot dip galvanised in accordance with Water Corporation Technical Specification H1 – Repair of Galvanised Coating and AS/NZS 4680;

d) Where locking nuts are specified, 'Nylock' or similar approved nuts shall be used. The use of two plain nuts locked against each other is not allowed.

11.3.3.3 Steel Roof Sheeting

Steel roof sheeting shall be designed and detailed to comply with the following:

a) The sheeting material shall be of Zincalume aluminium/zinc/magnesium alloy coated steel complying with AS 1397. Minimum yield strength shall be G550 (550 MPa). Minimum coating shall be AM150 (150 g/m2). Base metal thickness shall be either 0.42 mm or 0.48 mm. Preferred profiles are Spandek or Trimdek;

b) where the roof sheeting and accessories are to be coloured, the material shall be 'Colorbond Ultra' with the same steel properties as at point (a) above, or similar approved;

c) Flashing and accessories shall be of similar finish to the main roof sheet material and shall be of Zincalume aluminium/zinc alloy coated steel complying with AS 1397. Minimum yield strength shall be G300 (300 MPa). Minimum coating mass shall be AM150 (150 g/m2). Minimum base metal thickness shall be 0.55 mm;

d) flashings and mouldings are to overlap sheeting by a minimum of 200 mm;

e) the sheeting shall withstand permanent deflection under any combination of loads specified in AS/NZS 1170;

f) all sheeting and flashing fasteners, are to be in accordance with AS 3566 and hot dip galvanised in accordance with AS/NZS 4680;

g) pop rivets shall not be used;

h) concealed fastener type sheeting is not approved for use due to:

- crevice corrosion at the fastener;
- inability to readily inspect fasteners;
- Difficulty in removing and reinstalling existing sheets.

i) Roof sheeting of lengths adequate to cover the length from ridge to the edge of tank perimeter shall be used to avoid end-lapping of sheets. End-lapping of sheets will be permitted only if it can be justified that such approach is required due to transport, handling or other constraints;

j) Sheeting and flashing fasteners shall be coated to Class 4 corrosion resistance (AS3566.2) and be self-drilling hexagonal head screws of length to suit sheet profile all in accordance with AS 3566 and installed with EPDM washers. Fastener minimum thread size shall be ST 6.3 (No. 14) in accordance with AS3566.

11.3.3.4 Roof Vent, Security Mesh and Fly Screen

Roof Vent, Security Mesh and Fly screen shall be designed and detailed to comply with the following:

- The roof vents shall prevent the entry of insects (mosquitoes, flies and larger), birds and animals. Maximum gaps shall be 2 mm or less at any point on the vent.
- Roof vents shall be designed for the appropriate wind loadings. 'Wind jumps' shall be at maximum 500 mm spacing.
- Roof vents shall be manufactured of 'Colorbond Ultra' sheets of minimum 0.55 mm base metal thickness.
- A minimum open vent area of the order of 65% to 70% is required in order to ensure the effectiveness of venting is maintained. This minimum open area shall take into account the security screen and fly screen.
- Roof slope and ridge vent openings shall be covered by two screen layers, a security screen underlain by a fly screen. An acceptable security screen is Locker Group hot dip galvanised Louvre LV10G or approved equivalent (strand 4.8 mm wide by 1.0 mm thick and open area of 88%). This is the lightest type of security screen that successfully can be hot dip galvanised with acceptable minimal warping.
- An acceptable fly screen is Locker Group 316 stainless steel plain weave Mesh 10 Gauge 26 or approved equivalent (0.457 mm strand, 2.08 mm opening, and open area of 67%).
- The security screen shall be securely fixed to all four edges of the vent using a fixing strip and Class 4 corrosion resistance fasteners at maximum 200 mm spacing, all in accordance with AS 3566 and installed with EPDM washers. A preference exists for self-drilling hexagonal head timber screws, which fasten securely to sheet metal. Grade 316 stainless steel pop rivets are also acceptable. The use of fasteners without a fixing strip is not acceptable.

11.3.3.5 Roof Platform and Guard Rails

Roof platform and guard rails on it shall be designed and detailed to comply with the following:

- The arrangement shall be as shown on type drawings.
- Material of platform shall be aluminium grade 5251-H34 or 5083-H116 and 6063-T5 or 6063-T6. The floor thread plate shall be made from Grade 5251-H34 or 5083-H116. Aluminium extrusion shall be made from Grade 6063-T5 or 6063-T6 materials.

11.4 Aluminium Roofs

11.4.1 Application

Although aluminium framed and sheeted roofs have been used on reservoirs, the use of aluminium roofs on Water Corporation tanks had been limited due to cost reasons. However, this trend is changing and an aluminium roof on tank as alternative to steel roof is acceptable to the Water Corporation subject to project specific details being agreed with the Water Corporation.

Appropriate aluminium alloys suitable for required durability and workability shall be selected and used.

11.4.2 Design Criteria

The minimum design criteria for aluminium framed and sheeted roofs are:

a) The minimum design criteria for steel framed and sheeted roof in Section 11.3.2 items a) to q) shall apply;

b) A roof sheeting manufacturer's warranty of 40 years against perforation by weathering in natural elements, and against perforation due to condensation on the underside of the sheeting, should be obtained. The warranty is subject to conditions set by the manufacturer. The warranty shall not be less than 30 years manufacturer's warranty.

11.4.3 Aluminium Roof Materials

11.4.3.1 Aluminium Purlins and Bridging

Aluminium purlins and bridging shall be designed and detailed to comply with the following:

a) requirements in Section11.3.3.1 10.3.3.1, items b) to d) for steel purlins and bridging shall apply;

b) All bolts, nuts and washers for purlin and bridging connections shall be hot dip galvanised with appropriate isolation.

11.4.3.2 Aluminium Roofwork

Aluminium roofwork shall be designed and detailed to comply with the following:

a) All aluminium work shall comply with AS/NZS 1664.

b) Where locking nuts are specified, 'Nylock' or similar approved nuts shall be used. The use of two plain nuts locked against each other is not allowed.

c) Welding of aluminium and aluminium alloys shall comply with AS 1665 and Water Corporation's welding standard WS1. Welding quality shall be assessed to Table 6.1, Category "B". Quality assurance requirements shall comply with CF2 where the mode of failure is expected to result from lack of strength as per Table B1.

11.4.3.3 Aluminium Roof Sheeting

Aluminium roof sheeting shall be designed and detailed to comply with the following:

a) The sheeting and fascia cladding material shall be Permalite minimum BMT 0.9 mm Alspan standard with one-sided polyester paint finish fixed in accordance with manufacturer's recommendations.

b) Requirements in Section 11.3.3.3 items d) to i) for steel roof sheeting shall apply.

c) Sheeting and flashing fasteners shall be coated to Class 4 corrosion resistance and be self-drilling hexagonal head screws of length to suit sheet profile all in accordance with AS 3566 and installed with EPDM washers.

11.4.3.4 Roof Vent, Security Mesh and Fly Screen

Roof Vent, Security Mesh and Fly screen shall be designed and detailed to comply with the following:

a) Requirements in Section 11.3.3.4, for steel vent, security mesh and fly screen, shall apply subject to steel members being adequately isolated from aluminium members to prevent galvanic corrosion and provide the required durability.

b) Alternative roof vent, security mesh and fly screen arrangement made using aluminium alloys are acceptable subject to the details being approved by the Water Corporation.

11.5 Concrete Roofs

Reinforced concrete roofs are generally provided where:

- clear water stored has a high chlorine concentration and the enclosed airspace is heavily charged with chlorine vapour;
- environmental, social and security issues favour a concrete roof;
- Cost effectiveness of whole of life cost favours concrete over other materials.

The minimum requirements of a reinforced concrete roof are:

a) roof should drain outward with a slope of minimum 1^{o}

b) Runoff from elevated tank roofs shall be collected along the outer perimeter of the tank and drained to the ground using a drainage pipe aesthetically designed on the structure's outer wall. The use of the tank's internal overflow pipe is not preferred;

c) concrete for the roof shall be of Class S40 or mix of higher strength;

d) Roof slab shall be supported by a reinforced concrete column grid with reinforcement top and bottom in both directions to prevent excessive deflection.

e) Ventilation shall be as for steel roofs.

11.6 Fibre Reinforced Plastic Roofs

Fibre reinforced plastic roofs shall only be used on FRP tanks. The roof shall be designed and constructed as part of the tank package by the FRP tank manufacturer. The roof slope may exceed 3^{o} but should be kept to the minimum practical.

Special attention shall be given to the anchorage system to hold down the tank and hatches under severe wind conditions.

11.7 Other Roofs

Roofs of other construction methods and materials shall be referred to the Water Corporation for approval, but as a minimum shall comply with the design requirements detailed above and elsewhere in this Standard.

11.8 Roof Replacement

Timber members shall not be used in tank roof replacement work. Where it is possible, existing timber members should be replaced with steel members.

Only reinforced columns shall be used to replace the existing columns within a concrete tank.

11.9 Safety Grates

Portable and removable safety grates shall be designed to meet the following load and deflection criteria:

- Imposed actions as required for the category "Structures for access and working" in Table B1 of AS 1170.1:2002 Structural design actions – Permanent, imposed and other actions (Uniformly distributed load of 2.5 kPa and concentrated load of 1.1 kN);
- Deflection not to exceed 5 mm;
- Load combination to be in accordance with AS/NZS 1170.0:2002 Structural design actions – general principles;
- Removable safety grates shall be signposted with "No Step" or the international symbol of a person walking with diagonal line over with the words, "No Step" below;
- Where practicable, a lifting tool should be used to remove safety grates. The tool could be a rod with a hooked end and handle.

12 Tank Pipework

12.1 General

The minimum general design requirements for tank pipework are as follows. Typical arrangements for tank pipework are shown in the tank type drawings.

a) A design for tank pipework shall be in accordance with the Water Corporation's document "Criteria for Drinking Water Supply"(Nexus #58615523);

b) Tanks shall be fitted with the following pipework:

- Inlet pipework
- Outlet pipework
- Overflow pipework
- Scour pipework
- Tank bypass pipework
- Other auxiliary pipework

c) cast-in or built-in tank pipework shall be designed to allow for the ultimate flow rates, at flow velocities not exceeding 3 m/sec;

d) where a proposed tank is part of a current or future multiple tank installation, the tank shall be fitted with an outlet for connecting to the other tanks;

e) All underfloor pipework shall be concrete encased with a Class N25 concrete to provide a 200 mm minimum thick encasement. The encasement shall extend a minimum of 100 mm beyond the zone of influence of the tank footing;

f) All pipework DN100 and larger within the tank site shall be MSCL;

g) for elevated tanks or water towers, encasement is not required except for strength or anchorage requirements, and special consideration shall be given to the effect of tank movement on the pipework;

h) Concrete-encased pipework shall be constructed of mild steel, externally coated with fusion bonded polyethylene and internally cement-lined pipe with welded joints.

i) where the water to be transferred is harmful to cementitious lining of the pipe, other lining or pipe materials shall be considered for the encased pipes;

j) Where steel pipes penetrate through the tank wall or floor slab, a minimum clearance of 20 mm shall be maintained between the pipe wall and the tank reinforcing steel to prevent galvanic corrosion. The electrical isolation of the pipe from the reinforcing bar shall be checked once all the steel has been fixed, and also after the concrete is placed;

k) valves for tank pipework shall be located as near as practicable to the tank but allow for ease of future valve replacement;

l) Pitometer points and sampling points shall be provided as agreed with the Customer Services Division/Drinking Water Quality Branch/Region of the Corporation.

12.2 Differential Settlement

The designer shall mitigate the potential and the effects of differential settlement between tank components. Design solutions may involve deeper rock cutting for under slab pipework to provide a uniform depth of fill, additional slab design to prevent punching shear, seal designs that can accommodate the anticipated range of motion, etc.

For example the Harvey Summit Tank has an underlay layer of rock which was excavated to a uniform level. This resulted in the depth of fill underneath the scour's concrete encasement being much smaller than under the rest of the slab. The differential settlement between the tank slab and scour pipework resulted in a punching shear failure.

12.3 Tank Inlet Pipework

"*The Criteria for Drinking Water* (Nexus #58615523)" requires separate inlets and outlets for tanks. Tank inlet pipework may consist of a through-the-floor inlet or an over-the-wall inlet dependent on the location, Corporation requirements and mixing requirements discussed in Section 12.10.

Through-the-floor inlets shall be angled to promote circulation of the stored water in accordance with Section 12.10. Where a floor inlet is flush with floor, it shall be fitted with an FRP grill capable of supporting a 1.1 kN point load.

Over-the-wall inlets may be specified where the inflow requires aeration. This is determined in the definition or preliminary design stage, in consultation with the Water Quality Branch. It may be required on tanks in schemes such as the Goldfields and Agricultural Water Supply Scheme (GAWS) and the Great Southern Towns Water Supply Scheme (GSTWS) where aeration mitigates the effects of disinfection by-products or in other schemes where water quality issues prescribe aeration.

Over-the-wall inlets are sometimes specified for the prevention of backflow, or to provide backpressure for sand filters.

The over-the-wall inlet pipework is generally installed on the outside of the tank, and an adequately sealed protrusion shall be provided through the roof. The inlet shall be angled to promote mixing of the stored water in accordance with Section 12.10, and directed away from roof members. The installation of an air vent in this area will help dissipate water vapour that may lead to premature corrosion of roof members/sheeting. For pumped schemes with this inlet configuration, the pump head is constant regardless of the water level in the tank, and may result in slightly higher operating costs.

