WATER CORPORATION ABN 28 003 434 917	*Inspection Guidelines for the Condition Assessment of Steel Tanks*
Doc ID #11822038	**Custodian** Principal Engineer, In Service Assets, Asset Planning Group
Version Date 18 January 2018	**Accountabilities Framework** 1 - Manage Infrastructure Assets 2 - Plan & Investigate Asset Renewals
Next Review Date 18 January 2021	

Steel Tanks Condition Assessment Guideline

(Business Rules)

18 January 2018
Revision - 2

Water Corporation

ABN 28 003 434 917

629 Newcastle Street, Leederville WA 6007

PO Box 100, Leederville WA 6902

Telephone: (08) 9420 2420

www.watercorporation.com.au

Document Status				
Rev	**Prepared by**	**Reviewed by**	**Approved by**	**Date**
1.0	Venkat Coimbatore	Des McEwan Sam Lee Mohan	Janet Ham	27 October 2014
1.1	Venkat Coimbatore	Jakob Verhoef	Tino Galati	15 May 2017
2.0	Venkat Coimbatore	Zororai Choto	Tino Galati	18 Jan 2018

FOREWORD

Inspection guidelines are prepared to ensure that the Corporation's staff, consultants and contractors are informed as to the Corporation's requirement on the methodical approach to asset condition assessment.

Inspection guidelines are intended to promote uniformity so as to simplify the condition assessment methodologies and reporting practice. Corporation's ultimate objective of this Guideline is to ensure the provision of safe and functional plant and equipment at minimum whole of life cost.

In 2014, Water Corporation, Western Australia developed the inspection guideline for steel structures (other than the pipelines) in water and wastewater infrastructures operating areas in Western Australia where the Water Corporation has been licensed to provide water services subject to the terms and conditions of its Operating License.

Using the steel structures methodology and its framework various levels of inspections were carried out in a methodical manner using cutting-edge technologies [Refer: AquaDoc. No. 11118245].

During this time, comments suggestions and criticisms were given to In-Service Assets by the Metro, Regional Operations and also by the internal and external Inspection Service Provider's (ISP's). They were captured in the internal document [Refer: AquaDoc. No. 11822908] reviewed and incorporated in this revision.

The Corporation's inspection methods and assessments described in this guideline have evolved over a number of years as a result of design and field experience. Research publications by engineering associations, construction agencies, consultants, inspection equipment manufacturers and suppliers are gratefully acknowledged and referenced in this document.

Deviation, on a particular method, from this inspection guideline may be permitted in special circumstances, but only after endorsement by the Materials and Corrosion Specialist in the Corporation's Asset Planning Group. Users are invited to forward recommendations for continuous improvement to the Supervising Engineer or Manager, Asset Planning Group, Water Corporation who will consider these for incorporation into future revisions.

This document contains colour pictorials. For optimum resolution colour printing is recommended.

Tino Galati
Section Manager
In-Service Assets - Metro

DISCLAIMER

This Guideline is intended solely for inspection of water and waste water infrastructure in operating areas in Western Australia where the Water Corporation has been licensed to provide water services subject to the terms and conditions of its Operating License.

This Guideline is provided for use only by a suitably qualified professional inspector, engineer or technician who shall apply the skill, knowledge and experience necessary to understand the risks involved and undertake all infrastructure condition assessment work.

Any interpretation of anything in this Guideline that deviates from the requirements specified in the project design drawings and construction specifications shall be resolved by reference to and determination by the design engineer.

The Corporation accepts no liability for any loss or damage that arises from anything in the Guideline, including loss or damage that may arise due to the errors and omissions of any person.

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.

TABLE OF CONTENTS

AMENDMENT REGISTER

Section	Version/Revision	Date	Description of Amendment	Authoriser
All	1.0/0	14.08.14	New Version/Revision	SM
All	1.0/0	05.09.14	Updated Stakeholder comment	SM
5.0	1.0/0	27.10.14	Updated Figure 8 with Optioneering	SM
4.1- 4.3	1.1/0	10.12.14	Corrosion calculation revised	SM
4.4	1.1/0	10.12.14	Added Remaining life measurement	SM
All	1.1/1	15.05.17	Rev 2.0 draft was compiled	TG
All	2.0	15.01.18	Incorporated and revised the lessons learnt	TG

GLOSSARY OF TERMS & ABBREVIATIONS

ACA	Asset Condition Assessment
ACS	Asset Class Strategy – Specific to an asset class
ADWG	Australian Drinking Water Guidelines
AINDT	Australian Institute of Non-Destructive Testing
APAS	Australian Paint Approval Scheme
APG	Asset Planning Group
ARA	Asset Risk Assessment
AS/NZS	Australian Standards
ASTM	American Society for Testing Materials
BS	British Specification
CA	Condition Assessment
CML	Condition Monitoring Locations
CRA	Corrosion Risk Assessment
IIMM	International Infrastructure Management Manual
IPWEA	Institute of Public Works Engineering Australia
ISO	International Standards Organisation
ISP	Inspection Service Provider
MFL	Magnetic Flux Leakage
NACE	National Association of Corrosion Engineers
NATA	National Association of Testing Authorities
NDI	Non-Destructive Inspection
OC	Operations Centre
OETL	Operational Engineering Team Leader(s)
OH & S	Occupational Health and Safety

RWT	Remaining Wall Thickness
SAP	Systems Analysis Program
SCUBA	Self-Contained Underwater Breathing Apparatus
SIBC	Strategic Investment Business Case
SOP	Standard Operating Procedure
SSBA	Surface Supply Breathing Apparatus
SSPC	Steel Structures Painting Council
TRU	Transformer Rectifier Unit
TWI	The Welding Institute
UT	Ultrasonic Thickness (Testing)
WBS	Work Breakdown Structure

REFERENCES

[1] Steel Structures Condition Assessment Methodology, Renewals Branch, Asset Management Branch [Aqua Doc No. 11118245].

[2] Design Life Pages for Water Corporation Design Standard DS 61, Water Supply Distribution – Tanks [Aqua Doc No. 7899391].

[3] Water Environment & Reuse Foundation (WERF), Remaining Asset Life: A state of the Art Review, 2009.

[4] AS/NZS 3978 Non-Destructive Testing - Visual Inspection of metal products and Components.

[5] Forms of Corrosion, Recognition and Prevention, C.P. Dillon, Editor, NACE Publications, Texas, USA.

[6] [Pressure Vessel Inspection Code: In-Service Inspection, Rating, Repair, and Alteration, API 510, Ninth Edition, June 2006.

[7] NACE RP0775, Preparation, Installation, Analysis, and Interpretation of Corrosion Coupons in Oilfield Operation.

[8] ASTM G46 – 94 (Re-approved 2005), Standard Guide for Examination and Evaluation of Pitting Corrosion.

[9] SSPC VIS 2, Standard Method for Evaluating Degree of Rusting on Painted Steel Surfaces.

[10] Design Standard DS 95 - Standard for the Selection, Preparation, Application, Inspection and Testing of Protective Coatings on Water Corporation Assets.

[11] AS/NZS 2312 Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings.

[12] AS/NZS 3894.9 Site testing of protective coatings - Determination of adhesion.

[13] Control of Pipeline Corrosion, A.W. Peabody, NACE Corrosion Association, Houston, Texas, USA.

[14] Water Corporation Design Standard No. DS 91, Standard for the Selection, Design and Monitoring of Cathodic Protection (CP) Systems.

[15] Condition Assessment & Asset Performance Guidelines, Practice No.7, IPWEA, Inst. of Public Works Engineering Australia, http://www.ipwea.org.au.

[16] Australian Diver Accreditation Scheme (ADAS), https://www.adas.org.au/index.php?option=com_content&view=article&id=271&Itemid=119.

[17] The Welding Institute, http://www.twi-global.com.

[18] Steel and Concrete structures repairs by Divers [Aqua Doc No. 17587451].

ENGINEERING STANDARDS & DESIGN DOCUMENTS

ASTM Standards

G46 - Standard Guide for Examination and Evaluation of Pitting Corrosion.

G16 - 13 Standard Guides for Applying Statistics to Analysis of Corrosion Data.

Australian Standards

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

AS/NZS - 4680 Hot dip galvanised coatings on fabricated ferrous articles.

AS/NZS - 1214 Hot-dip galvanised coatings on threaded fasteners.

AS/NZS - 4853 Electrical hazards on metallic pipelines.

AS/NZS - 2832 CP standards AS 2832, Parts 1-3.

AS/NZS - 2239 Galvanic (sacrificial) anodes for cathodic protection.

AS/NZS - 2832.3 Cathodic protection of metals - Fixed immersed structures.

AS/NZS - 6047.9 Effects of current on human beings and livestock.

AS/NZS - 60479.1 Part 1: General aspects of current on human beings and livestock.

AS/NZS - 60479.2 Part 2: Special aspects of current on human beings and livestock.

AS/NZS - 6155.8 Safety of power transformers, power supply units and similar (series).

AS/NZS - 1891.4 Industrial fall arrest systems and devices (Part 4).

NACE Standards

NACE RP01-73 Collection and Identification of Corrosion Products, Materials Protection and Performance, Volume 12, June 1973, p. 65.

Miscellaneous

S151 Water Corporation’s Prevention of Falls Standard - Worksafe WA Code of Practice - Prevention of Fall at Workplaces.

Design Standards

DS 61 - Water Corporation Design Standard DS 61, Water Supply Distribution – Tanks

DS95 - Standard for the Selection, Preparation, Application, Inspection and Testing of Protective Coatings on Water Corporation Assets

DS 91 - Cathodic Protection Standard

WS -1 - Welding Specification Metal Arc Welding

1.0 PURPOSE AND SCOPE

The purpose of this document is to establish the guidelines for the Condition Assessment (CA) of both the Elevated and Ground Level steel tanks. The guideline will assist the Inspection Service Providers (ISP's), Alliance Partners/Region Operations Group to conduct objective, consistent and reproducible asset condition ratings [1].

This document is also intended to assist Asset Investment Planners in the scoping of appropriate testing and investigation works such that the output received will be of a high standard and be a positive contribution to the management of steel tanks.

The corrosion assessment in this document is based on the relevant AS/NZS, ASTM, AWS, BS, NACE standards, Standard Operating Procedures (SOP's), Water Corporation design standards and steel structures inspection experience.

The guideline clarifies the qualification(s), responsibilities, accountabilities, inspection data capturing techniques, interpretation and reporting format for ISP's.

The guideline will also aid the ISP's to prepare and deliver the inspection findings to an appropriate format so that In-Service Assets, Asset Planning Group (APG) can determine the Remaining Service Life (RSL) of the asset and subsequently prioritise the renewal based on the informed Asset Risk Assessment (ARA) and Tank Decision Support Tool (TDST).

For more details on the steel structures condition assessment methodology, references shall be made to **Aqua Doc. 11118245** [2].

2.0 INTRODUCTION

2.1 Types of Steels Tanks and Sizes

There are two types of steel tanks in the Water Corporation, namely Ground Level Tank and Elevated Tank. The ground level tank which is generally cylindrical water storage structure constructed with the floor at ground level **[Refer: Photo 1 & 2]**. Exceptions are a few of the ground level liners tanks do not have steel floor plates welded to the wall. Elevated tanks are water storage structures built with the floor above ground level, either supported on a stand or an integral support structure **[Refer: Photos 3 & 4]**.

It was proposed that structural steel, including roof support beams is expected to achieve 100 years design life with major re-coating/maintenance at 25 year interval. For other component design life reference should be made to AquaDoc.7899391 [2].