A facility for chlorine dosing and/or water sampling points should be in accordance with the projects approved requirements baseline document (ARB). However, if dosing and sampling is not specifically mentioned in the ARB, a check should be undertaken, during concept design, of the need for dosing and sampling points.

Inlet dosing points contain a plastic valve that will require periodic maintenance (replacement). As such, inlet dosing should only be specified when needed, otherwise the installation introduces a maintenance requirement and a potential failure point for no real benefit.

Where required by the scheme operating requirements non-return valve may be considered for through-the-floor inlets.

12.4 Tank Outlet Pipework

A tank outlet shall be located at 60-90 degrees from the tank inlet to promote mixing of stored water. The orientation of outlet from inlet shall be determined considering the requirements in Section 12.10.

Tank outlets are typically through-the-floor outlets. For new tanks, the tank floor at the outlet shall be raised at least 100 mm above the surrounding floor level, in order to prevent sediments from being drawn into the outlet. A 100 mm high mud ring may be provided for existing tanks with outlets level with the floor. For operational safety, the outlet opening shall be fitted with an FRP grill capable of supporting a 1.1 kN point load.

It is important that air entrainment or vortexing at the outlet is avoided, and particularly so where the outlet supplies a pump. The 'unusable storage' depth provides the submergence required over an outlet to avoid air entrainment or vortexing.

Vortexing is a function of the velocity of the water at the outlet. Outlets shall be designed to avoid air entrainment and to minimise vortex formation. Stainless steel plate splitter vanes or 'tables' shall only be used as remedial measures.

To isolate surge from the gravity system, it is desirable that ground level tanks supplying both gravity and a pumped scheme have separate outlets, or a bification as close as practical to the tank.

Unless specifically stated as not required, a sample point shall be installed on the outlet of the tank The type of sample point should be agreed with the Corporation, (Water Quality Branch).eg a flammable tapping point or a sampling point as per the Corporate standards.

12.5 Combined Inlet/Outlets

To ensure water turnover, the ideal situation for a tank site is to have a separate inlet main and a separate outlet main, along with a separate tank inlet and a separate tank outlet. Most "greenfield" sites fall under this category.

At several existing tank sites, the inlet and outlet mains are combined. Water turnover at these sites is of concern.

To improve turnover at the site, an assessment shall be made of water demand to ensure water stored in the tank, and also stored in the combined inlet/outlet main, is turned over throughout the year. Control levels may need to be adjusted seasonally to promote tank turnover.

To improve water turnover within the tank, all new tanks shall be provided with a separate inlet and a separate outlet, each as described in 12.2 and 12.4above.

Combined inlet/outlet **shall not** be used without written permission from Infrastructure Planners or Design Branch.

12.6 Overflow Pipework

12.6.1 General

Overflow pipework is required for the rare situation where the failure of tank controls prevents the usual shutting of inflow into the tank. The tank freeboard provision is designed in conjunction with the overflow pipework and provides sufficient head over the overflow and a margin of safety to pass the design inflow. The design shall be such that over-topping of the tank wall shall never be allowed to occur. Overflow pipework shall be conservatively sized to allow for discharge of the maximum possible inflow rate.

Overflow pipework can either be internal or external to the tank. Internal overflow pipes shall be internally mounted and constructed from corrosion resistant materials such as FRP. The overflow pipe shall be fitted with a bellmouth structure to improve the rate of overflow. Details are provided in the tank type drawings. Overflow pipework exits through the tank floor and connects to external pipework leading to the overflow/scour sump. Internal pipework is generally used on tanks where aesthetics is important, on high level tanks as an extension of the overflow pipe mounted within the tank support stem and on limited depth tanks where the additional cost of FRP pipe is small. Internal overflow pipe can, however, not be inspected without emptying the tank.

External overflows have generally been used on large tanks, particularly in isolated non-urban locations where aesthetics are not paramount. The 'PWD' design generally has a steel plate launder to carry water from the tank perimeter to the vertical MSCL overflow pipe. The launders have been prone to corrosion and required regular refurbishment. New launders shall be constructed from materials resistant to corrosion, chlorine and UV, such as welded steel plate, hot dipped galvanised after fabrication.

12.6.2 Freeboard

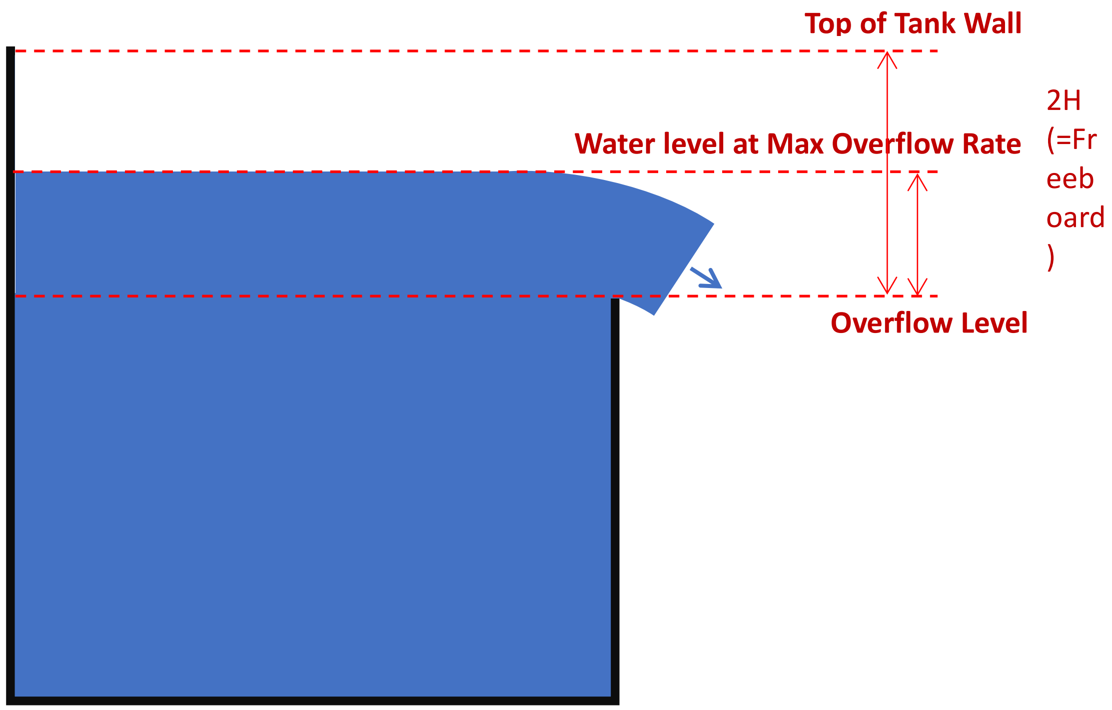
Freeboard is the height of wall above the overflow pipe level. The minimum freeboard shall be as per Table 12.1

In the case where the inflow rate to an existing tank has been increased, the freeboard may need to be increased or the overflow capacity increased, or the overflow outlet lowered.

All tank items, including roof members and inlet pipework must be at least 50mm above the water level at the maximum overflow level.

Table 12.1: Minimum Freeboard

Tank Size	Tank Location	Minimum Freeboard
≤ 1000 kL	Ground	Larger of 200 mm, or double water depth at design overflow
> 1000 kL	Ground	Larger of 300 mm, or double water depth at design overflow
≤ 500 kL	Elevated	Larger of 200 mm, or double water depth at design overflow
> 500 kL	Elevated	Larger of 300 mm, or double water depth at design overflow



12.7 Scour and Pipework

A scour is required in the floor of tanks for drainage of the unusable storage and for cleaning purposes.

The preferred scour arrangement is to have the scour entry located near the tank wall to minimise the amount of pipe cast in under the tank floor.

The scour entry shall be dished or bellmouthed, and fitted with an FRP grating. Typical arrangements are provided in the tank type drawings.

Central scour points have been provided for tanks up to 36 m in diameter (Exmouth 5000 kL); however the long term performance of the cast in pipe has not been proven. The fall in the floor for a central scour is reversed to that of a scour located near the tank wall.

Generally, scours should be able to drain the tank at a rate exceeding 300 mm depth per hour. The scour pipework size shall conform to the sizes shown in Table 12.2.

Table 12.2: Minimum Scour Size

Tank Volume	Minimum Scour Size
500 kL to 1000 kL	DN150
1000 kL to 10000 kL	DN200
Larger than 10000 kL	DN300

Scour pipework shall be laid at a grade no flatter than 1 in 500 to the discharge point. The scour pipework shall have a valve installed close to the tank wall. The valve shall be of the same diameter as the pipe (i.e. no reducers) to prevent sediments from becoming trapped at the valve.

Scours on elevated tanks shall have an additional valve installed at ground level so that the valve does not need to be operated or maintained from the tank platform or a landing.

Scours are required to discharge into the scour/overflow sump. The scour pipework is usually connected to the overflow pipework outside the plan outline of the tank.

12.8 Provision to Bypass the Tank during Maintenance

The pipework and tank shall be designed to allow the tank to be taken out of service for maintenance. This may be achieved by:

a) provision of a bypass between the tank inlet and outlet pipework;

b) determination of alternative supply options for the event of the tank being out of service;

c) for an elevated tank, provision of a bypass from the high level transfer pumps direct into the high level zone;

d) dividing an elevated tank into two separate and sealed compartments, allowing one compartment to remain in service while the other is out of service for maintenance. This requires an expensive duplication of ladders, hatches, pipework and instrumentation and would not normally be approved.

e) Where supply through tank bypass will not be providing sufficient contact time (Ct) to achieve disinfection for services downstream, the bypass has to be fitted with a double block and bleed arrangement. Required information on contact time (Ct) can be obtained from Drinking Water Quality Branch.

f) Provision of two or more tanks on site.

12.9 Additional pipework Requirements for Elevated Tanks

All valves must be able to be operated and replaced from a safe working position, preferably at ground level. A flexible joint shall be incorporated into the pipework near the tank to ensure the pipe is self-supported and not supported by the tank. The flexible joint must be designed to accommodate the movement of the tank and movement of the pipes due to changing operating levels and temperature.

Provision may be made for a DN25 or DN50 water service to be installed on the roof for cleaning purposes (This pipework may either connect to a mobile pumping unit, or to the high pressure side of the transfer pump station when operating in tank bypass mode.).

12.10 Mixing

To ensure adequate mixing within a tank, the following design parameters shall be determined in accordance with the procedures detailed in Appendix 5 – Mixing of Water in Tanks:

- Type of inlet (bottom or top)
- Size and inclination of inlet nozzle
- Orientation of outlet in relation to inlet

12.11 Pressure Testing

All pipework beneath a tank and within 2.0 metres from outside edge of wall foundation except the scour pipework shall be appropriately pressure tested before the floor and wall foundation are constructed.

The test pressure of the pipework shall be greater of 2 times the design pressure or 50 metres head.

All welded joints of scour pipework beneath a tank up to the first flanged joint outside edge of wall foundation shall be tested as follows in accordance with AS 4041 and WS1 prior to installation:

- Butt welds – 100% radiographic test
- Fillet welds – 100% Magnetic particle test

13 Undesirable Tank Conditions

Photographs providing examples of undesirable tank conditions are included in Appendix 6 – Examples of Undesirable Tank Conditions.

The conditions shown have developed generally due to either a design not meeting this standard or constructors/supervisors not strictly complying with the specification.

14 Commissioning and Handover

14.1 Disinfection

Disinfection and commissioning of tanks shall be carried out in accordance with the document, “Working on Storages and Bringing New Storages Online” (Nexus #58550798).

14.2 Leak Testing

The tank shall be tested by filling to full capacity with potable water. Filling of the tank shall be at a uniform rate except that for tanks larger than 5000 kL where filling shall be stopped at 25%, 50% and 75% volume intervals.

Levels shall be taken on the settlement measurement pins when the tank is empty, at the above intervals and where the tank is full. At the end of 7 days of holding water at the full supply level, levels on the settlement measurement pins shall again be taken.

Filling shall be stopped should any leaks or other defects become evident. If repairs are necessary, the tank shall again be disinfected and then re-tested. All repairs shall have an expected service life similar to or exceeding that of the tank.

The roof shall be tested for water tightness via the application of water through a hose or sprinkler system to provide a sheet flow of water over the entire roof, for a period of 6 hours. The direction of water application shall be varied to simulate the effects of strong winds on driving rain, with special attention being paid to protrusions, flashings and roof fittings. The roof is considered satisfactory if no leaks or damp patches show on the underside of the roof.

The testing procedure and acceptance criteria for the tank and roof shall be in accordance with Section 7 of AS 3735.

14.3 As Constructed Survey and Documentation

‘As constructed’ survey and documentation shall be in accordance with Design Standard DS80 –WCX CAD Standard.

The survey datum shall be to the Geocentric Datum of Australia co-ordinate system (GDA94).

14.4 Acceptance

The tank shall not be accepted until the microbiological, chemical and leak tests have been successfully passed, verified ‘As Constructed’ documentation received and the tank is considered to be satisfactory by the Water Corporation.

15 Appendix 1 – List of Australian Standards & Code of Practices

NOTE: This list may not be exhaustive.

Loads

AS 1170	Minimum design loads on structures Parts 1 to 4

Materials

AS/NZS 4020	Testing of products for use in contact with drinking water

Soil Testing

AS 1289	Methods of testing soils for engineering purposes

Concrete Work

AS 1012	Methods of testing concrete
AS 1141	Methods for sampling and testing aggregates
AS/NZS 1314	Pre-stressing anchorages
AS 1379	Specification and supply of concrete
AS 1478	Chemical admixtures for concrete
AS/NZS 1554	Structural steel welding
	(Part 3 - Welding of reinforcing steel)
AS/NZS 2350	Methods of testing Portland and blended cements
AS 2758.1	Concrete aggregates
AS/NZS 3582.3	Amorphous Silica
AS 3600	Concrete structures
AS 3610	Formwork for concrete
AS 3735	Concrete structures for retaining liquids
AS 3972	Portland and blended cements
AS/NZS 4671	Steel reinforcing materials
AS/NZS 4680	Hot dip galvanised coatings on fabricated ferrous articles
AS/NZS 4672	Steel pre-stressing material
AS 5100	Bridge design
SAA MP27	Manual on the physical testing of Portland cement

Steel and Metalwork

AS 1110	ISO metric hexagon bolts and screws
AS 1111	ISO metric hexagon commercial bolts and screws
AS 1112	ISO metric hexagon nuts, including thin nuts, slotted and castle nuts
AS 1163	Structural steel hollow sections
AS 1214	Hot-dip galvanised coatings on threaded fasteners
AS 1237	Plain washers for metric bolts, screws and nuts for general purpose
AS/NZS 1252	High strength steel bolts with associated nuts and washers for structural engineering

AS 1275	Metric screw threads for fasteners
AS 1397	Steel sheet and strip - Hot-dipped zinc-coated or aluminium/zinc coated
AS/NZS 1554	Structural steel welding (Part 1 - Welding of steel structures)
AS 1562	Design and installation of sheet roof and cladding (Part 1 – metal)
AS 1657	Fixed platforms, walkways, stairways and ladders - Design, construction and installation
AS/NZS 1664	Aluminium structures
AS/NZS 1665	Welding of aluminium structures
AS 2832	Guide to the Cathodic Protection of Metals
AS 2638	Sluice valves for waterworks purposes
AS2848	Aluminium and aluminium alloys—Composition and designations
AS 3566	Screws - self drilling - for the building and construction industries
AS/NZS 3679	Hot rolled structural steel bars and sections
AS 4087	Metallic flanges for waterworks purposes
AS 4100	Steel structures
AS/NZS 4600	Cold-formed steel structures
AS/NZS 4680	Hot-dip galvanised (zinc) coatings on fabricated ferrous articles
AS/NZS 4791	Hot-dip galvanised (zinc) coatings on ferrous open sections, applied by an in-line process
AS/NZS 2312	Guide to the protection of iron and steel against exterior atmospheric Corrosion

Drainage

AS/NZS 3500:3	Plumbing and Drainage – Stormwater Drainage.

Water Corporation Design Standards

DS91	Cathodic Protection Standard
DS95	Standard for the Selection, Preparation, Application, Inspection and Testing of Protective Coatings on Water Corporation Assets.
DS100	Suspended Flooring

Water Corporation Surface Preparation Specification (Part of DS95)

A1- Surface Preparation for the Application of Protective Coating on Steel or Cast Iron

A3 - Surface Preparation for the Application of Protective Coating on Galvanised Steel

A5 - Surface Preparation for the Application of Protective Coating on Concrete

A7 - Surface Preparation for the Application of Protective Coating on Fusion Bonded Polyethylene (Sintakote®)

Water Corporation Coating Specification (Part of DS95)

C2 - Zinc Rich Epoxy Primer, Epoxy Mastic Coat, Polyurethane Top Coat on Steel or Cast Iron

D1 - High Build Epoxy Coating on Steel or Cast Iron

H1 - Repair of Galvanised Coating

H2 - Galvanised Coating of Steel Structures

J1 - Anti-Graffiti Coating on New and Old Steel Structures

J2 - Anti-Graffiti Coating on New and Old Concrete Structures

M5 - Coating Procedure for Steel Pipe at the Concrete Interface

M6 - Coating Procedure for Sintakote Pipe at the Concrete Interface

M7 - Coating Procedure on galvanised steel for the decorative purposes

FRP/GRP Material Specification

FRP/GRP - FRP or GRP Structural Material

Water Corporation Welding Specification

WS1 Welding Specification Metal Arc Welding

Miscellaneous

WorkSafe WA Code of Practice - Prevention of Falls at Workplaces

AS 1891.4 Industrial fall arrest systems and devices. Part 4 Selection, use and maintenance

AS 1768 Lightning Protection

S151 Water Corporation's Prevention of Falls Standard

16 Appendix 2 – Assessment of Underdrainage Requirements for Tanks

16.1 Background to Risk Posed by Large Tanks

Large tanks, typically 10ML and greater, are key components of the Water Corporation's water supply systems. Typically they have high stored energy (normally located on the top of a hill) and are often close to housing or other developed property or land.

Large tanks could pose a significant risk to people and property if a sudden, uncontrolled release of the stored water through tank failure occurred, caused by a sudden foundation movement/failure.

16.2 Defining the Risk Event and the Possible Consequences

The *risk event* is undetected, uncontrolled tank leakage into the tank foundation.

If the foundation is *susceptible* to leakage water, *possible foundation saturation, weakening, damage or dissolution* may result. The foundation damage may be dissolution of the foundation rock (generally limestone in WA coastal areas) or a softening, weakening or swelling of weathered rock/clay foundation (mainly in inland WA).

The *potential consequences*, in order of decreasing likelihood and increasing severity, could be:

1. Significant deformation of and damage to the tank structure (no uncontrolled release of stored water). This would necessitate the taking of the tank offline for weeks or months to enable foundation and structural repairs. The resulting operational incident would disrupt supply and generate adverse media, public and political reactions.
2. Significant deformation of and damage to the tank structure, resulting in the uncontrolled release of the stored water. This would necessitate the taking of the tank offline for weeks or months to enable foundation and structural repairs. The resulting operational incident would severely disrupt supply and generate adverse media, public and political reactions.
3. Failure of the tank structure due to major foundation collapse and/or slope instability, resulting in the uncontrolled release of the stored water and possibly fluidised foundation materials. Operational consequences as for Event 2.
4. The uncontrolled release of water and possibly fluidised foundation materials from Event 2 or 3 damaging property such as housing, roads and railways.
5. The uncontrolled release of water and possibly fluidised foundation materials from Event 2 or 3 resulting in injuries and deaths.

It is clear that, for *susceptible tank foundations*, the *potential consequences* range from *Moderate* to *Catastrophic*, and the *resulting risks* are in the range of *Moderate* to *Extreme* (*Corporate Risk Assessment Criteria: refer S389)*).

The risks posed by large tanks on foundations susceptible to leakage water damage are therefore comparable with the risks posed by other large Water Corporation storage structures, namely service reservoirs and dams.

16.3 Large Tank Leakage Sources

All tanks leak, to various degrees. Concrete tanks typically leak through joints, unhealed large cracks, and voids in poorly sealed tie rod holes or in the concrete mass due to poor compaction. Welded steel tanks can leak through poor welds, and with time through the corroded, unprotected underside of the floor plates.

Any leakage through tank walls or the wall/floor joint is easily observed from outside the tank, and can be repaired. However, leakage through the floor is generally unquantified (unless it is massive), and therefore presents a "known unknown" type risk of foundation damage.

16.4 Examples of Foundation Damage by Leakage Water and the Costly Consequences

The Water Corporation has had notable examples of significant foundation damage by leakage water, both in sand and clay soils.

Leakage from Tamworth Hill Reservoir, in Baldivis on the Swan Coastal Plain, was creating "solution pipes" in the foundations to the point where the ability of the reservoir to hold water without uncontrolled release was in doubt. The Water Corporation subsequently spent over $5M in 2002 on remedial works at the reservoir.

Leakage from the Mt Clarence Reservoir in Albany had softened the floor material to a slush, producing a whole history of problems and leading to a recommendation for its decommissioning, foundation improvement and replacement by a tank. The new 25 ML Mt Clarence Tank was constructed in 2006/07 at a cost of over $9M.

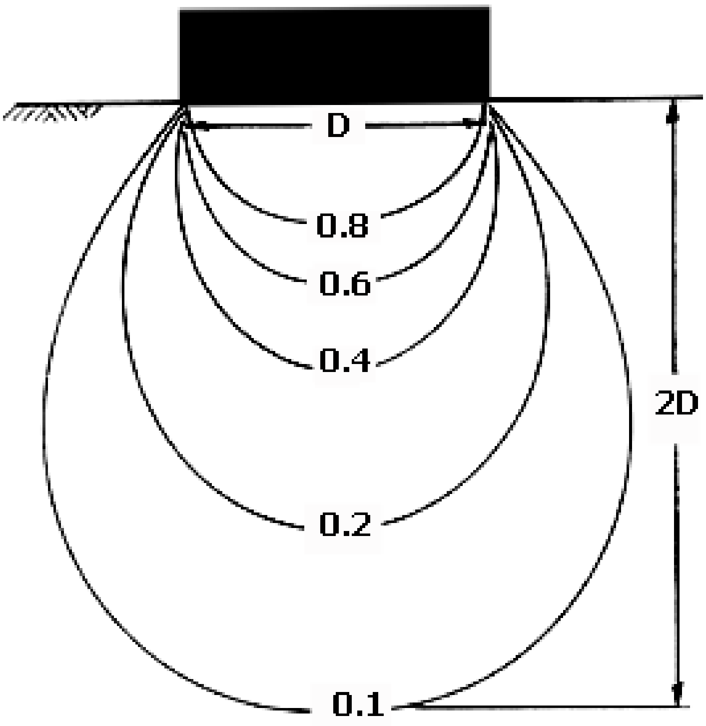
The risk event is largely governed by the tank foundation conditions, including groundwater seepage/flow as well as tank leakage. Hence a thorough evaluation of tank foundation conditions by an experienced geotechnical engineer is critical in determining the susceptibility of foundation damage by water.

16.5 Geotechnical Assessment of the Overall Tank Site and Foundation Zone of Influence for Susceptibility

For a large tank a detailed site investigation by an experienced geotechnical engineer is required in order to assess the susceptibility of foundation damage by tank leakage and groundwater seepage.

The investigation shall be of *sufficient extent in plan and depth*, covering the tank zone of influence to a *depth where the additional load resulting from the tank is negligible relative to the existing in-situ stresses*, and use appropriate investigation techniques in order to sufficiently characterize the site's geotechnical issues.

Tank zone of influence (diagrammatic):



The geotechnical issues investigated shall cover but not be limited to:

- Local geology;
- Understanding of the site hydrogeology and groundwater flow regime;
- Groundwater pressures that pose a risk of damaging the liner;
- Range of possible foundation saturation;
- Long term erosion/foundation damage or alteration by leakage;
- Underdrainage performance;
- Soil erodibility and dispersivity;
- Foundation piping risk due to leakage or groundwater flow;
- Evidence of past slope instability;
- Global and local stability of the tank foundation under the full matrix of operating and loading conditions;
- Pinnacles;
- Cavities and/or sink holes;
- Weak shear planes in soil and rock;
- Aggressiveness of the soil;
- Vertical settlements (primary and secondary consolidation, creep, crushing of calcareous particles, etc.);
- Swelling pressures;
- Horizontal movements;

- Soil/structure interaction;
- Surface erosion;
- Recommended foundation preparation;
- Surface drainage requirements, including surface water courses, tank overflows and scouring, and rainfall storm runoff; and
- Sub-surface drainage requirements, including groundwater and tank leakage collection.

The geotechnical investigation and tank foundation design, including site drainage, any upstream cut-off drainage and any underdrainage systems, shall be subject to Third Party Review.

16.6 Assessment of Potential Foundation Damage by Leakage Water

Foundations can be grouped very broadly into the following four types in terms of potential increasing foundation damage due to tank leakage and/or groundwater seepage:

16.6.1 Monolithic Rock Outcrop

Geotechnical characteristics (not exhaustive):

- Fresh to slightly weathered;
- No dykes or intrusions of other rocks;
- No chemically altered zones;
- No corestones;
- Joints within tank foundation zone of influence investigated by PQ coring;
- Joints not adverse or slickensided; and
- Joints not susceptible to tank leakage and/or groundwater seepage.

Typical of many WA hill top locations.

This is the safest foundation.

2007 West Northam 30 ML Tank foundation is a recent example.

Warning: Ensure that the geotechnical investigation is of sufficient scope (depth, extent, thoroughness) in order to identify any joints and/or weathered zones within the tank's foundation zone of influence that could be affected by tank leakage and/or groundwater seepage. A 2007 example is the Cunderdin tank site for two 60 ML tanks, where a weak layer was found underneath a significant thickness of slightly weathered rock, impacting foundation performance.

16.6.2 Sand

Geotechnical characteristics (not exhaustive):

- Low carbonate content;
- Not soluble;
- Not collapsible; and
- Limestone not present in tank foundation zone of influence, leakage path or groundwater seepage path.

Typical of many WA coastal town dune locations.

This is also a very benign foundation.