2.1.1 Ground Level Tank

The nominal capacities (Kilo-Litres) of existing ground level tanks are: 100, 200, 225, 500, 1000, 1500, 2500, 4500, 5000, 9000, 10000, 15000, 25000, 32000 and 50000.

The ground level tanks are either internally coated using potable water approved (AS/NZS 4020) paint or plastic lined. The internals of the potable water tanks are normally coated with two packs of high build epoxy for corrosion protection. For more information on the coating of Water Corporation assets, reference shall be made to DS 95, Standard for the Selection, Preparation, Application, Inspection and Testing of Protective Coatings on Water Corporation Assets.

In addition, the internal structures of the tank may be protected with cathodic protection. For more information on the Cathodic Protection reference shall be made to Water Corporation Water Corporation DS 91, Standard for the Selection, Design and Monitoring of Cathodic Protection (CP) Systems.

Photo 1 – Ground Level Steel Tank.

Photo 2 – Ground Level Steel Tank.

2.1.2 Elevated Tank

The nominal capacity of existing elevated tanks ranges from 100kL to 4000kL. The elevated tanks are also internally coated with two packs of epoxy coating or lined with plastic liner. The tanks may be internally protected with sacrificial anode cathodic protection system.

Photo 3 – Elevated Steel Tank.

Photo 4 – Elevated Steel Tank.

2.2 Pre-Inspection Preparation

Prior to conducting any tank inspection, the Operator/Inspector/Diver (collectively "Inspector") must fully understand the Corporation's steel tanks condition assessment and data capture process. The inspectors must also be familiar with the criterion (condition rating & priority for repair works) used to assess the tank condition.

Any Inspector undertaking on-site condition assessments shall be appropriately qualified and experienced for the task. This is applicable to in-house personnel or external ISP's. The data collection and reports will provide valuable information not only on the asset condition, but also assists in understanding the risk and current performance of the tank.

The inspector should ensure that the assessment is complete with appropriate levels of detail for each relevant component of the tank with a rated condition. The corrosion measurements and assessments must be made with high degree of accuracy. The data collected should adhere to the criteria provided so that there is consistency between surveys.

The various levels of inspection checklist and condition rating are included in the Appendices of this document.

All inspecting personnel shall hold appropriate safety inductions both general and site specific. If the asset is deemed to be a confined space and/or working at heights, then appropriate valid certification shall be possessed by the in-house personnel and ISP's. The certificates shall be available to the Water Corporation for at least 10 working days prior to the inspection.

2.2.1 Ladder Safety

Due to operational reasons, Steel, Stainless Steel and FRP ladders in the ground level and elevated tanks are not assessed regularly and hence the condition is not known. The Ladder Climbing Systems (LCS) is no longer inspected by qualified personnel and shall not be used for safety reasons. The condition of the ladder may be in poor condition and the inspector shall follow Water Corporation S151 Prevention of Falls standard prior to the inspection of the tanks [**Refer: Aqua Doc 580792**]. The ISP's shall seek clarifications from Alliance Partners/Regional Operations Group prior to the inspection.

2.2.2 Roof Safety

Due to corrosive environment resulting from chlorine dosing for disinfection purpose in the tank, there is a likelihood of severe corrosion on the roof structural members. It is highly recommended to review past Divers inspection report and understand the risk of working on the tank roof. All the working at heights safety procedures shall be reviewed on-site and ensure appropriate controls are in place. If in doubt, the inspectors shall not walk over the roof without consulting Alliance Partners/Regional Operations Group.

During the diving operation(s), the Divers shall ensure they are hooked on to the "Skyhook" or similar safety equipment approved by Worksafe, WA [**Refer: Photo 5**].

Any hazards when identified, the ISP's should alert Site Supervisor and a site safe entered in the OSH branch Sentinel program, http://sentinel/Cintellate/jsf/main.jsp for preventive actions.

Photo 5 – Use of Sky Hook for safe working on the tank roof.

2.3 Roles and Responsibilities

Activities	Role(s)*	Responsible Branch*
Level 1	Visual Inspection	Alliance Partners/Region /Divers/Water Corporation employees
Level 2	External & Internal Inspection	Inspection Services Providers†
Level 3	Detailed & Laboratory Assessment	External Consultants◆
ARA	Alliance Partners/Region Civil Asset Planners and Maintainers	Alliance Partners/Region/In-Service Assets, APG
Inspection data review	Level 1 by APG & Region/Alliance Partners. Level 2 and 3 inspection data analysis by In-Service Assets team.	In-Service Assets, APG
Inspection data update in Database	Analyst in In-Service Assets team	In-Service Assets, APG

Table 1 – Roles and Responsibilities Matrix for Steel Tank Condition Assessment.

* Changes in Roles and Responsibilities matrix shall only be approved by Section Manager, In-Service Assets.

† Approved External Contractors – Refer ACA Panel, [AquaDoc. No. 16729525].

◆ Approved Materials Testing and Corrosion Specialists - Refer ACA Panel, [AquaDoc. No. 16729525]

2.4 Defects Notification

During tank cleaning process, Level 1 and Level 2 inspections, corrosion related failures may be identified by the ISP's that requires urgent attention shall be notified to the Operations Group in the Region/Alliance.

The defects/issues recognised needs to be addressed as soon as practicable, so that the asset can be brought back to operation. Some of the common issues that may require immediate notification include:

- Safety compliance issues.
- Tank security issues.
- A structural defect that will have detrimental effect on the asset if not rectified.
- A structural defect including water quality issues that is adversely affecting the service being provided by the asset.

2.5 Inspection Data Interpretation

After completion of Level 1 Divers inspection, the report should be sent to the Asset Investment Planner or Responsible Person in the Assets Planning Group (APG). The inspection data will then be updated and analysed in the Tank Decision Support Tool (TDST) database. All the inspection reports should be saved into the ACA database linked to the relevant Functional Locations for easy access and future references.

Persons responsible for identifying and recording defects, service conditions and construction features for preparing reports and operating equipment shall hold a suitable qualification for various levels of inspection and is discussed in Section 3.0.

In-Service Assets is responsible for analysing the tank inspection data (Level 1, Level 2 & Level 3) provided by ISP's and shall be competent in the following:

- Interpreting information contained in the inspection reports.
- Identifying defects and other features.
- Verifying the inspection scoring/grading system.
- Recording the inspection scoring/grading system in TDST tool.
- Recognising corrosion related defects and the likely parameter contributing to the defects.
- Recognising poor quality inspection videos and camera inspection.

3.0 CONDITION RATING INTERPRETATION

3.1 WERF – Why This Approach?

Prior to 2014, various condition rating systems were used in the Corporation to assess the civil structures. They were all so called industry practice and/or based on the "hearsay". Also, the assessments were qualitative, debateable and hence inconsistent rating.

The main purpose of rating the tank is to evaluate the condition in an objective approach and its effective RSL. The assessment will assist further decision-making about the Level of Service (LOS) provided by the tanks. It is well known that deterioration of material range from 0% to 100%. Currently, the best deterioration model readily fits to this approach is Water Environment & Reuse Foundation (WERF).

The WERF model approach is either "aged based" or "condition based". If no prior inspection or condition data is available, then the service life of the asset will be based on the age and will take the precedence over the condition and vice versa.

Corporation's inspection experience and condition assessment of the asset clearly proved only certain levels of inspection (Level 1 – Visual, Level 2 – Formal and Level 3 – Destructive) is warranted. It is well known that the asset failure leading to physical mortality is not uniform and at certain point it is unserviceable and beyond economic repair. Also, Capacity, Level of Service and Finance factors play major role in the renewals planning decision[3]. So, after any inspection activity the condition rating should be within the margin of "Serviceable and Unserviceable". If this concept is not followed, the rating in 5 scale will also provide a huge margin of error when compared to the 10 rating. In simple words, for a rating 4 in 5 scale, the deterioration is 80%, because each scale will equate to 20% deterioration; whereas the same 80% deterioration equates to a condition rating of 8 in a10 scale.

For the past 3 years, Level 2 inspection of water and wastewater assets clearly showed that the steel structures are still within the serviceable range. The asset condition rating of 10 scale provides a pragmatic maintenance repair works on the assets individual components. Most importantly, Corporation follows Capital Program which is of 5 years plan for repairs and replace approach. Hence, asset with 30% deterioration which is rated as 3 in a ten point scale can be repaired in 3 to 5 years.

3.2 Condition Rating System

For the condition assessment of tanks, In-Service Assets utilises TDST model **[Refer: Figure 1]**. The condition rating is based on 1 to 10 scale and the outcome is summarised as below [3].

☑ **Excellent condition** - Observable deterioration is none. Less than 10% physical life is consumed.

☑ **Very Good condition** - Observable deterioration is insignificant. No adverse service reports. 30% physical life is consumed.

☑ **Good condition** - Observation and/or testing indicate that the asset is meeting all service requirements. Sound Physical condition. Minor deterioration/minor defects observed. 50% physical life is consumed.

☑ **Fair condition** - Moderate deterioration evident. Minor components or isolated sections of the asset need replacement or repair now but not affecting short term structural integrity. 70% physical life is consumed.

☑ **Poor condition** - Serious/Significant deterioration evident and affecting structural integrity. Asset is now moving into zone of failure. 90% physical life is consumed.

☑ **Very Poor** - Failed or failure imminent. Immediate need to replace most or the entire asset. 100% physical life is consumed.

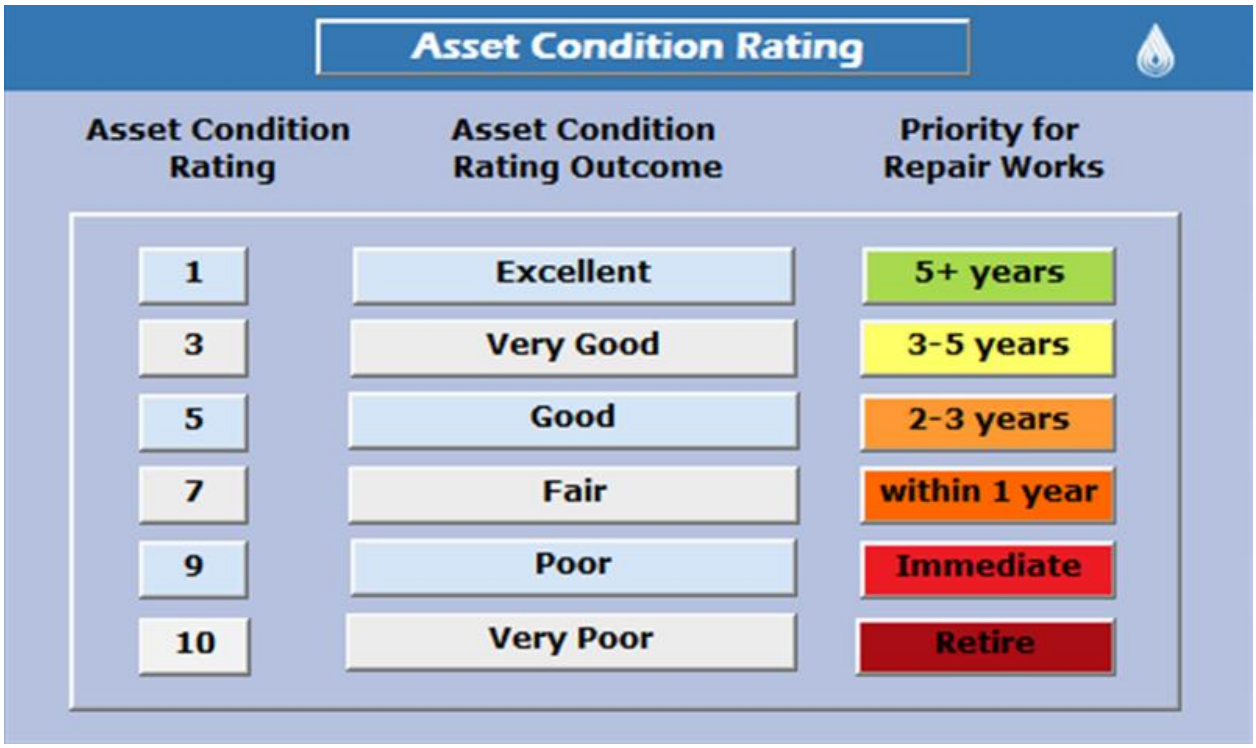


Figure 1 – Asset Condition Rating based on TDST model.