2006 Dalyellup 6 ML Tank is a recent example.

16.6.3 Sand and Limestone (or other calcareous rock)

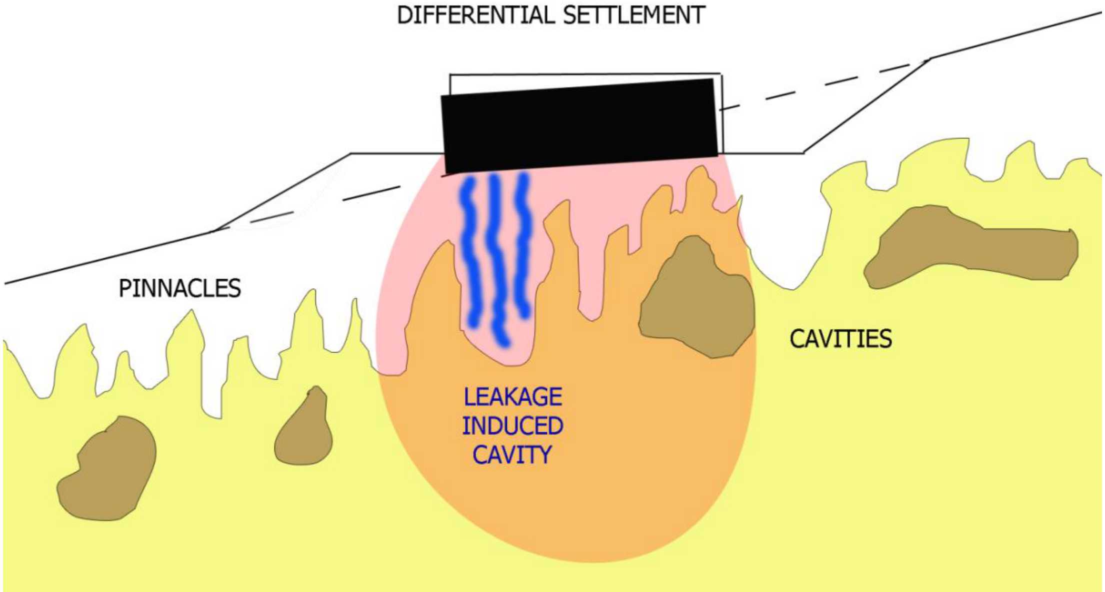
Geotechnical characteristics (not exhaustive):

- Low to high carbonate content;
- Soluble sand and rock;
- Potentially collapsible sand and rock;
- Sand subject to long term creep;
- Possible sink holes and cavities in rock;
- Extremely irregular, often pinnacled rock surface;
- Sharp boundary between soil and rock;
- Strong rock around solution tubes and cavities in weak, porous rock;
- Very weak, low density, erodible weathered materials;
- Extremely high permeabilities;
- Extreme variations in permeability;
- Possible deep, major leakage paths.

Also typical of many WA coastal locations.

This is a potentially problematic foundation.

Examples of recent geotechnical investigations in this setting include Thomsons No 2 Reservoir, Carabooda tank site and Tamworth Hill Reservoir.



Diagrammatic illustration of potential sand and limestone foundation problems.

2002 Tamworth Hill Reservoir Solution Pipes in Weak Honeycomb Limestone Foundation

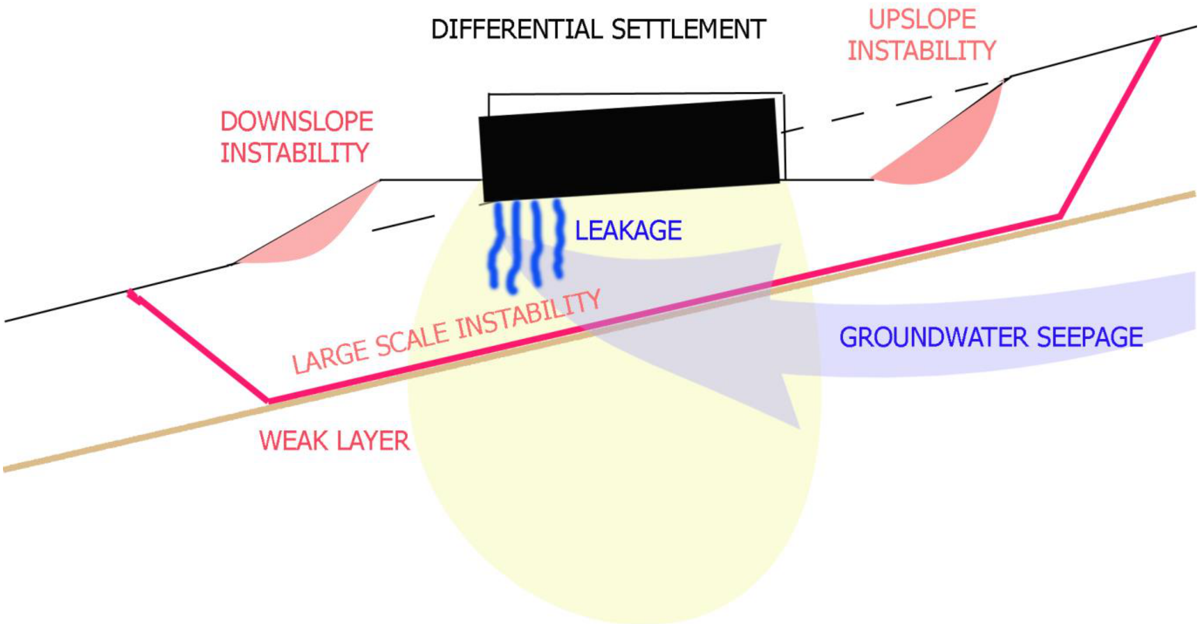
16.6.4 Weathered Rock or Clay

Geotechnical characteristics (not exhaustive):

- Variably weathered, with some moderately to completely weathered zones;
- Dykes and/or intrusions, with high weathering;
- Chemically altered zones;
- Corestones;
- Joints within tank foundation zone of influence possibly adverse or slickensided;
- Joints susceptible to tank leakage and/or groundwater seepage;
- Clay is erodible;
- Clay is dispersive; and
- Clay is subject to shrink and swell.

This is a potentially problematic foundation.

Examples of recent geotechnical investigations in this setting are the tank sites at Mt Clarence, Harvey, Cunderdin, Bullabulling and Merredin.



Diagrammatic illustration of potential weathered rock or clay foundation problems.

2006 Clarence Foundation – highly variable and problematic

16.7 Recommended Risk Assessment Process for Assessing the Need for Tank Underdrainage

The recommended risk assessment process for assessing the need for tank underdrainage is as follows:

1. *Initial Desktop Geotechnical Evaluation of the Tank Site*
2. An experienced geologist/engineering geologist and a geotechnical engineer carries out a desktop geological and geotechnical evaluation of the tank site. Detail the geological setting and the anticipated range of foundation problems. Seek comment from the Water Corporation Principal Geotechnical Engineer.
3. *Carry Out Initial Geotechnical Investigation and Evaluate Foundation Suspectibility to Leakage and Groundwater Seepage*. Characterise the confidence level for this evaluation based on the scope of the initial geotechnical evaluation. Seek comment from and review by the Water Corporation Principal Geotechnical Engineer.
4. *Scope and cost the additional geotechnical investigation* that would be required to prove the foundation susceptibility or otherwise *beyond reasonable doubt*.
5. *Concept design and cost an underdrainage system for the tank site*, holistically and coherently with the concept designs for surface water and groundwater drainage systems.
6. Conduct a *risk assessment workshop* involving, among other stakeholders, the Water Corporation Principal Geotechnical Engineer and Principal Civil Engineer Water Drainage Civil and Standards Section, in order to determine whether underdrainage is required. Document the decision.
7. Obtain *Third Party Review* of the tank site geotechnical investigation and foundation design (even if the final decision is not to include underdrainage).

In general, it is expected that Sand and Limestone (Foundation Group 3) and Weathered Rock or Clay (Foundation Group 4) would be susceptible to leakage damage and therefore require underdrainage unless sufficient geotechnical investigation has been carried out to prove that the foundation is not susceptible to leakage and/or groundwater seepage damage beyond reasonable doubt.

16.8 Preferred Underdrainage System

A fail-safe underdrainage system under the tank floor is recommended as the most cost-effective and simple risk mitigation measure.

The most cost-effective underdrainage system has been developed through a comprehensive study of underdrainage options during the preliminary design of Thomsons No 2 Reservoir (*GHD 2007*). The fail-safe underdrainage system consist of a HDPE “tray” with a protective geotextile layer containing parallel, straight Draincoil pipes in a gravel bed or gravel pack surrounds, draining by gravity to outside the tank foundation. This system:

1. *Keeps the foundation dry from leakage*. It protects the foundation from possible saturation, alteration and damage by leakage by cutting off, collecting and safely discharging leakage water.
2. *Provides a direct asset management measure of tank leakage performance* by enabling the direct measurement of the leakage rate through the underdrainage system.
3. *Helps in finding and repairing leaks*. Aids in narrowing down the source of leakage to the tank floor area contributing to a single pipe.
4. *Is simple, easy to construct, access and maintain*. The straight pipes can be inspected by cameras and cleaned by rodding, flushing or chemical sparging.

Underdrainage Has recently installed and successfully proven in the two 200 ML Kalgoorlie Reservoir ponds as well as in the 200 ML Tamworth Hill Reservoir remedial works.

17 Appendix 3 – Design, Installation and Testing of Portable Davit System

17.1 Scope

This Appendix sets out the criteria for the design, installation and testing of davit bases for use with standard portable davits on Water Corporation assets.

Standard portable davits are davits that meet the dimensional and load rating specified by the Water Corporation and detailed in this Appendix.

17.2 Davit and Davit Base

Portable davits and bases that had been confirmed to comply with design load requirements stated in section 17.4 will be supplied by the Water Corporation. When davit bases supplied by the Water Corporation are not available they can be procured from Water Corporation approved suppliers. The main dimensions of the bases and supplier information are included in Reference Drawing IP76-14-1.

The minimum and maximum radius limits of standard portable davits are 762 mm and 1219 mm respectively. Dimensions of the portable davit can be confirmed with the supplier or the Water Corporation Design Representative before a design is undertaken.

The davit and winch arrangement are specifically rated for fall arrest and for both lowering and lifting a person through an access opening and for rescue operations.

17.3 Types of Davit Bases

Davit bases as shown in Reference Drawing IP76-14-1, three types of davit bases namely top mounted, side mounted and flush mounted are available for use.

Flush mounted davit bases should be used in preference to top mounted or side mounted, where feasible.

Whilst flush mounted bases are not subject to load test, the side mounted and top mounted bases that are mechanically or chemically anchored to supporting structure shall be subject to load test as described in section 17.7.

Loads for proof tests of chemically or mechanically anchored bolts shall be shown on the design drawings by the Designer.

17.4 Design and Test Load

The davit system shall be designed to be capable of sustaining a fall arrest ultimate load of 15 kN at the point of suspension of the person. In addition, the davit system shall be designed to be capable of sustaining the moment imposed at the davit base as a result of this load acting at 1219 mm, the maximum radial extension of the davit arm.

Davit bases, the supporting structure and the support connections shall be designed to withstand the load described above, with an appropriate factor of safety.

17.5 Location of Davit Bases

A davit base shall be located in accordance with the criteria stated below and considering any obstruction, access, strength of support system to carry out load tests on chemically/mechanically anchored fixing bolts. The winch shall be installed at a height above any opening (including open covers), such that none of the asset components, nor the guardrail, inhibit or interfere with the movement of an attached person.

The minimum and maximum radius limits of davits are 762 mm and 1219 mm respectively. Davits are to be located so that the following criteria are met:

- Guardrails do not interfere and impede the manual operation of the davit. A nominal distance of 500 mm is specified between the davit centre and adjacent guardrails, so as not to impede davit operations. In some cases more than this minimum is required depending on guardrail arrangement.
- Davit arm swing allows a person to be tethered 300 mm from a vertical ladder to provide fall arrest while climbing down parts of an asset and moved to a safe location.
- A minimum of 500 mm clearance between any part of an asset (e.g. from the edge of opening) and tethered object shall be allowed at maximum davit reach.

Adequate standing space shall be provided for a person to operate the winch of davit under all situations.

17.6 Support of Davit Bases

The minimum thickness of reinforced slab/member that supports a davit base and the distance from the edge to the location of davit base shall be as in the following table.

Type of Base	Minimum Thickness (mm)	Minimum edge Distance (mm)
Flush Mounted	350	300 (to centre of base)
Top Mounted	250	180(to centre of any bolt)
Side Mounted	350	180 (to centre of any bolt)
Top mounted on spreader	125	100 (to centre of any bolt)

The minimum thickness and edge distance in the above table shall apply to post tensioned slab/member.

The design of slab/member with hollow section shall be given due consideration to stresses developed in the slab to meet the design requirements.

Use of chemically or mechanically anchored bolts to fix top or side mounted davit bases on concrete slab/member shall be avoided wherever feasible. Unless justified otherwise the bolts should be placed in position using templates before casting of concrete slab/member.

17.7 Load Test

The Water Corporation requires pull out tests on the bolts of top mounted and side mounted davit bases to proof test the bases.

As part of the installation and prior to use, all fixing bolts of davit mounts shall be tested to the loads shown on the Design Drawings. Davit testing shall be done by a competent person and shall be in accordance with the:

1. Engineering Assets Maintenance Standard - Prevention of Falls Equipment – Testing, Inspection and Maintenance (Nexus #58574060), and
2. Maintenance and Test Procedure for Water Corporation Stainless Steel Davit Bases (Nexus #58612210).

Test certificates for each test shall be provided to the Water Corporation.

17.8 Signage

Certification Signage shall be provided at davit mount locations as detailed in Engineering Assets Maintenance Standard - Prevention of Falls Equipment – Testing, Inspection and Maintenance (Nexus #58574060).

17.9 Inspection and Maintenance

Inspection and maintenance of davit bases shall be carried out in accordance with the requirements in Engineering Assets Maintenance Standard - Prevention of Falls Equipment – Testing, Inspection and Maintenance (Nexus #58574060).