Note: A series of charts published by the AS/NZS engineering standards, Standard Practices (SP) published by NACE, ASTM standards and IPWEA can also be used to make an informed decision on the condition rating of the asset for Level 2 and Level 3 inspections.

4.0 CORROSION ASSESSMENT

In order to assess the corrosion deterioration, the tank shall be isolated, drained and cleaned thoroughly i.e. free from silt, debris, mud, scale, sand and other deposits. This is to ensure the defects on the floor plates, columns, columns base, overflow pipes, inlet pipes and scour pipes are identified and recorded.

Without ventilation and suitable lighting, inspection shall not be carried out under any circumstances. ISP's shall record all the necessary details in the inspection checklist **[Refer: Appendix B]** and provide detailed report **[Refer: AquaDoc 11160034 – Tank Condition Assessment Report Template]**.

If the corrosion or coating defects are found then a figure illustrating the dimensions and orientation of the defect relative to the access entry or ladder location should be attached in the report. The defects should be clearly photographed and labelled. The weld defects should be recorded in accordance with AS/NZS 3978 [4].

The condition assessment report shall include a summary that highlights specific problems associated with the defect and how it has assessed based on particular type of corrosion defect. Relevant national or international guidance, codes or standards should be referred as part of the corrosion assessment if appropriate. Internal and external corrosion should be distinguished very clearly.

The report should also identify the type of corrosion rather than "generic" metal loss. The report should identify the degradation mechanism that causes corrosion failures such as cracking, blistering, pitting (localised metal loss), uniform and lamellar corrosion [5].

If the tank components are noted with a regular pattern in corrosion, then they should be recorded and photographed in a sequence or the photos should be stitched **[Refer: Photo 6]**.

Photo 6 – Increasing "Localised Corrosion/Necking in Tek screw (Left to right).

Long-term and short-term corrosion rates should be compared as part of the data assessment. The inspector, in consultation with a corrosion specialist, shall select the corrosion rate that best reflects the current conditions [6].

The inspector should consult with a corrosion specialist when the short-term corrosion rate changes significantly from the previous identified rate to determine the cause. Appropriate responses to accelerated corrosion rates may include, additional thickness readings, UT scans in suspected areas, corrosion/process monitoring, and revisions to the tanks inspection plan.

Where thickness measurements are obtained at CMLs, the minimum thickness at a CML can be located by ultrasonic measurements. Additionally, for localised corrosion, it is important that examinations are conducted using pit gauge rather than ultrasonic technique.

When scanning with ultrasonics, several thickness measurements at the CML are taken to identify and confirm localised thinning. The lowest numerical value reading or an average of several measurement readings taken within the area of an examination point shall be recorded and used to calculate the corrosion rates.

A minimal number of CMLs are acceptable when the established corrosion rate is low and the corrosion is not localized. For tank shells susceptible to localized corrosion, corrosion specialists should be consulted about the appropriate placement and number of CML's.

A decision on the type, number, and location of the CMLs should consider results from previous inspections, the patterns of corrosion and damage that are expected and the potential consequence of loss of containment.

CML's and examination points should be permanently recorded, (e.g. marked on inspection drawings and/or on the equipment) to allow repetitive measurements at the same CML's. Repeating measurements at the same location improves accuracy of the calculated damage rate.

4.1 Remaining Wall Thickness (RWT) Measurement

Ultrasonic Thickness (UT) Gauge is used to carry out remaining wall thickness measurement. The ultrasonic pulse emitted by the test probe reaches the test object and transits back to the probe. The time required for the ultrasonic pulse to travel through the material, reflect from the back or inside surface of test material will be calculated as thickness of the material **[Refer: Photo 7]**.

Photo 7 - Remaining Wall Thickness Measurement Gauge using UT gauge.

The % metal loss is determined by measuring the thickness of the steel plate after cleaning the corrosion deposits [7]. The design wall thickness should be obtained from the tank design document or drawing(s).

$$\% \text{ Metal Loss} = \frac{\text{Thickness}_{designed} - \text{Thickness}_{actual}\ (mm)}{\text{Thickness}_{designed}\ (mm)} \times 100$$

Where,

$\text{Thickness}_{designed}$ = Design wall thickness, mm

$\text{Thickness}_{actual}$ = Measured wall thickness, mm

4.2 Short Term Corrosion Measurement

The short-term (ST) corrosion rate shall be calculated from the following formula:

$$\text{Corrosion rate, (ST)} = \frac{\text{t previous} - \text{t actual (mm)}}{\text{time bewtween tinitial (\&) tactual (years)}}$$

Where,

$t_{initial}$ = the initial thickness at the same Condition Monitoring Locations (CML) as t_{actual}. It's either the first thickness measurement at this CML or the thickness at the start of a new corrosion rate environment, mm.

t_{actual} = the actual thickness of a CML, mm, measured during the most recent inspection.

$t_{previous}$ = the previous thickness measured during the prior inspection. It is at the same location as tactual measured during a previous inspection, mm.

The interpretation of % metal loss from corrosion to condition rating is shown in below Table 2.

% Metal loss due to uniform corrosion	Condition Rating	Priority for Repair Works
10	1	5+ years
30	3	3-5 years
50	5	2-3 years
70	7	Within 1 year
90*	9	Immediate*
100**	10	Retire*

Table 2 - Quantitative categorisation of Corrosion Rates vs. Condition Rating.

* Possible hole on the steel plate

** Hole on the steel plate (mark the location as “leaks”)

4.3 Long Term Corrosion Measurement

The long-Term (LT) corrosion rate shall be calculated from the following formula:

$$\text{Corrosion rate, (LT)} = \frac{t\ initial - t\ actual\ (mm)}{time\ bewtween\ t\ initial\ (\&)\ tactual\ (years)}$$

$t_{initial}$ = the initial thickness at the same Condition Monitoring Locations (CML) as tactual. It's either the first thickness measurement at this CML or the thickness at the start of a new corrosion rate environment, mm.

t_{actual} = the actual thickness of a CML, mm, measured during the most recent inspection.

$t_{previous}$ = the previous thickness measured during the prior inspection. It is at the same location as tactual measured during a previous inspection, mm.

4.4 Remaining Life Measurement

$$\text{Remaining Life} = \frac{t\ required - tactual(mm)}{corrosion\ rate\ (mm/year)}$$

t_{actual} = the actual thickness of a CML, mm, measured during the most recent inspection.

$t_{required}$ = the required thickness at the same CML or component, mm, as the t_{actual} measurement. It does not include corrosion allowance or manufacturer's tolerances.

Notes:

- If the corrosion rate is not available from the previous inspection data/CML location, then the corrosion rate can be assumed (For example 0.1 mm/year) or may be estimated from prior experience.

- APG, Water Corporation will also utilise TDST to calculate RSL based on the condition rating which is more realistic, given the fact that there are no previous records of CML.

Thickness measurements at CMLs are intended to establish general and localized corrosion rates in different sections of the tank shell. Factors that can contribute to reduced accuracy of UT measurements include the following:

- Improper instrument calibration;
- External coatings or scale;
- Excessive surface roughness;
- Excessive "rocking" of the probe (on curved surfaces);
- Subsurface material flaws, such as laminations.

4.5 Pitting Corrosion

Pitting corrosion is a localized type of corrosion in the form of holes that can penetrate in materials extremely rapidly **[Refer: Figures 2 & 3]**. It is one of the most frequent forms of corrosion in steel water tanks, mainly caused by chlorides [8].

Pitting corrosion is quantified in different ways e.g. average pit depth measurement, maximum pit depth measurement and remaining wall thickness **[Refer: Photos 8 & 9]**.

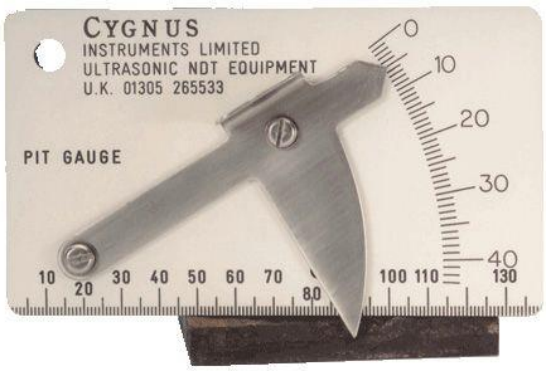


Photo 8 - Underwater Cygnus® Pit Gauge.

Photo 9 - ESR® Digital Pit Depth/Crack Gauge.

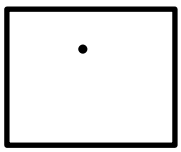
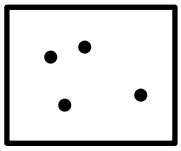
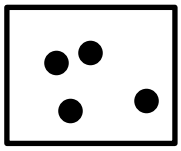
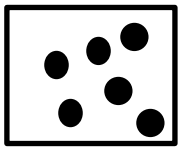
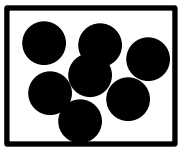
(A) DENSITY	(B) SIZE	(C) DEPTH
		
2.5 x $10^3/m^2$	0.5 mm^2	0.4 mm
		
1 x $10^4/m^2$	0.5 mm^2	0.4 mm
		
5 x $10^4/m^2$	8.0 mm^2	1.6 mm
		
1 x $10^5/m^2$	12.5 mm^2	3.2 mm
		
5 x $10^5/m^2$	24.5 mm^2	6.4 mm

Figure 2 - ASTM G 46 – Standard Guide for Examination and Evaluation of Pitting Corrosion [Ref: ASTM Standard G 46].

4.5.1 Types of Pitting Corrosion

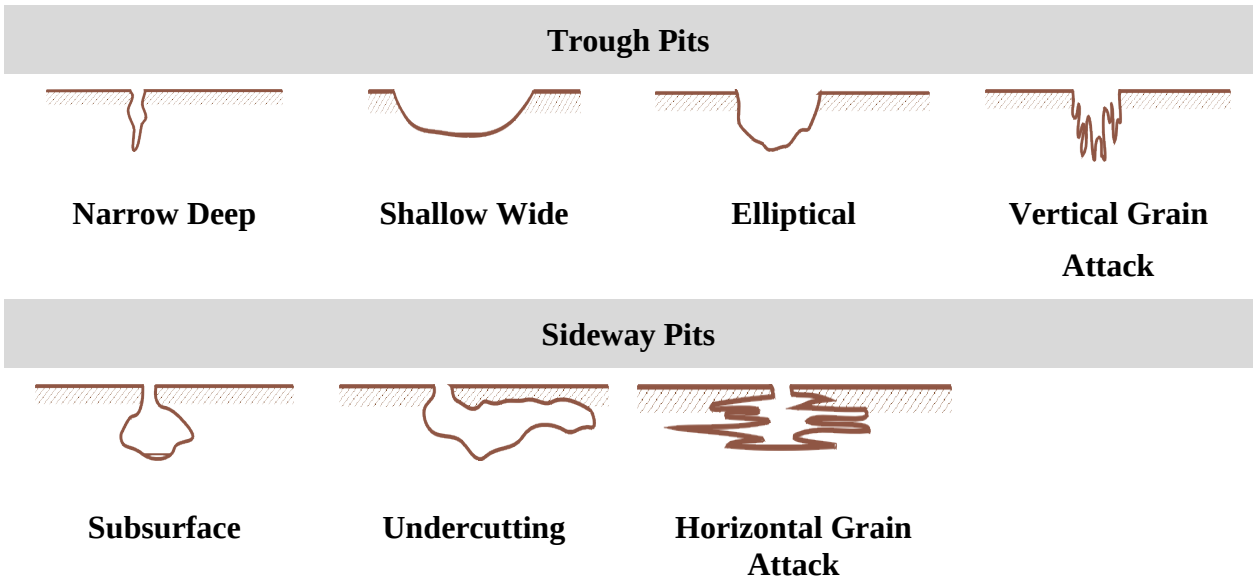


Figure 3 - Types of Pitting Corrosion [Ref: http://www.nace.org/Pitting-Corrosion/].

4.5.2 Pit Depth Measurement & Analysis

Pit depths may be measured with a depth gauge or a micro-meter calliper with needle point anvils. The pitting rate should be determined in accordance with NACE Standard SP0775 [7] which states that:

$$\text{*Pitting Rate (mm/year)} = \frac{\text{Depth of deepest pit (mm)}}{\text{Exposure Time (days)}} x365$$

Note: * Pitting characterisation by calculation of pitting rate may be misleading if pitting onset occurs after an incubation period. Time to pitting onset varies and pit growth may not be uniform. Therefore, care should be exercised in applying calculated pitting rates to project time-to-failure.

In order to determine the severity of the corrosion from an operation standpoint, the following guideline should be used:

Table 3 - Qualitative Categorisation of Pitting Corrosion.

Metal loss due to Pitting Corrosion (Pit Depth), (%)	Asset Condition Rating	Priority for Repair Works
10	1	5+ years
30	3	3-5 years
50	5	2-3 years
70	7	Within 1 year
90	9	Immediate
100	10	Retire

4.6 Coating Thickness Measurement

Steel usually rusts when it is exposed to water and oxygen through the formation of tiny electrical cells on the surface. Protective coatings provide a barrier to oxygen, moisture and other corrosive elements. For optimum protection, the barrier should be as impermeable, adequately thick, and continuous as practical. The surface to be coated is called the substrate. The coatings applied on the substrate can be made of a single coat or multiple coats **[Refer: Figure 4]**.

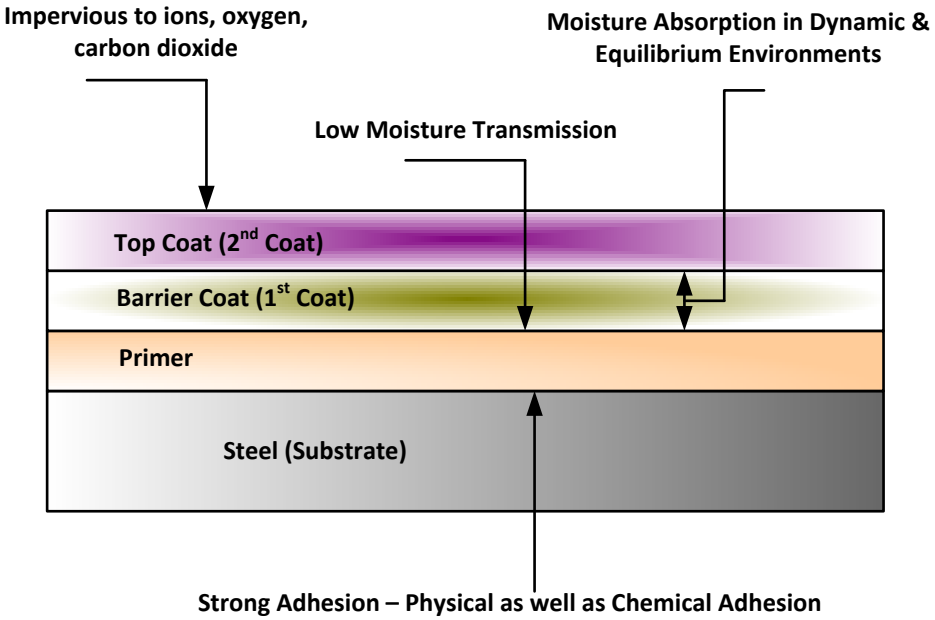


Figure 4 – Schematic drawing of a typical three coat system.

Degree of Rusting is defined as the rating characterising the degree of rust formation (rust broken through and visible under rust) on a coating. This assessment should be carried out under good lighting. The degree of rust percentage is explained in the following schematic representations. These are also known as "Measles Charts" as shown in Figure 5. References shall also be carried out to SSPC Standard, SSPC Vis 2 for details [9]. Repair painting is also necessary in the following typical cases:

(i) For surfaces where there is evidence of rusting underneath the film.

(ii) If the rust percentage is 50% and greater, it may be more cost effective to completely recoat the structure.

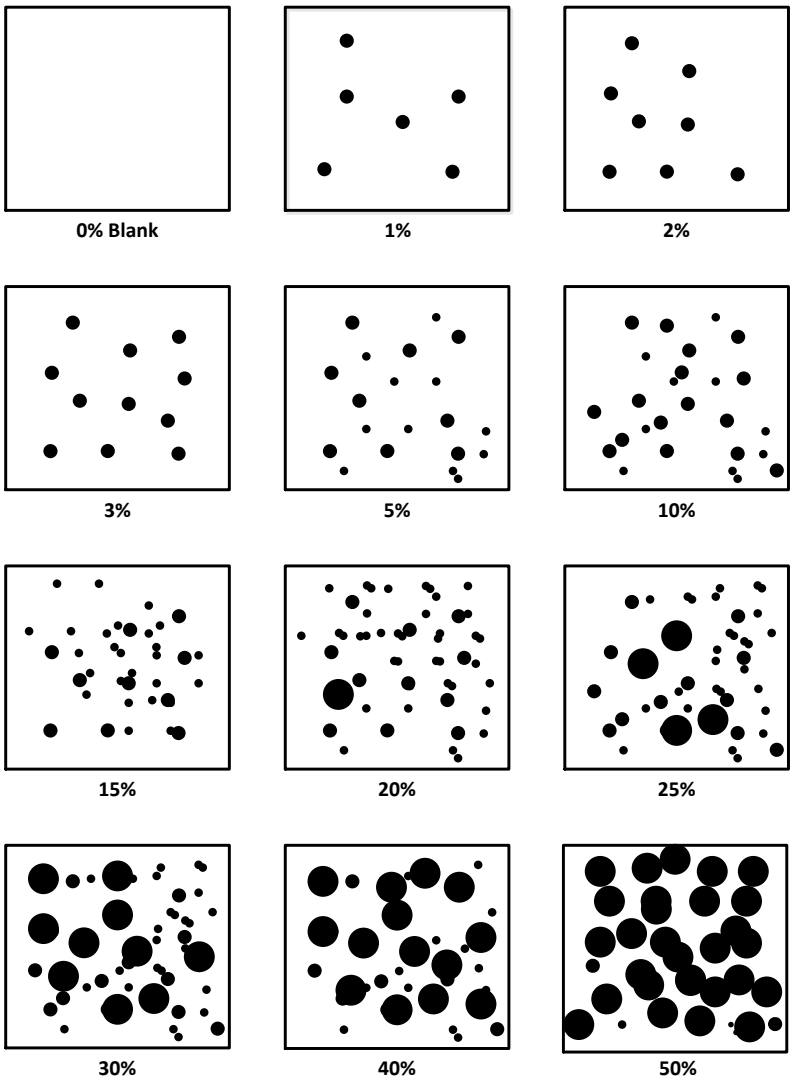


Figure 5 – Schematic representation of estimating rust percentages in 1 m2 area.

Coating Damage (%)	Asset Condition Rating	Priority for Repair Works
10	1	5+ years
30	3	3-5 years
50	5	2-3 years◆
70	7	Within 1 year◆
90	9	Immediate*
100	10	Retire*

Table 4 - Qualitative Categorisation of Coating Deterioration.

◆ Depending on the substrate condition, either re-patch or carryout full paint repair.

* Re-blast the steel surface and Recoat the surface using appropriate paint type. Refer: Water Corporation Coating Design Standard DS 95 for more details [10, 11,12].

4.7 Cathodic Protection

Cathodic Protection (CP) is defined as "reducing or eliminating" corrosion by making the metal a cathode by means of an impressed direct current (DC) or an attachment to a sacrificial anode (usually magnesium, aluminium or zinc).

The main difference between a sacrificial and an impressed current system is, the sacrificial system relies on the potential difference between the anode and structure, whereas the impressed current system uses an external power source to drive the current [13].

Caution:

When the steel tanks are protected with Impressed Current Cathodic Protection (ICCP), the CP system shall be **switched off prior to diving inspection**.

- Warning notices advising of the danger of electrical gradients near the anodes shall be prominently displayed at all entry points to the water body [Refer: Water Corporation Cathodic Protection design standard DS 91, Section 5.2].

Divers should check if the steel tank is cathodically polarised (protected) by dropping reference electrode (e.g. Copper/Copper Sulphate) through the access hatch and measure the potential around the roof hatch before CP is turned off **[Refer: Figure 6].**

Note:

- All tanks are fitted with portable reference electrode ports which are spaced all around the tank perimeter; divers can also use these ports for measurement.

The Asset Owner must ensure that Transformer Rectifier Unit (TRU) be **turned on** after the **completion of inspection**.

To ensure corrosion protection of internals of the steel tanks, CP system should be installed, monitored and maintained [Refer: Water Corporation Cathodic Protection Design Standard DS91]. To mitigate corrosion on the steel tanks, the OAM should ensure the following [14]:

- Impressed Current Cathodic Protection (ICCP), power supply inspection/adjustment interval should be carried out monthly by Region.

- Sacrificial CP, potential survey 2 monthly by Region. Physical inspection on the anode condition should be carried out by the region during shutdown.

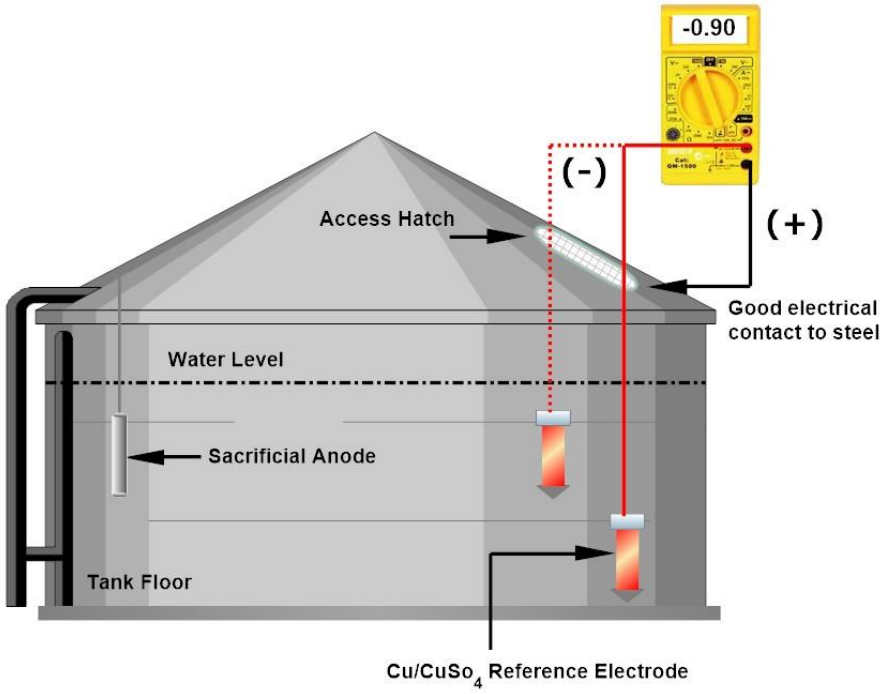


Figure 6 – CP potential measurement in the steel tank using portable $Cu/CuSO_4$ reference cell.