18 Appendix 4 - Wall Form Ties

This Appendix provide Indicative Arrangements of Proprietary Wall Tie Systems currently available in the market

18.1 General Notes

1) All system configurations are indicative only and should not limit the use of a more effective wall form tie system.
2) As indicated in the design requirement, all sealing and plugging products must satisfy the water retaining intent of the structure and must be potable water compliant and comply with AS 4020.
3) All systems are proprietary and components were designed to match within each system; therefore under any circumstances shall not be mixed with other manufacturers' components.
4) Manufacturer's installation methodology and instruction for each system shall be strictly followed to achieve successful results.

18.2 Max Frank Wall Tie System

Descriptions	Figure	Suitability / Wall Thickness
Tie System Components: a) Tie Bar (Sacrificial) b) Cast Iron Water Stop to match tie bar diameter c) Steel/Plastic tie cone to match tie bar diameter (this component is reusable - will be removed during formwork de-installation) d) Non-shrink cementitious grout to fill the hole around the exposed tie bar (as indicated) after removal of tie cone e) Fibre concrete sealing cone to match steel/plastic cone diameter with appropriate adhesive.	FIGURE A.1	≥ 350 mm

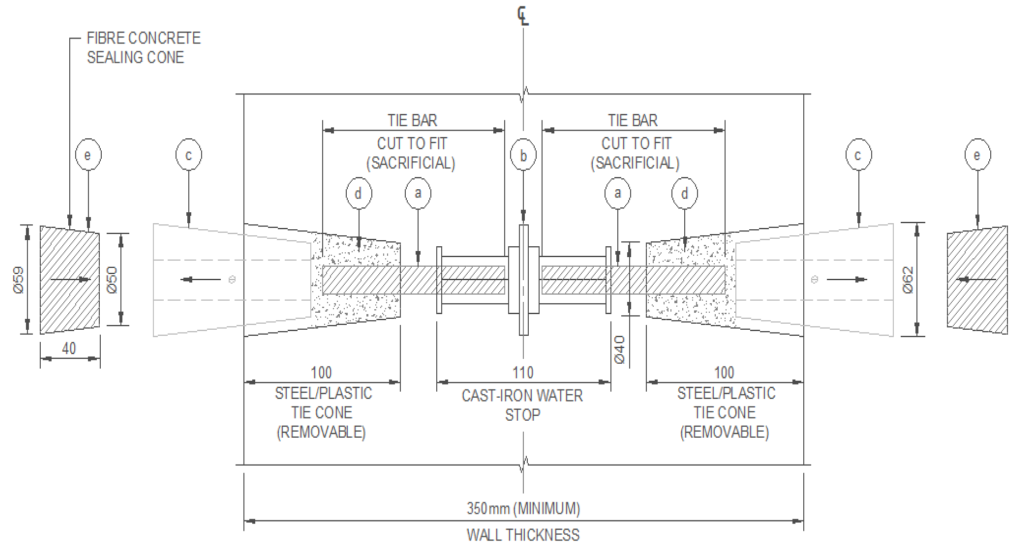


FIGURE A.1

(LOST TIE SYSTEM)

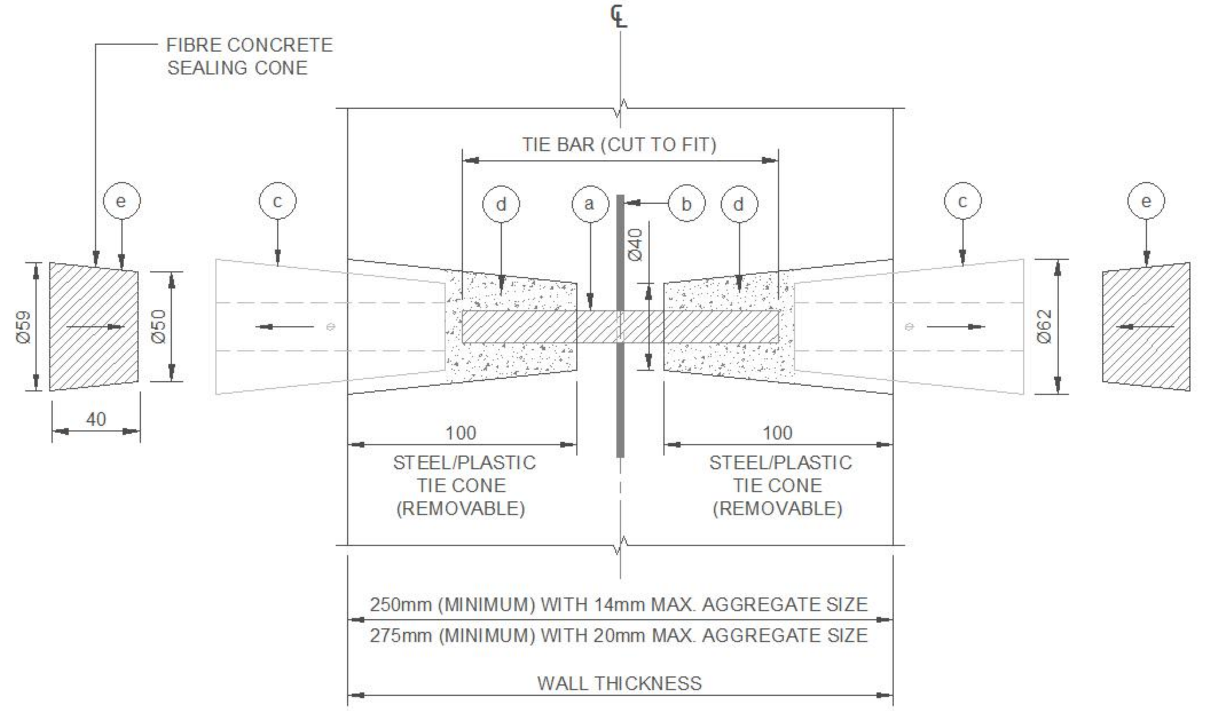
NOTES:

All dimensions are indicative only and will very depending on tie bar diameter.

Dimensions, sizes and specifications are to be confirmed with the manufacturer

II Max Frank Wall Tie System (continued):

Descriptions	Figures	Suitability / Wall Thickness
Tie System Components: Tie Bar (Sacrificial) Steel plate water stop – 120 mm x 120 mm x 2 mm thick welded to tie bar Steel/Plastic tie cone to match tie bar diameter (this component is reusable - will be removed during formwork de-installation) Non-shrink cementitious grout to fill the hole around the exposed tie bar (as indicated) after removal of tie cone Fibre concrete sealing cone to match steel/plastic cone diameter with appropriate adhesive	FIGURE A.2	≥ 250 mm



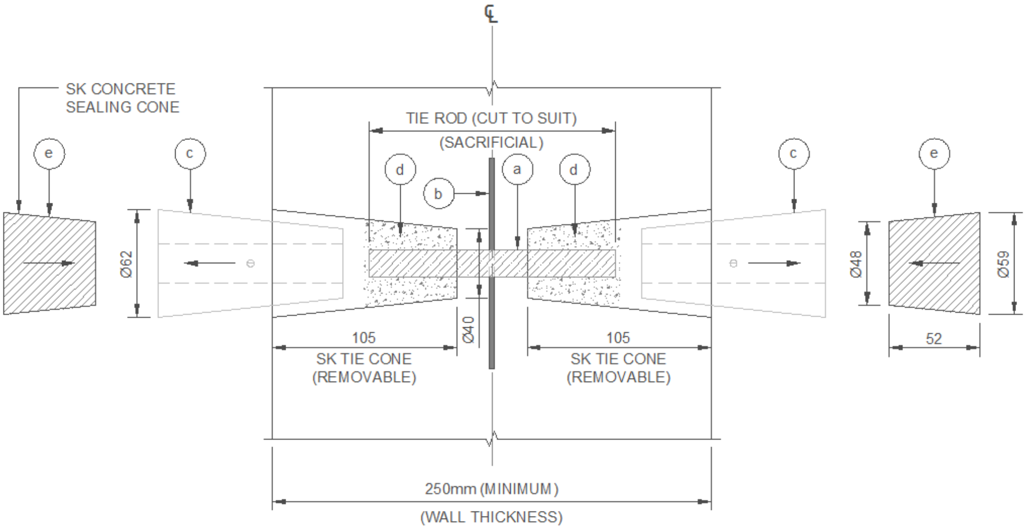
NOTES:

All dimensions are indicative only and will very depending on tie bar diameter.

Dimensions, sizes and specifications are to be confirmed with the manufacturer

Peri Wall Tie Systems

Descriptions	Figures	Suitability / Wall Thickness
SK System Components: a) Tie Rod b) Steel plate water stop 120 mm x 120 mm x 2 mm thick welded to tie rod c) SK Tie Cone to match tie rod diameter (this component is reusable - will be removed during formwork de-installation) d) Non-shrink cementitious grout to fill the hole around the exposed tie bar (as indicated) after removal of tie cone e) SK concrete sealing cone to match SK tie cone with appropriate adhesive	FIGURE B.1	≥ 250 mm



(LOST TIE SYSTEM)

NOTES:

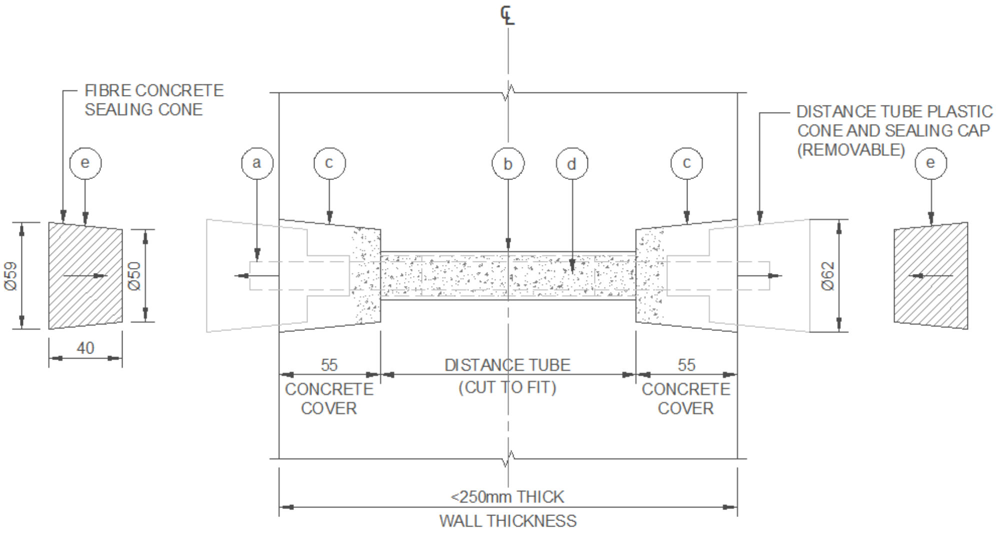
All dimensions are indicative only and will very depending on tie bar diameter.

Dimensions, sizes and specifications are to be confirmed with the manufacturer.

Conventional Tie System for Wall Thickness <250 mm

Descriptions	Figures	Suitability/ Wall Thickness

System Components: a) Tie Rod – reusable – will be removed during formwork de-installation b) Fibre concrete distance tube to match tie rod diameter – this will be cast-in and will form part of the wall structure c) Removable distance tube plastic cone and sealing cap (this component is reusable - will be removed during formwork de-installation) d) Non-shrink cementitious grout to fill the hole after removal of tie rod e) Fibre concrete sealing cone to match distance tube plastic cone diameter with appropriate adhesive	FIGURE C.1	≥ 250 mm



NOTES:

All dimensions are indicative only and will very depending on tie bar diameter.

Dimensions, sizes and specifications are to be confirmed with the manufacturer.

19 Appendix 5 – Mixing of Water in Tanks

19.1 Procedures for Determining Inlet/Outlet Arrangements in Tanks for Optimal Mixing

The steps below are to be followed in determining the mixing requirements for tanks

19.1.1 Step 1 – Obtain Planning/System Information

Obtain the following planning and system information from planning reports or planning advice from Asset Planning Group of the Water Corporation and the Preliminary Design for the tank (if available).

- Location
- Physical tank size, diameter, volume and depth at Top Water Level
- Operating volume and depth, e.g. over summer and winter seasons
- Reserve plus unusable storage
- Inlet pipe diameter, location and geometry
- Seasonal inflow and outflow flow rates (summer/winter), pump rates (L/s)
- Temperature ranges of the inflow and outflow water (if available)

19.1.2 Step 2 – Position Inlet and Outlet relative to each other

Finalise the locations of inlet and outlet considering site constraints. On plan the orientation of an inlet to outlet shall be between 60° and 90°.