5.0 OVERVIEW OF TANK CONDITION ASSESSMENT LEVELS

In-Service Assets, APG propose on all the Water Corporation steel tanks that the condition assessment is undertaken at three levels [15]:

5.1 Level 1 – Routine Operation and Maintenance Inspection

Level 1 inspection is carried out as part of routine operational budgets and activities. Level 1 inspection will assist in assessment of the overall safety and performance of the steel tank structure. A Level 1 inspection can be carried out by Water Corporation employees including treatment plant operators, chemical dosing plant supervisors, asset maintainers, asset planners, service delivery representative and diving contractors. Relevant inspection data is captured as part of the on-going operation and maintenance process.

If corrosion defects are a threat to the structural integrity of the tank, then an Asset Deficiency Report (ADR) must be created by the asset inspector. The Asset Manager or responsible person must also use the Asset Risk Assessment (ARA) system and verify the likelihood and consequence of failure i.e. risk rating for the steel tank.

In-Service Assets, APG recommends all the asset owners to complete ARA which can be found on the APG website in the Water Corporation intranet http://waternet.watercorporation.com.au.

In-Service Assets, APG will then validate the risk assessment and also use the Tank Decision Support Tool (TDST) to calculate the indicative Remaining Service Life (RSL) from the Level 1 assessment. Where the indicative RSL is calculated to be within 5 years, a Level 2 inspection may be initiated and planned in the appropriate year for condition assessment.

Level 1 inspection is carried out as part of routine operational budgets and activities. Refer **Appendix A** inspection checklist for Level 1 inspection by Water Corporation employees and external Inspection Service Providers (ISP's). In the Corporation, the following inspection activities are classified as Level 1 inspection **[Refer Photos 10 & 11]**.

Photo 10 – Inspection of the elevated tank roof using RPA.

Photo 11 – Tank internal inspection using ROV.

5.2 Level 2 – Formalised Inspection (Intrusive)

Level 2 is a planned/formalised inspection after an ARA on the steel tank structure has been endorsed by APG.

Level 2 inspection findings will be sent to In-Service Assets for further analysis. In Level 2, In-Service Assets, APG will then carry out ARA and infer the effective remaining life using Tank Decision Support Tool (TDST) model **[Refer: AquaDoc 11161621]**.

Renewals decision for asset replacement shall be made based on the condition of the main structural components e.g. tank wall, floor, roof etc.

On an annual basis, the Renewals Planning team will carry out an evaluation of steel tank structures using TDST and where the theoretical RSL is shown to be between 3 to 5 years, a Level 2 inspection may be triggered. For all assets requiring a Level 2 inspection, an ARA must be completed by the Renewals Planning team and approved by the OAM.

Level 2 inspection is carried out as part of the planned condition assessment capital program.

Where the RSL is calculated to be within 3 years, a Level 3 assessment may be initiated by the Renewals Planning team where it is deemed cost effective and/or further data is required to determine the requirement for intervention.

5.3 Level 3 – Detailed Investigation (Destructive Testing)

Level 3 inspections will be carried out, where the ARA is very high and/or Level 2 inspection showed that the asset is nearing the end of its physical life. In-Service Assets will recommend Level 3 inspection based on the asset Physical Life and Level of Service (LOS). The methodology below describes how the Corporation is undertaking condition assessments on its steel structure assets.

An overview of the process is depicted in **Figure 7** with each stage explored in further detail in the following sections. Level 3 inspection is carried out as part of the planned condition assessment capital program.

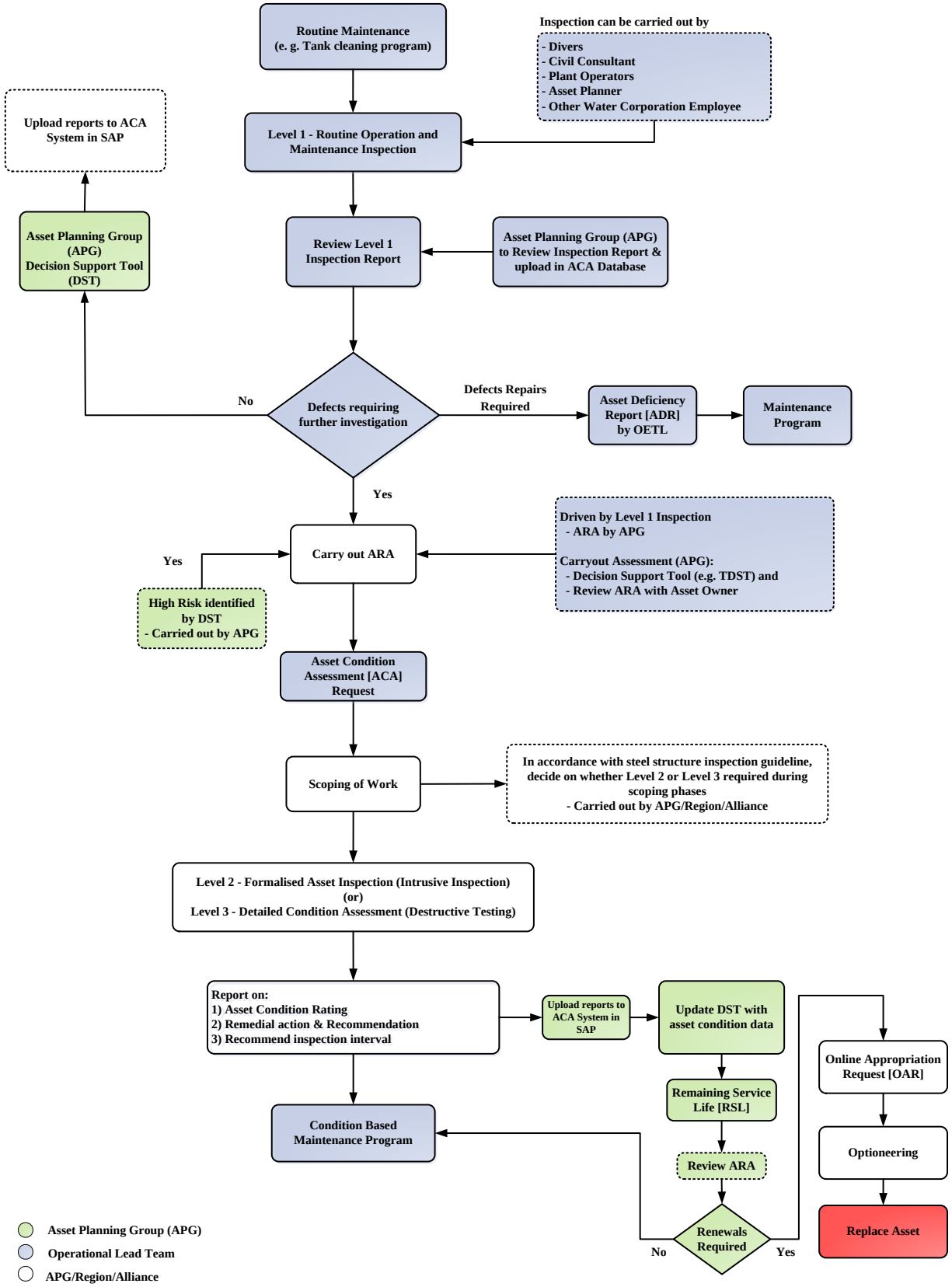


Figure 7 - Summary of the steel structure inspection guidelines.

6.0 LEVEL 1 - TANK INSPECTION

6.1 Aim of Level 1 Inspection

The aim of Level 1 inspection is to confirm the tank continues to perform its operational requirements under acceptable conditions of safety and with minimised cost of maintenance. A level 1 inspection is undertaken as part of routine maintenance works/budgets.

Level 1 inspection are undertaken to ensure the following objectives are met:

- The tank continues to operate to the required level without operational problems;
- To record the current asset condition i.e. corrosion, general wear and tear;
- To assess and determine maintenance requirements such as replacing cathodic protection sacrificial anodes, nuts and bolts etc.;
- To forecast future operational problems;

Confirm if the previous repairs works that are carried out are functioning properly or new repair methodologies are required to remediate the problem

Note: The diving company shall ensure the competency and the validity of the divers certificates for the given task.

6.2 Divers Inspection

6.2.1 Tank Cleaning and Standard Inspection by Divers

The divers shall vacuum all the sediment and ensure the tank floor is thoroughly cleaned. Once cleaned, a "Standard Inspection" should be carried out by taking photos of key components.

The diver's standard inspection, (i.e. after tank cleaning), shall capture typically 60 to 100 photographs. The photos should be labelled with the name of the tank component followed by the numbering sequence i.e. a photo should be called "Wall to Floor Joint 2".

Videos with high a resolution handheld camera with voice commentary to highlight key issues are also required (this does not require setting up the large video systems). If there are problems found within the asset, a greater volume of photos should be taken to capture the problem.

All findings as a result of the inspection are reported by the Contractor using the excel spreadsheet template [**Refer: Appendix B**].

6.2.2 Tank Cleaning - Divers Qualifications

For Diving Inspector, the minimum level of qualification to carry out inspection of Water Corporation tanks shall be a valid Part 2 - Surface Supply Breathing Apparatus (SSBA) accredited by ADAS [22].

The qualification for Diving Supervisor is a valid Part 1 - Occupational Self-Contained Underwater Breathing Apparatus (SCUBA) to 30 metres. It is intended to establish occupational SCUBA qualification for engineering inspection diving.

The qualification limits the diver to using hand tools or conducting inspections. The Part 1 certified diver cannot operate surface controlled power tools, or dive in operations where the use of overhead lifting or other similar activities is required [16].

6.2.3 Detailed Inspection by Divers

Detailed inspections are usually done less frequently and will be included in the Program of Works. Where a detailed inspection is required by the Program of Works, it will replace the basic inspection. Detailed Inspections are also performed after the tank has been cleaned. The current format of a "Civil Inspection" is where the diver completes the same process outlined above but with more detail. It is recommended that more photos are taken on each component and problematic areas. The volume of written information on each component is also usually more. The diver shall shoot an interactive video of the entire tank internals, which is usually an hour or two long and looks at every part of the asset in detail with commentary by the diver.

Photos should not be individually renamed, but are filed in named folders, so the Corporation can get a folder called "walls" with a bundle of un-named photos of the walls.

The divers shall produce interactive video typically an hour or two long and record every part of the asset in detail with commentary by the diver and supervisor. The video record shall include the entire inspection. The diver shall submit 3 copies of the tank inspection video and inspection report in electronic format able to read by the Corporation including the following defects or features:

- Deformed or broken appurtenances.
- Multiple failed components.
- Continuous defects or features such as defect coating, corrosion on the floor, wall, weld joint corrosion etc.
- Significant erosion, corrosion or surface damage.
- Defective steps, ladders, platforms, inlet pipe, columns, scour pipe, overflow pipe etc.
- A minimum of one image should be a direct view showing the defect feature in the context of the tank. Images from zoomed, titled or panned camera are supplementary and should not be used alone.
- Lighting and focus should be adjusted to ensure a quality image. If the feature is not identifiable it may be useful to capture several images from different positions.

The minimum resolution for the photographs shall be 4500 x 3000 pixel dimensions and the file size for individual photos shall be 5 MB or higher. The file size for individual videos should be

no more than 2GB. The Contractor may therefore need to submit multiple video files for the same tank.

All findings as a result of the inspection are reported by the Contractor using the excel spreadsheet template or interactive pdf format or similar [**Refer: Appendix C**].

Note: During civil inspection, Diver shall use appropriate and approved Ultrasonic Thickness (UT) and localised metal loss (pit depth) gauges to record remaining steel thickness readings of the wall and floor and any problem areas of the tank.

6.2.4 Tank Civil Inspection - Divers Qualifications

For Civil Inspection, the divers shall possess valid CSWIP 3.1U - NDT Inspection certification issued by The Welding Institute (TWI) [17].

6.2.5 Divers Inspection Report

The inspection report shall consist of structural elements nominated in the scope of work. The report shall be computerised version detailing the observations including location and characteristics of reportable features including defects and features of interest.

The supervisor shall fill out a Microsoft Excel® template with information based on the diver's comments. Refer **Appendix A** for the standard inspection checklist template.

6.2.6 Underwater Repairs

The Contractor may perform minor repairs in accordance with the Principal's Tank Repair Register [18]. Repairs will be based on predefined scopes and services. Minor repairs may include:

- Repairing cracks or leaks;
- Replacement of bolts;
- Cleaning and coating of corroded elements;
- Replacement of cathodic protection anodes; and
- Other minor repairs as agreed with operations

Any repairs and repair materials need to be approved by the Principal's Representative before they are undertaken and/or applied to the water storage tanks. The cost of the approved materials must be clearly identified in the invoice for reimbursement.

6.3 Inspection by Others - Water Corporation Personnel

Before carrying out visual inspection, the Water Corporation employees shall complete and possess approved permits including Job-Safety Analysis (JSA), Job Safety and Environment Analysis (JSEA) and site-safe inductions. If the Corporation employees carry out roof inspection then they shall also possess valid working at heights certificates.

The inspection finding shall be reported to OAM/Regional Alliance/APG. If the defects deemed to be significant, then OAM will conduct an ARA. APG will review the ARA and is discussed in Section 3.0 **[Refer: Figure 7 - Summary of the steel structure inspection guidelines]**.

In general, the scope of a routine visual inspection includes:

- Inspection of the road surface to the tank site, guardrails/barriers, vegetation and debris, deterioration of tank ring beam, observe and identify any water leaks.
- Close attention will be paid to establish the effectiveness and condition of previous repairs.

7.0 LEVEL 2 - TANK INSPECTION

7.1 Aim of Level 2 Inspection

The aim of the inspection is to ensure the tank continues to perform its operational requirements under acceptable conditions of safety with minimised cost of maintenance. Level 2 inspections are undertaken to ensure the following objectives:

- Ensure that the tank continues to operate to the required level without operational problems;
- To record the current asset condition i.e. corrosion deterioration, general wear and tear;
- To assess and determine maintenance requirements such as replacing cathodic protection sacrificial anodes, nuts and bolts etc.;
- To forecast future technical problems;
- Confirm if the previous repairs works that are carried out functioning properly or new repair methodologies are required to remediate the problem.
- Determine the RSL of the tank and tank appurtenances.

7.2 Calibration of Inspection Gauges

Inspection gauges shall be calibrated in accordance to the manufacturers recommended practices and interval. Calibration certificates shall be available to the Water Corporation prior to the inspection.

7.3 Qualification of Level 2 Inspectors

The formalised tank inspection shall only be carried out by qualified and experienced inspectors. This is to ensure quality and reliability of inspection and data obtained for further analysis. Under no circumstances, non-qualified ISP's shall be engaged for Level 2 inspection.

The Level 2 inspectors shall prove to Water Corporation that they have enough experience in tank inspection and shall submit any one of the certification gained from Australasian Corrosion Association:

- Corrosion Technician certification;
- Corrosion Technologist certification;
- Cathodic Protection certification;

For coating inspection, the inspector shall possess ACA Coating Inspector (or) National Association of Corrosion Engineers (NACE) minimum NACE CIP Level II Coating Inspector.

The Non-Destructive Inspection (NDI) of tank floor by FloorScanner 3D® or equivalent shall be carried out by personnel who are trained in the relevant equipment operation and data collection. The inspection results shall then be analysed and approved by Australian Institute of Non-Destructive Testing (AINDT) Level II certified personnel.

The tank wall inspection using Scorpion® Remote Access Ultrasonic Crawler or equivalent shall be carried out by personnel who are trained in the relevant equipment operation and data collection.

The inspection report shall be submitted by the Contractor in accordance with the template [**Refer: Appendix C**].

7.4 Inspection Equipment

All the equipment's should be calibrated and tagged accordingly. Calibration certificates shall be produced upon request by Water Corporation.

Figures 8 and 9 show some of the tank integrity assessments inferred from Level 2 inspection activities.

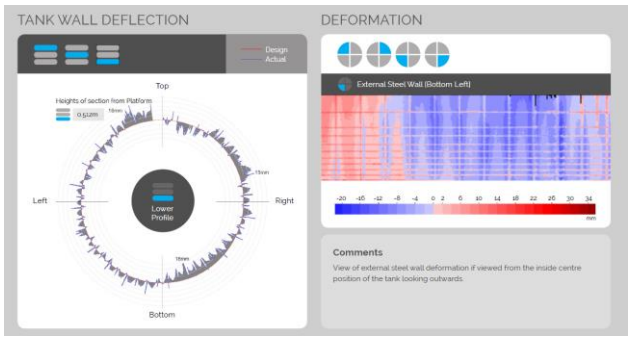


Figure 8 – Out of shape/roundness of the steel tank wall

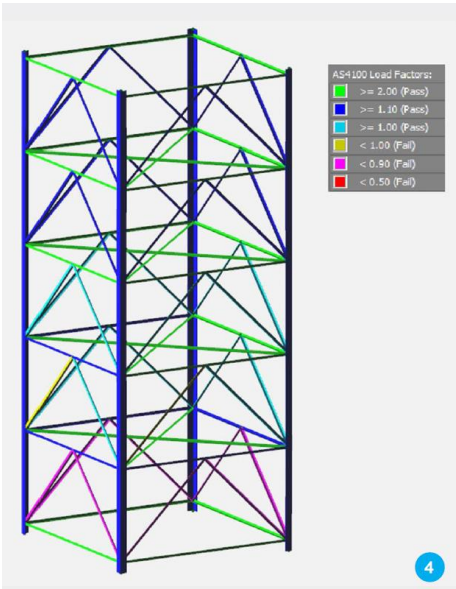


Figure 9 – Steel tank stand structural analysis using proprietary software.

8.0 LEVEL 3 - TANK INSPECTION

8.1 Aim of Level 3 Inspection

Level 3 inspections may be required due to concerns over tank structural safety, due to complexity of remediation works recommended during Level 2 inspection.

The main aim of Level 3 inspection is to identify likely future problems and the approximate timing of those problems. The Level 3 assessment should identify appropriate testing and investigation works on the deterioration mechanisms and common defects. This is to determine the type and extent of the remedial works for the tanks.

The Level 3 assessment will establish a history of material performance of the various components of the tank which will be used by engineers, asset maintainers and Inspectors.

8.2 Qualification of Level 3 Inspectors

In general, the Contractor shall be very knowledgeable in various engineering discipline including Metallurgy, Corrosion, Materials Science and Cathodic Protection. The Contractor should be very thorough in non-destructive testing methods of steel and engineering techniques as well as various aspects of construction materials including design, construction, rehabilitation and maintenance.

The material failure investigation shall be carried out in a National Association of Testing Authorities (NATA), Australia laboratories.

The Level 3 report shall be submitted by the Contractor in accordance with the template [**Refer: Appendix D**].

9.0 APPENDIX A - ASSET CONDITION RATING

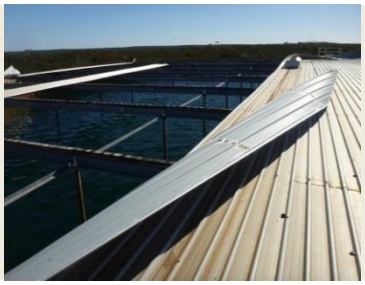
The following should be taken into consideration when condition rating various components of the steel tank:

- Condition Rating is adopted from WERF model [15].
- Level 1 inspection is visual and condition rating is subjective. Therefore, ACA Outcome can include multiple Condition Ratings for the Excellent to Fair categories.
- Level 2 is a formalised inspection will be carried out by the Corporation ACA panel Inspection Service Providers. Hence, more accurate condition rating can be achieved.

9.1 Tek Screws

ACA Rating	ACA Outcome	Description	Descriptive Photograph
1 or 2	**Excellent**	• No or very minor defects	
3 or 4	**Very Good**	• Minor corrosion/deterioration to Tek Screws • Light surface rust to Tek Screws • Light surface rust to thread portion of the Tek Screws	
5 or 6	**Good**	• Moderate corrosion/deterioration to Tek Screws • Moderate surface rust to Tek Screws • Early signs of Necking surface rust to thread portion of the Tek Screws	
7 or 8	**Fair**	• Severe corrosion/necking to Tek Screws • Severe surface rust to Tek Screws • Severe signs of localised thinning or Necking rust to thread portion of the Tek Screws	
9	**Poor**	• Severe corrosion/necking to Tek Screws • Imminent failure to Tek Screws • Severe signs of Necking surface rust to thread portion of the Tek Screws	
10	**Very Poor**	• Tek Screw broken or disconnected from the roof sheeting	

9.2 Roof - External

ACA Rating	ACA Outcome	Description	Descriptive Photograph
1 or 2	**Excellent**	• No or very minor defects	
3 or 4	**Very Good**	• Minor corrosion/deterioration observed on the roof sheet	
5 or 6	**Good**	• Moderate corrosion/deterioration observed on the roof sheet • Moderate surface rust to Tek Screws • At times, random holes are observed on the roof sheet	
7 or 8	**Fair**	• Severe corrosion/necking to the internal roof sheet support structures • Sagging of roof sheet observed	
9	**Poor**	• Imminent failure to roof sheet collapsing inside the tank • High velocity wind may lift the roof sheeting off from the structure	
10	**Very Poor**	• Tek Screw broken or disconnected from the roof sheeting	

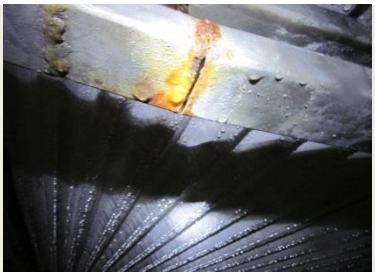
9.3 Wall - External

ACA Rating	ACA Outcome	Description	Descriptive Photograph
1 or 2	**Excellent**	• No or very minor defects	
3 or 4	**Very Good**	• Minor corrosion/deterioration to wall coating • Light surface rust to steel substrate	
5 or 6	**Good**	• Moderate corrosion/deterioration to wall coating • Light surface rust to steel substrate • Showing signs of hot dip galvanising (zinc) reaction with the environment	
7 or 8	**Fair**	• Severe corrosion due to hot dip galvanising coating deterioration • Severe surface rust noted on large areas	
9	**Poor**	• Coating delamination and failure of protective coating	
10	**Very Poor**	• Severe corrosion/ on the wall • Severe signs corrosion build up on most of the wall surfaces • Imminent leak due to steel corrosion	