An inlet nozzle is generally directed into tank at the following angles to the planes passing through it as shown on Attachment 1

- 60 degrees to radial vertical plane
- 45 degrees to horizontal plane

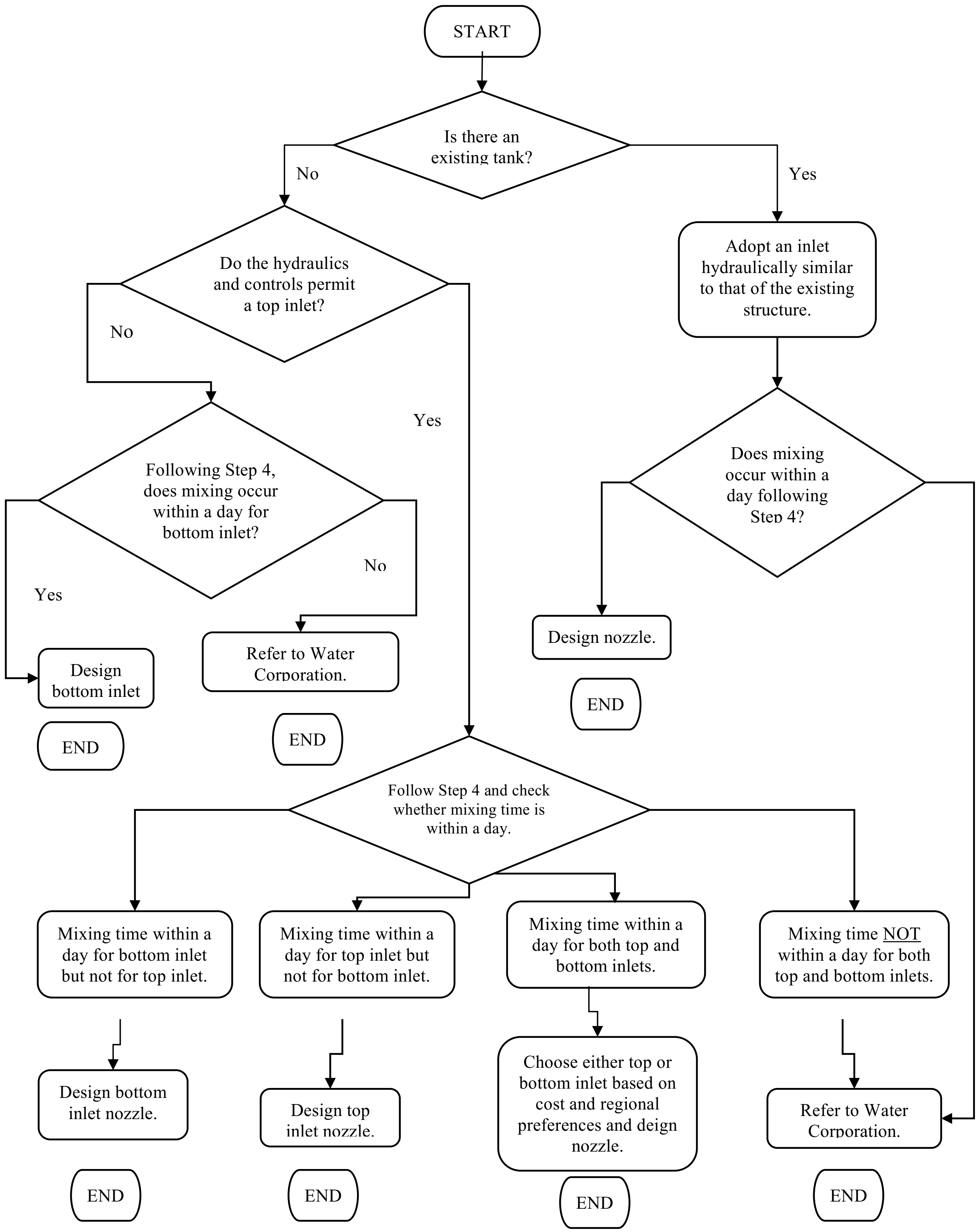
Outlets are generally floor mounted and vertical.

19.1.3 Step 3 – Determine whether a top or a bottom Inlet is required

Using the flow diagram below determine whether a top or bottom inlet is required

The most important criterion is to **match existing hydraulics and/or controls**. This may dictate the location of the inlet.

After hydraulics and controls are satisfied, either a top inlet or a bottom inlet may be used **provided that the tank will be mixed with the proposed inlet geometry in one day under all flow and seasonal conditions** (refer to Step 4).


START
Is there an existing tank?
No
Yes
Adopt an inlet hydraulically similar to that of the existing structure.
Do the hydraulics and controls permit a top inlet?
No
Yes
Following Step 4, does mixing occur within a day for bottom inlet?
Yes
No
Design bottom inlet
END
Refer to Water Corporation.
END
Does mixing occur within a day following Step 4?
Design nozzle.
END
Follow Step 4 and check whether mixing time is within a day.
Mixing time within a day for bottom inlet but not for top inlet.
Mixing time within a day for top inlet but not for bottom inlet.
Mixing time within a day for both top and bottom inlets.
Mixing time NOT within a day for both top and bottom inlets.
Design bottom inlet nozzle.
END
Design top inlet nozzle.
END
Choose either top or bottom inlet based on cost and regional preferences and deign nozzle.
END
Refer to Water Corporation.
END

19.1.4 Step 4 – Check that the Tank/Reservoir mixes in one day

Check whether mixing in tank is achieved within a day at the end of the filling cycle by using the spreadsheet Vertical Mixing Assessment Tool*, which is based on flow data, volumes and adequate mixing in 24hrs. Note that the inlet nozzle size and/or the winter and summer operating level may need to be varied to achieve mixing under all conditions. See Attachment 2 for instructions on how to use the spreadsheet.

The basis of the mixing analysis is to answer the following questions.

1. Can the inflow jet penetrate the full depth of the tank?
2. Can the jet entrain the volume of the tank in the filling time?
3. If the answer to either question is no, water in the tank will not be well mixed at the end of the filling cycle.
4. The limitations of the Vertical Mixing Assessment Tool* are that:
5. It does not indicate how long it takes to mix the tank; and
6. It does not consider horizontal circulation which is likely to be important in large tanks.

19.1.5 Step 5 – If the water in the Tank does not mix within a day

If the spreadsheet Vertical Mixing Assessment Tool* indicates that mixing cannot be achieved within a day then advice shall be sought from the Water Corporation on inlet arrangement to be adopted.

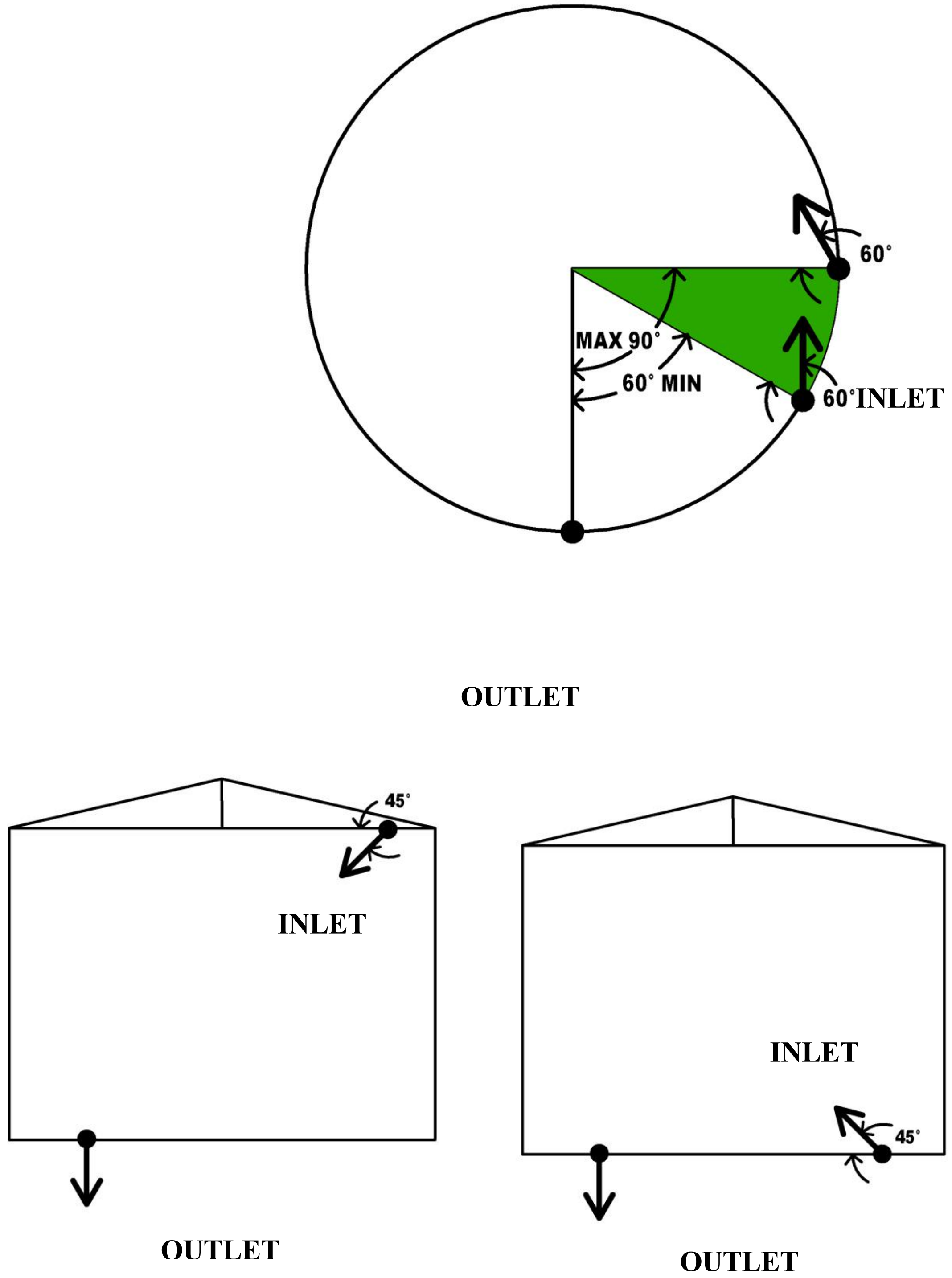
If mixing is critical and concerns remain, a specific mixing study by a specialist consultant will arranged by the Water Corporation. This arrangement may impact on design time and designer shall seek Water Corporation's advice during early stages of the design to avoid any delays. .

19.1.6 Step 6 – Design Inlet Nozzle

Having followed Steps 1 to 5 and decided on the type of inlet the inlet shall be designed.

* The Vertical Mixing Assessment Tool is issued as a separate document to accompany this standard.

ATTACHMENT 1
TANK INLET /OUTLET ARRANGEMENT



ATTACHMENT 2
INSTRUCTIONS ON USING THE "VERTICAL MIXING ASSESSMENT TOOL" SPREADSHEET

(For further details read the report here mixing in Tanks and Service Reservoirs, GHD, November 2005)

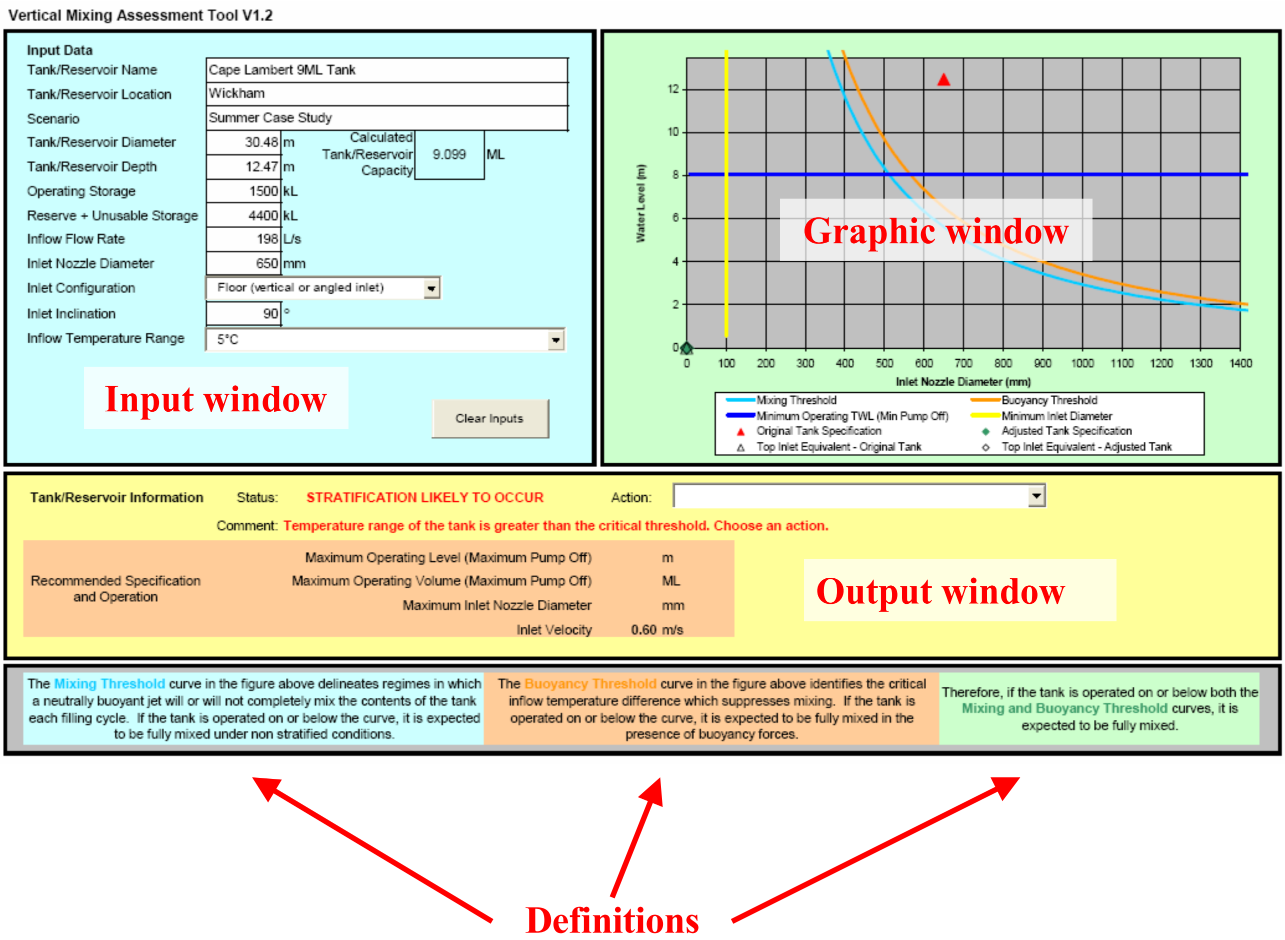
Basis of Mixing Analysis

Download a copy of the spreadsheet onto your working drive.