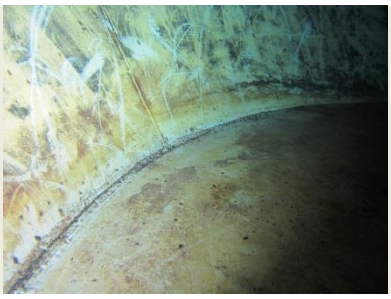
9.4 Access Hatch

ACA Rating	ACA Outcome	Description	Descriptive Photograph
1 or 2	**Excellent**	• No or very minor defects	
3 or 4	**Very Good**	• Minor corrosion/deterioration to zinc coating • Light surface rust to steel substrate	
5 or 6	**Good**	• Moderate corrosion/deterioration to access coating • Light surface rust to steel substrate	
7 or 8	**Fair**	• Severe corrosion due to hot dip galvanising coating deterioration • Severe surface rust noted on large areas	
9	**Poor**	• Zinc coating delamination and failure of protective coating resulting in corrosion	
10	**Very Poor**	• Severe corrosion/ on the access hatch • Imminent failure due to steel corrosion	

9.5 Beams

ACA Rating	ACA Outcome	Description	Descriptive Photograph
1 or 2	**Excellent**	• No or very minor defects	
3 or 4	**Very Good**	• Minor corrosion/deterioration to roof beams • Light surface rust resulting from hot dip galvanised zinc depletion	
5 or 6	**Good**	• Moderate corrosion/deterioration to roof beams • Most of the hot dip galvanised zinc depleted on the roof beam	
7 or 8	**Fair**	• Severe corrosion to steel • Early signs of lamellar corrosion	
9	**Poor**	• Severe corrosion to steel • Severe signs of lamellar corrosion on larger areas of the component	
10	**Very Poor**	• Imminent failure of the beams • Failure on the weld joints	

9.6 Wall - Internal

ACA Rating	ACA Outcome	Description	Descriptive Photograph
1 or 2	**Excellent**	• No or very minor defects	
3 or 4	**Very Good**	• Minor corrosion/deterioration to wall coating • Light surface rust to steel substrate • Random appearance of coating blisters	
5 or 6	**Good**	• Moderate corrosion/deterioration to wall coating • Light surface rust to steel substrate • Random appearance of coating blisters	
7 or 8	**Fair**	• Severe corrosion due to coating deterioration • Severe surface rust noted on large areas	
9	**Poor**	• 100% coating “Osmotic blister” observed • Coating delamination and failure of protective coating	
10	**Very Poor**	• Severe corrosion/ on the wall • Severe signs corrosion build up on most of the wall surfaces	

9.7 Purlins

ACA Rating	ACA Outcome	Description	Descriptive Photograph
1 or 2	**Excellent**	• No or very minor defects	
3 or 4	**Very Good**	• Minor corrosion/deterioration to purlins • Light surface rust resulting from hot dip galvanised zinc depletion	
5 or 6	**Good**	• Moderate corrosion/deterioration to purlins • Most of the hot dip galvanised zinc depleted on the roof beam	
7 or 8	**Fair**	• Severe corrosion to steel • Early signs of corrosion and localised deterioration	
9	**Poor**	• Severe corrosion to steel • Severe signs of corrosion on larger areas of the component	
10	**Very Poor**	• Imminent failure of the purlins	

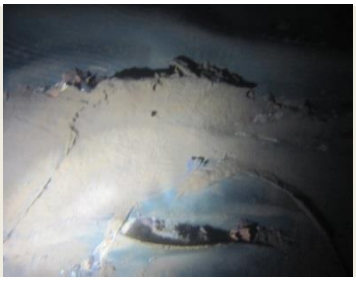
9.8 Roof - Internal

ACA Rating	ACA Outcome	Description	Descriptive Photograph
1 or 2	**Excellent**	• No or very minor defects	
3 or 4	**Very Good**	• Minor corrosion/deterioration observed on the roof sheet	
5 or 6	**Good**	• Moderate corrosion/deterioration observed on the roof sheet • Moderate surface rust to Tek Screws • At times, random holes are observed on the roof sheet	
7 or 8	**Fair**	• Severe corrosion/necking to the internal roof sheet support structures	
9	**Poor**	• Imminent failure to roof sheet collapsing inside the tank • High velocity wind may lift the roof sheeting off from the structure	
10	**Very Poor**	• Tek Screw broken or disconnected from the roof sheeting Roof	

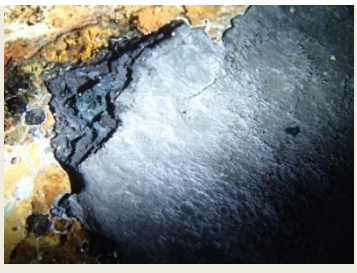
9.9 Columns

ACA Rating	ACA Outcome	Description	Descriptive Photograph
1 or 2	**Excellent**	• No or very minor defects	
3 or 4	**Very Good**	• Moderate deterioration to the column coating	
5 or 6	**Good**	• Moderate deterioration with signs of coating blisters • Corrosion on the hold down bolts are observed	
7 or 8	**Fair**	• Severe corrosion on the tank columns • Severe signs of localised thinning of columns	
9	**Poor**	• Severe corrosion on the columns • At times, large pitting corrosion (holes) are observed	
10	**Very Poor**	• Cracking of columns resulting in structural failure	

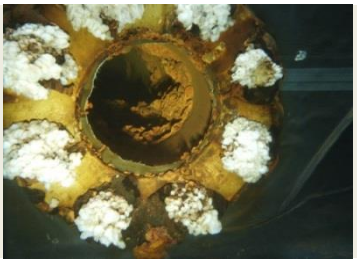
9.10 Floor - Plastic Lining

ACA Rating	ACA Outcome	Description	Descriptive Photograph
1 or 2	**Excellent**	• No or very minor defects on the plastic liner	
3 or 4	**Very Good**	• Moderate deterioration to the plastic lining	
5 or 6	**Good**	• Bubbles on the plastic lining • Possible damage to the liner around those areas	
7 or 8	**Fair**	• Signs of corrosion on the tank hold down bolts	
9	**Poor**	• Severe corrosion on the plastic liner hold down bolts • Plastic liner damages are observed around the bolts	
10	**Very Poor**	• Failure of plastic liner due to natural ageing • Imminent leak from the tank floor	

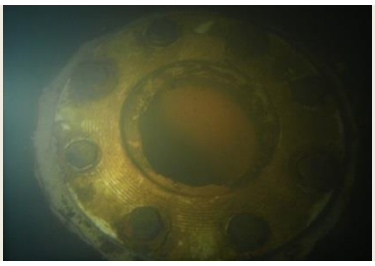
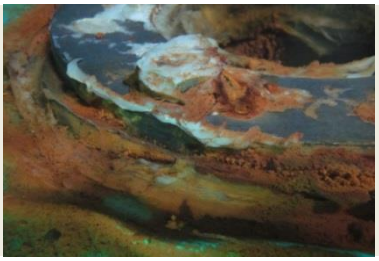
9.11 Floor - Coating

ACA Rating	ACA Outcome	Description	Descriptive Photograph
1 or 2	Excellent	• No or very minor defects on the floor protective coating	
3 or 4	Very Good	• Moderate deterioration to the floor coating	
5 or 6	Good	• Moderate deterioration with signs of coating blisters • Upon removal of the protective coating shiny metal can be observed	
7 or 8	Fair	• Upon removal of rust, severe localised pitting corrosion (craters) on the tank floor	
9	Poor	• Severe corrosion on the floor • At times, large pitting corrosion (craters) are observed	
10	Very Poor	• Clusters of pitting corrosion (craters) on the weld joints, floor and annular plates • Imminent leak from the tank floor	

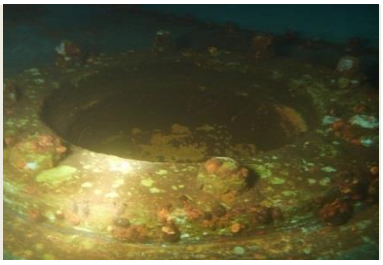
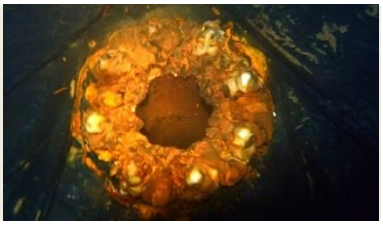
9.12 Inlet Pipe

ACA Rating	ACA Outcome	Description	Descriptive Photograph
1 or 2	**Excellent**	• No or very minor defects on the inlet pipe	
3 or 4	**Very Good**	• Moderate deterioration/signs of corrosion to the inlet pipe	
5 or 6	**Good**	• Deposition of chloride on the zinc coated bolts • Moderate to severe corrosion	
7 or 8	**Fair**	• Signs of corrosion on the inlet pipe	
9	**Poor**	• Severe corrosion on the inlet pipe	
10	**Very Poor**	• Severe corrosion on the inlet pipe	

9.13 Scour Pipe

ACA Rating	ACA Outcome	Description	Descriptive Photograph
1 or 2	**Excellent**	• No or very minor defects on the scour pipe	
3 or 4	**Very Good**	• Moderate deterioration/signs of corrosion to the scour pipe	
5 or 6	**Good**	• Deposition of chloride on the zinc coated bolts • Moderate to severe corrosion	
7 or 8	**Fair**	• Signs of corrosion on the scour pipe	
9	**Poor**	• Severe corrosion on the scour pipe	
10	**Very Poor**	• Severe corrosion on the scour pipe resulting in the blockage of scour pipe.	

9.14 Outlet Pipe

ACA Rating	ACA Outcome	Description	Descriptive Photograph
1 or 2	**Excellent**	• No or very minor defects on the outlet pipe	
3 or 4	**Very Good**	• Moderate deterioration/signs of corrosion to the outlet pipe	
5 or 6	**Good**	• Deposition of chloride on the zinc coated bolts • Moderate to severe corrosion	
7 or 8	**Fair**	• Signs of corrosion on the outlet pipe	
9	**Poor**	• Severe corrosion on the outlet pipe	
10	**Very Poor**	• Severe corrosion on the outlet pipe	

9.15 Overflow Pipe

ACA Rating	ACA Outcome	Description	Descriptive Photograph
1 or 2	**Excellent**	• No or very minor defects on the overflow pipe	
3 or 4	**Very Good**	• Moderate deterioration/signs of corrosion to the overflow pipe	
5 or 6	**Good**	• Moderate to severe corrosion on the overflow	
7 or 8	**Fair**	• Signs of severe corrosion on the overflow pipe	
9	**Poor**	• Severe corrosion on the bell-mouth of the overflow pipe	
10	**Very Poor**	• Failure of the overflow pipe due to sever corrosion/deterioration	

9.16 Ladder

ACA Rating	ACA Outcome	Description	Descriptive Photograph
1 or 2	**Excellent**	• No or very minor defects	
3 or 4	**Very Good**	• Minor corrosion/deterioration to the rails and rungs	
5 or 6	**Good**	• Moderate corrosion/deterioration to the ladder rails and rungs • Early signs of moderate rust	
7 or 8	**Fair**	• Severe localised corrosion/necking on the ladder rails	
9	**Poor**	• Severe localised corrosion/necking on the ladder rails • Imminent failure to the ladder	
10	**Very Poor**	• Ladder broken or disconnected from the wall	

10.0 APPENDIX B – LEVEL 1 INSPECTION TEMPLATE (TANK CLEANING)

Date of Inspection	
Report Completed By	
Inspection Completed By	
Client	
Tank / Reservoir Name	
Asset ID (Functional Location)	
Tank / Reservoir Location	
Tank / Reservoir Height	
Tank / Reservoir Diameter	
Tank Stand Height (if applicable)	
Volume	
Construction Year	
Construction Materials	

INSPECTION SUMMARY AND KEY OBSERVATIONS

Urgent safety issues exist	

Tank Leakage Visible		**Estimated Leakage volume**	
Tank Seal Inadequate			
Pre-clean sediment visible			
Peak Pre-Clean Sediment Depth (mm)		**Average Pre-Clean Sediment Depth (mm)**	