Overview

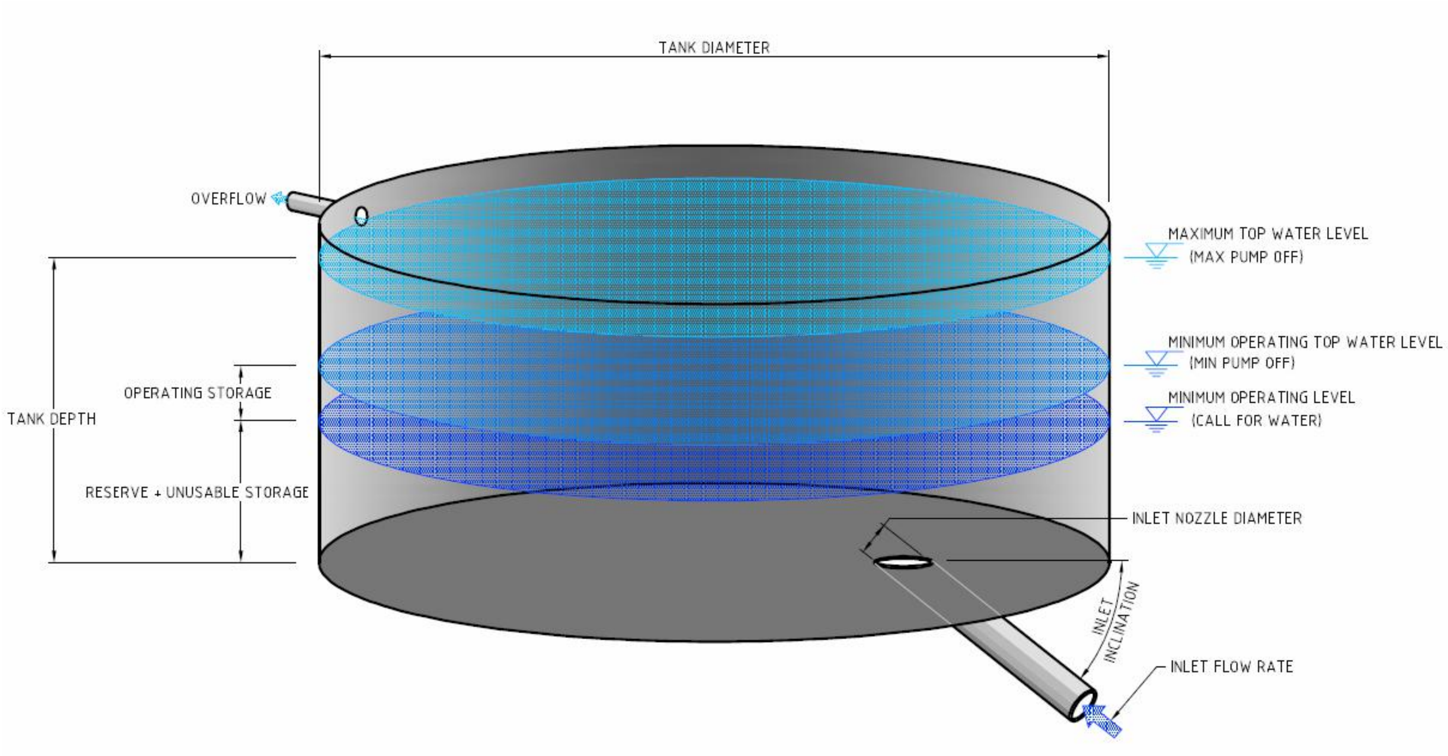
The whole window will look like this.

Input, graphics and outputs are all on this printable page.



Definitions

The tank data definitions are defined in the diagram below.



Input Data

Enter the input data in the blue input box:

Vertical Mixing Assessment Tool V1.2

Input Data

Tank/Reservoir Name	Cape Lambert 9ML Tank	
Tank/Reservoir Location	Wickham	
Scenario	Summer Case Study	
Tank/Reservoir Diameter	30.48	m
Tank/Reservoir Depth	12.47	m
Operating Storage	1500	kL
Reserve + Unusable Storage	4400	kL
Inflow Flow Rate	198	L/s
Inlet Nozzle Diameter	650	mm
Inlet Configuration	Floor (vertical or angled inlet)	
Inlet Inclination	90	°
Inflow Temperature Range	5°C	

Calculated Tank/Reservoir Capacity: 9.099 ML

Clear Inputs

Tank/Reservoir Name .... Enter name

Tank/Reservoir Location .... Enter location

Scenario .... Enter scenario (e.g. summer or winter)

Tank/Reservoir Diameter .... Enter tank diameter. For rectangular tanks an equivalent diameter will need to be calculated.

Tank/Reservoir Depth................ Enter water depth to overflow

Operating Storage .... Minimum volume of water added to the tank during each filling event (note that the filling event has to be shorter than 24hrs).*

Reserve+Unusable Storage........ Minimum volume of water that must always be in the tank (may be different in summer and winter). *

Inflow Rate .... Proposed or current inflow rate through the inlet into the tank. *

Inlet Nozzle Diameter................ Proposed or actual diameter of the inlet nozzle through which water enters the tank.

Inlet Configuration .... Proposed or actual configuration of the inlet on the tank or reservoir. The following three options are available in a drop-down menu to choose from:

- Bottom side entry (horizontal inlet)
- Floor (vertical or angled inlet)
- Top (over the top or angled inlet)

Inlet Inclination.......................... The inclination of the inlet jet in degrees measured from the horizontal plane.

Inflow Temperature Range .... The difference between the temperature of the inlet water and the ambient temperature in the tank or reservoir. The drop-down menu has values from 0-10 degrees in one degree increments. If no data or estimates are available, the drop-down menu has the following three broad categories for which default temperature range values are assumed:

- Tank > 200 km inland and aboveground pipe > 5 km
- Tank within 200 km of coast
- Supply pipe aboveground length < 5 km

* Information provided by the Asset Planning Group of the Water Corporation (APDG)

Graphics Output

The graphics output is in the green box:

The **Mixing Threshold** curve delineates regimes in which a neutrally buoyant inlet jet will or will not completely mix the contents of a tank or reservoir during the filling cycle. If the tank is operated on or below the curve, the tank is expected to be fully mixed under non-stratified conditions.

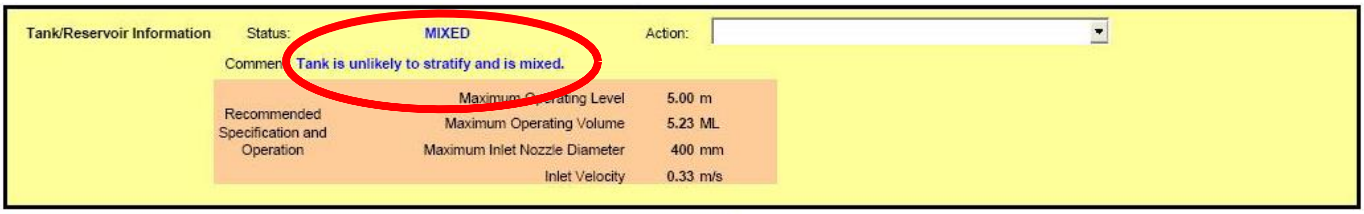
The **Buoyancy Threshold** curve identifies the critical inflow temperature difference which suppresses mixing. If the tank is operated on or below the curve, it is expected to be fully mixed in the presence of buoyancy forces.

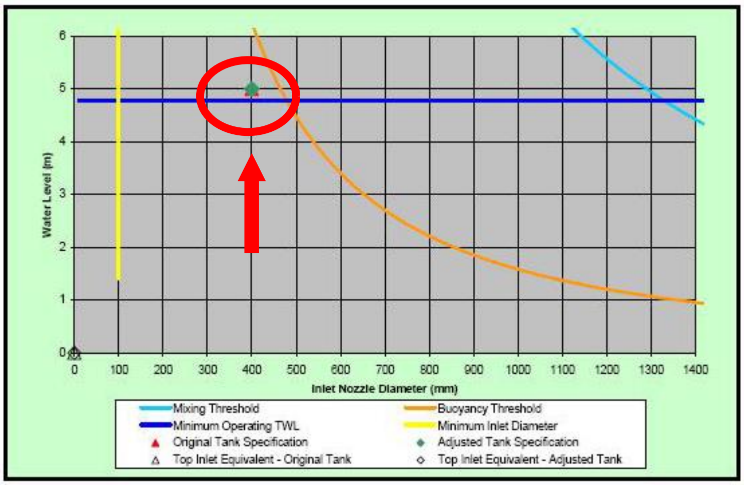
Therefore the tank is expected to be fully mixed is operated below both the Mixing and Buoyancy Threshold curves.

Analyse the Base Case

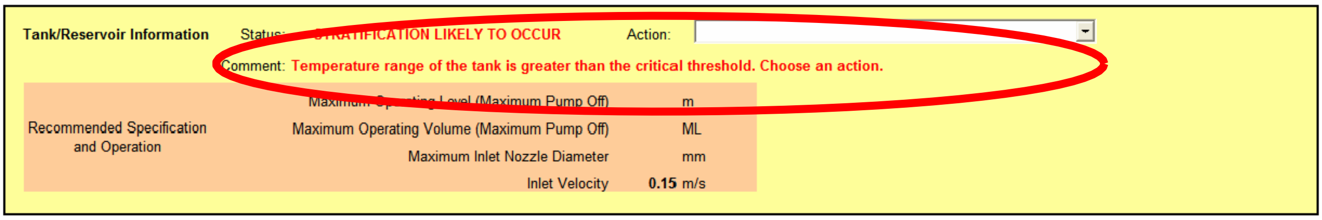
Analyse the base case to see if the tank will mix or not.

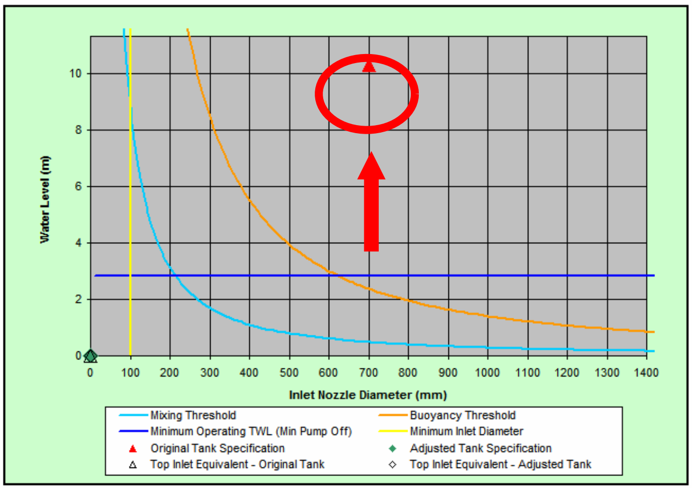
If the tank mixes, these are the expected outputs and no further action is required.





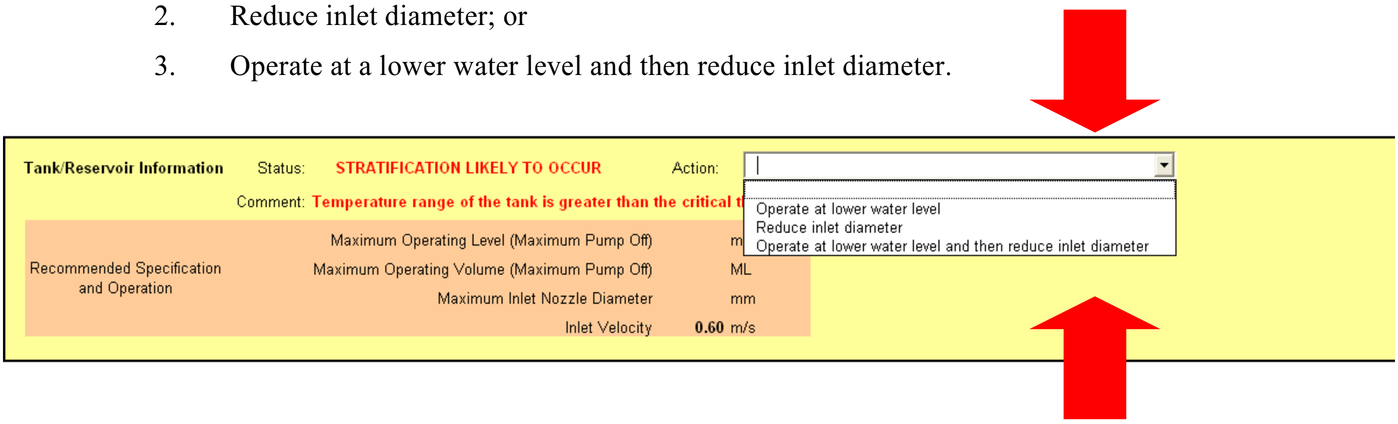
If the tank does not mix, a warning message will be given in the output and you will be prompted to choose an action:





To improve mixing, three actions are available from the drop-down menu:

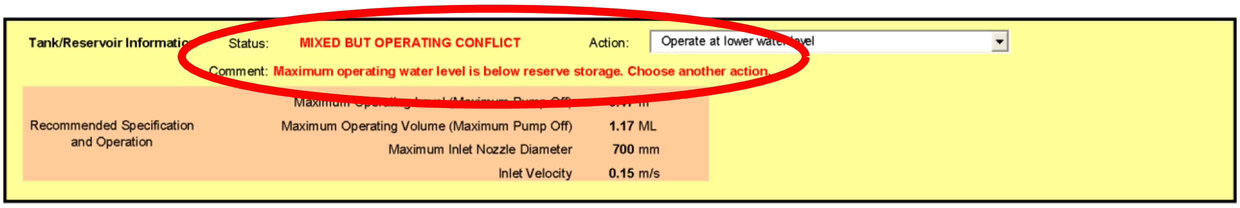
1. Operate at a lower water level; or
2. Reduce inlet diameter; or
3. Operate at a lower water level and then reduce inlet diameter.

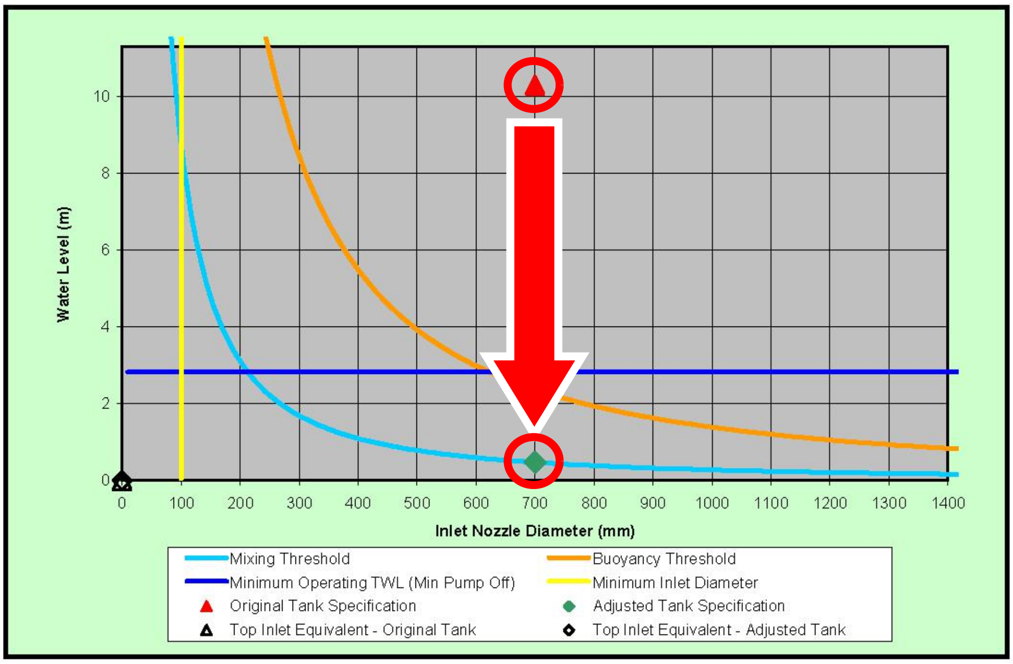


Trial different actions, depending on operational system constraints, until the tank is mixed.

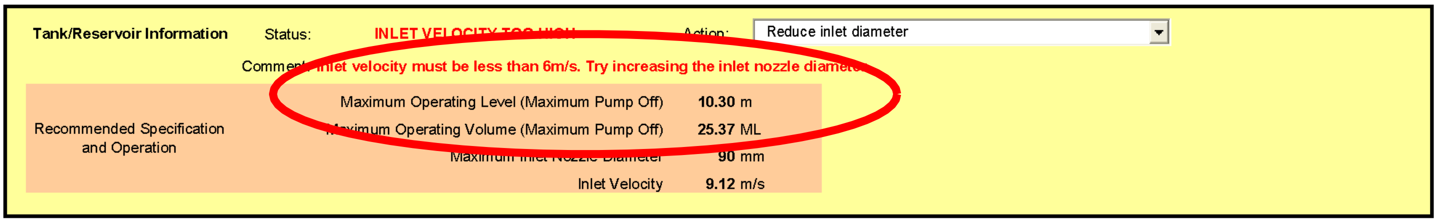
The physical limits are a minimum DN100 inlet nozzle diameter, nozzle velocity limit of 6 m/s, and a minimum storage level > reserve + unusable storage.

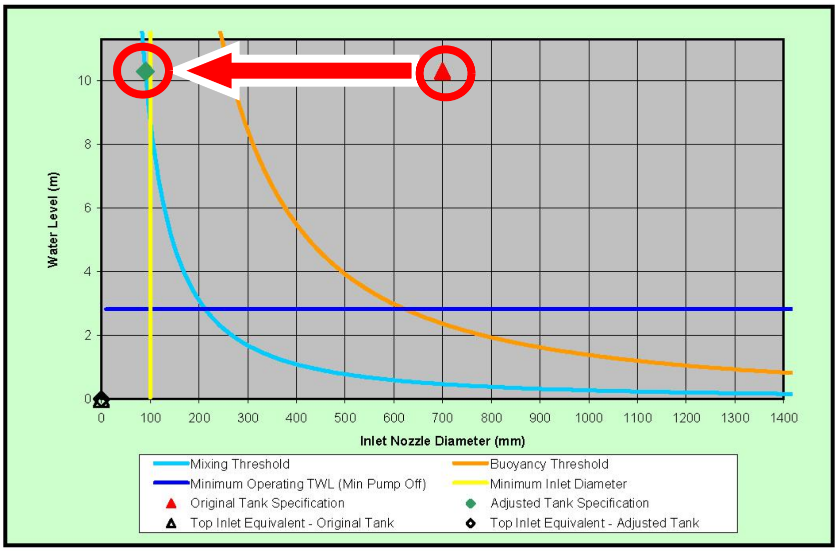
For a **lower operating level**, the following is a sample output:


Tank/Reservoir Informatio
Status:
MIXED BUT OPERATING CONFLICT
Action:
Operate at lower water level
Comment: Maximum operating water level is below reserve storage. Choose another action.
Recommended Specification and Operation
Maximum Operating Volume (Maximum Pump Off)
1.17 ML
Maximum Inlet Nozzle Diameter
700 mm
Inlet Velocity
0.15 m/s

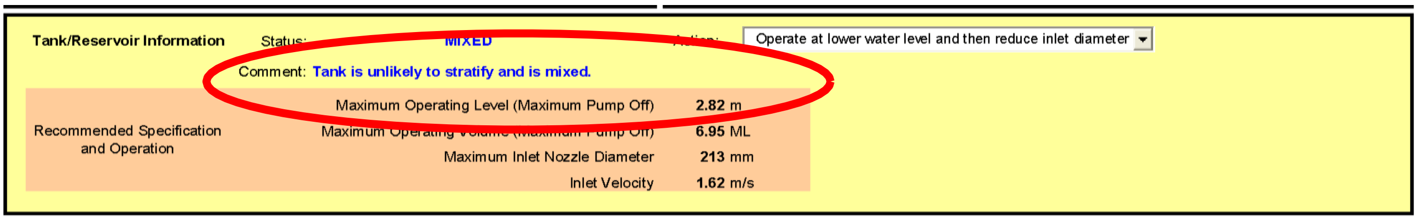

Water Level (m)
0
2
4
6
8
10
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
Inlet Nozzle Diameter (mm)
Mixing Threshold
Buoyancy Threshold
Minimum Operating TWL (Min Pump Off)
Minimum Inlet Diameter
Original Tank Specification
Adjusted Tank Specification
Top Inlet Equivalent - Original Tank
Top Inlet Equivalent - Adjusted Tank

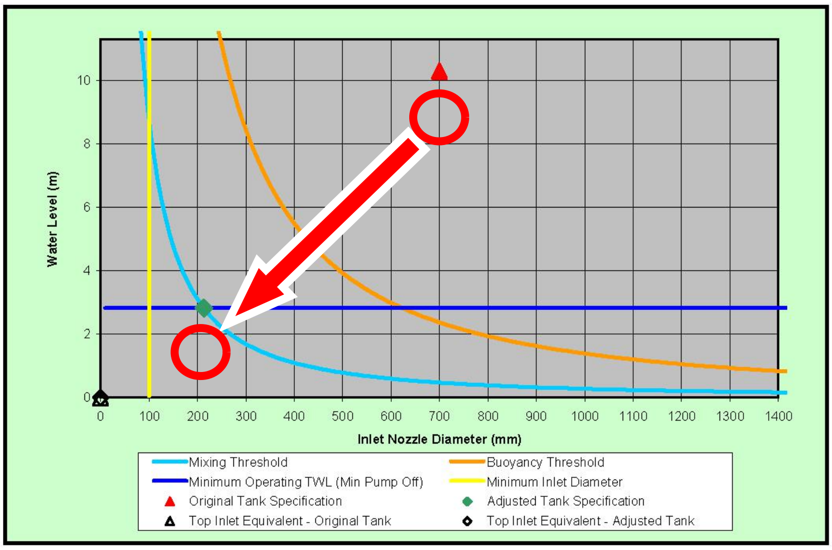
For a **reduced inlet diameter**, the following is a sample output:





For **operate at a lower water level and then reduce inlet diameter**, the following is a sample output:





PLEASE ALSO SEE VERTICAL MIXING ASSESSMENT TOOL EXCEL SPREADSHEET WHICH ACCOMPANIES THIS STANDARD

20 Appendix 6 – Examples of Undesirable Tank Conditions

1. Corrosion of Universal Beam at Chlorine Dosing Point

2. Corrosion of commercial grade bridging to purlin connection (coating less than Z450 and crevice corrosion)

3. Corrosion due to the use of "hook lok" and tek screws of lower grade than specified.

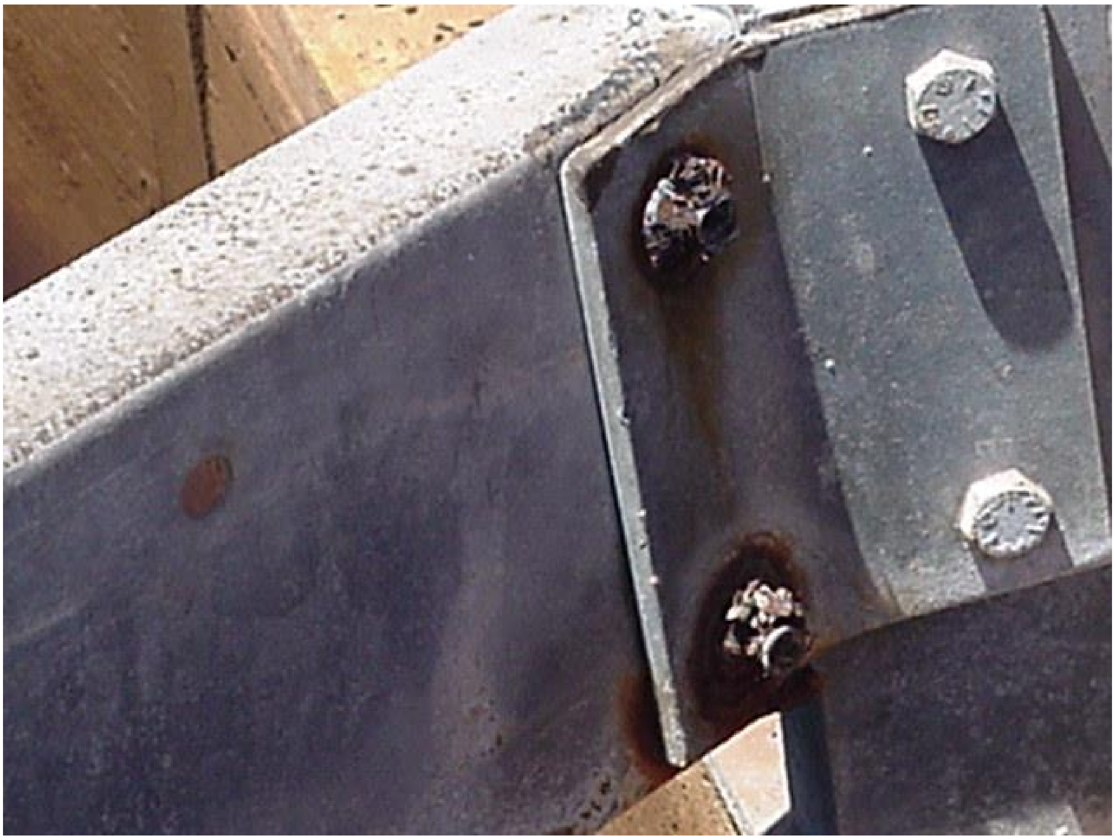
4. Corrosion of commercial grade purlin without a down turned lip. Hot dipped galvanized bridging and beams are in good condition.

5. Ineffective seal between hatch and platform & platform and sheeting, No chequer plate foot grip. Hot dipped galvanised lids too heavy.

6. Inlet too close to roof member

7. Roof sheet corrosion due to absence of bituminous paint between metal interfaces

8. Corrosion of “Kliplok” sheeting system. Clips corroded due to lower coating class and crevice corrosion.



9. Corrosion due to absence of bituminous paint between interfaces

10. Corrosion of low grade "tek screws" (Minimum Class 4 required)

END OF DOCUMENT