EXTERNAL COMPONENTS INSPECTION

ITEM #	COMPONENT DESCRIPTION	CONDITION RATING	COMMENTS	WATER CORPORATION REVIEW REQUIRED?*
1	Access Track			
2	Site Security			
3	Compound Fencing			
4	Site Drainage			
5	Concrete Walls Structural Condition			
6	Steel Walls Structural Condition			
7	Side Access Hatch			

8	**Paint or Coating Condition (walls)**			
9	**Tank / Reservoir Roof**			
10	**Tek Screws and Fasteners (roof)**			
11	**Tank Footing Ring**			
12	**Tank Stand**			
13	**Tank Stand Concrete Footings**			
14	**Visible Leaks Around Tank**			
15	**Inlet**			
16	**Outlet**			
17	**Overflow**			
18	**Antenna / Tower**			
19	**Level Indicator**			
20	**Valve Pit**			
21	**External Access Ladder**			
22	**Ladder Ascenders & Compliance Plates**			
23	**Working Platform on Roof**			
24	**Hatch**			

25	**Handrails / Edge Protection**			
26	**Rescue Davit & Compliance Plate**			
27	**Davit Mount & Compliance Plate**			
28	**Fall Arrest Points & Compliance Plates**			
29	**Ventilation**			
30	**Bird / Insect Proofing**			

INTERNAL COMPONENTS INSPECTION

ITEM #	COMPONENT DESCRIPTION	CONDITION RATING	COMMENTS	WATER CORPORATION REVIEW REQUIRED?*
31	**Concrete Walls Structural Condition**			
32	**Steel Walls Structural Condition**			
33	**Paint or Coating Condition (walls)**			
34	**Liner Condition (walls)**			
35	**Concrete Floor Structural Condition**			
36	**Concrete Floor Expansion Joints**			
37	**Steel Floor Structural Condition**			

38	**Paint or Coating Condition (floor)**			
39	**Liner Condition (floor)**			
40	**Wall to Floor Joint**			
41	**Wall to Roof Joint**			
42	**Roof Support Columns**			
43	**Roof Main Beams**			
44	**Roof Secondary Support (purlins)**			
45	**Roof Sheeting and Fasteners**			
46	**Ventilation**			
47	**Inlet**			
48	**Outlet**			
49	**Scour**			
50	**Overflow**			
51	**Anodes / Cathodic Protection**			

52	**Internal Ladder**			
53	**Level Indicator**			
54	**Pre-Clean Sediment Depth**			
55	**Pre-Clean Sediment Description**			
56	**Foreign Objects, Insects, Animals**			

INSPECTION VIDEOS AND IMAGES

Refer to electronic data for comprehensive inspection video of internal asset components (Attach the links)

11.0 APPENDIX C – LEVEL 1 INSPECTION TEMPLATE (DETAILED TANK INSPECTION)

1.0 Cover Page

2.0 Report Detail

3.0 Items for Review

4.0 Water Quality

5.0 Safety

6.0 External Components

7.0 Internal Components

8.0 Tank Arrangement

9.0 Asset condition rating for various tank components (Refer Appendix B Section 10).

12.0 APPENDIX C – LEVEL 2 INSPECTION TEMPLATE

1.0 Introduction

1.1 Background

1.2 Scope of Works

2.0 Findings and Discussion

2.1 Concrete Components

2.2 Steel Components (Tank Stand)

2.3 Steel Components (Tank)

3.0 Conclusion

4.0 Recommendations

4.1 Concrete Components

4.2 Steel Components (Tank Stand)

4.3 Steel Components (Tank)

4.4 Maintenance Strategy

Appendices

Appendix A – Typical Defects Photos

Appendix B - Drawings

Appendix C – Summary Inspection Findings

Table C1 – Summary of inspection findings of concrete elements

CONCRETE COMPONENTS									
Item	**Comments**	**Condition (refer Appendix. B) (% surface area observed) In-Service Assets, APG – Condition Rating**						**Overall Rating (Rounded)**	**Recommendations**
		1	**3**	**5**	**7**	**9**	**10**		
Column	Sample		100					3	Minor surface cracks should be monitored and investigated during the next maintenance shutdown.

Table C2 – Summary of inspection findings of Steel elements

METAL ELEMENTS									
Item	**Comments**	**Condition (refer Appendix. B) (% surface area observed) In-Service Assets, APG – Condition Rating**						**Overall Rating (Rounded)**	**Recommendations**
		1	**3**	**5**	**7**	**9**	**10**		
Inlet Pipe	Sample		50			50		6	Replace the deteriorated area.

Table C3 - Condition assessment criteria for concrete structures

Condition Rating Assessment Criteria for Concrete Structures		
Reinforced concrete may be cast-in-situ or precast. Components include wall, floor slab, ring beam etc.		
Rating	**Observed Component Condition**	**Repair / Maintenance Required**
1 – Excellent	– No or minimal concrete surface deterioration. As-built condition. – No or minor dark coloured staining, dampness, mould growth or white efflorescence. – Hairline cracking (≤ 0.1mm) may be present, majority of cracks are most likely from construction stage, thermal/restraint or drying shrinkage. – No etching or loss of cement matrix	No repair works required.
3 – Very Good	– Fine cracking (> 0.1 and ≤ 0.3mm) with no rust staining, majority of cracks are most likely from construction stage, thermal / restraint or drying shrinkage cracks. – Concrete may have localised delamination's or spalls with exposed corroded reinforcement. Loss of reinforcement cross section from active corroding reinforcement is unlikely from the observed condition. – A protective coating, if applied, is predominately intact however has experienced isolated/localised minor coating defects such as blisters, chalking, fading etc. – Localised dark coloured staining, dampness, mould growth or white efflorescence. – Minor surface etching or loss of cement matrix up to 3mm depth	No structural repair works required, however some minor repair work may be required for aesthetical purposes. Generally repair cost is low

5 - Good	– Medium cracking (>0.3 and ≤ 0.7mm) with or without rust staining, majority of fine cracks are most likely from construction stage, thermal/restraint or drying shrinkage cracks. – The concrete surface has inconsistent dark coloured dampness or efflorescence with substantial stalactites and lime leaching. – A protective coating, if applied, has experienced random deterioration with reduced barrier protection in the form of blistering, minor peeling. – The concrete surface has minor localised rust stains or concrete delamination's or spalling with exposed corroded reinforcement. – Exposed reinforcement exhibited advanced corrosion with loss of section, less than 5% – Medium surface etching or loss of cement matrix up to 10mm depth – Moderate cost for repair and refurbishment.	Some minor structural repair work required within 2 – 3 years. Protective treatments maybe required to achieve the design service life of the structure. A detailed investigation (Level 3) may be required to understand the mechanism of the deterioration and for the repair assessment. Moderate cost for repair works.
7 – Fair	– Cracks in the concrete are greater than the aforementioned medium (>0.7 and ≤1mm). Rust staining maybe evident in the cracks. – The concrete surface has substantial concrete delamination's or spalls with exposed corroded reinforcement. Exposed reinforcement exhibited some or moderate loss of section, upto 10%. – The observed defects are not of an immediate structural concern. – Widespread dark coloured staining, dampness, mould growth or white efflorescence (with numerous stalactites, and lime flows visible), combined with rust stains and/or concrete cracks, delamination's or spalls. – A protective coating, if applied, has widespread deterioration and required level of protection is no longer provided and subsequent minor concrete corrosion. – Advanced biogenic corrosion of concrete with substantial section loss, up to 20mm.	Substantial structural repair works required within 1 year. Protective treatment required to extend the service life of the structure. A detailed investigation (Level 3) is required to understand the mechanism of the deterioration and for the repair assessment. Moderate to high cost for repair works
9 – Poor	– Heavy cracking (>1mm) and spalling with consistent rust staining at the defect. – The concrete surface has widespread and numerous concrete delamination's or spalling with advanced corrosion of reinforcement with substantial loss of section and large areas of reinforcement exposed. The corroded areas of reinforcement have suffered a substantial loss in section, up to 25%. – The observed defects are not of immediate structural concerns yet further deterioration will compromise the structural integrity. No sign of deformation or deflection to the structure. – A protective coating, if applied, has widespread failure and	Substantial structural repair works required immediately. A detailed assessment is required to determine the economic viability of repair. Protective treatments required to extend the service life of the structure.

	subsequent substantial concrete corrosion – Advanced biogenic corrosion of concrete with substantial section loss, more that 20mm but hasn't reached to cover depth. – Minor isolated leaking or weeping is evident. – Widespread dark coloured staining, dampness, mould growth or white efflorescence (with numerous stalactites, and lime flows visible), combined with heavy rust stains and/or concrete cracks, delamination's or spalls.	A detailed investigation (Level 3) is required to determine the mechanism of the deterioration and economic viability of repairs. High cost for repair.
10 – Very Poor	– Multiple or frequent severe cracking, with consistent rust staining at the defect. – The concrete surface has widespread and numerous concrete delamination's or spalling with advanced corrosion of reinforcement with substantial loss of section and large areas of reinforcement exposed. The exposed reinforcement has suffered substantial severe loss in section, more than 50% or complete loss. – Advanced biogenic corrosion of concrete with substantial section loss, exposing reinforcement with severe corrosion. – Widespread leaking or weeping is evident – The observed defects are of immediate structural concerns with signs of deformation or deflection to the structure.	Beyond economic repairs and replacement of the structure is the only viable option.

Table C4 - Condition assessment criteria for steel structures

Condition Rating Assessment for Steel Structures		
The metal components may include stainless steel, aluminium, mild steel, galvanised steel etc. The components include roof beams, roof sheeting, support structures, flashings, ladder, access hatch etc.		
Rating	**Observed Component Condition**	**Priority for Repair works**
1 – Excellent	Appearance in "As- Built" condition. As-built condition Generally coated surfaces in "as-built" condition with no chalking, blisters, delamination etc. All connections / fasteners are present and secure and have no observed corrosion.	No action required till next scheduled inspection
3 – Very Good	– Isolated areas of surface corrosion with some localised pitting or crevice corrosion resulting in minor (≤ 10%) section loss. – A protective coating, if applied, is predominately intact however has experienced isolated/localised minor coating defects such as blisters, chalking, fading, etc... – The cost of repair or refurbishment is low. – The connections may have slight surface corrosion.	3 – 5years

5 - Good	– Surface corrosion throughout with some localised pitting corrosion resulting in minor (≤ 20%) section loss. – A protective coating, if applied, has experienced random deterioration with reduced barrier protection in the form of blistering, intercoat delamination, minor rust spotting (rashing), filiform etc. – The cost of repair or refurbishment is moderate. – The connections/fasteners may be corroded but are in a full serviceable condition.	2 – 3 years
7 – Fair	– Significant surface corrosion and/or localised corrosion, suggesting that moderate loss of cross section has occurred. The cost of repair or refurbishment is high. – A protective coating, if applied, has widespread deterioration and required level of protection is no longer provided. – The connections are loose or moderately corroded.	1 year
9 – Poor	– Substantial widespread corrosion resulting in a substantial loss of section jeopardising structural integrity. The component or structure is beyond economic repair. – A protective coating, if applied, has widespread deterioration and required level of protection is no longer provided. – The connections are loose, severely corroded or missing.	Immediate assessment for repair viability
10 – Very Poor	Failed – component has to be replaced Severe widespread corrosion, substantial loss of section and loss of structural integrity. Large numbers of connections/fasteners severely corroded and/or missing.	Renew / Replace

13.0 APPENDIX D – LEVEL 3 INSPECTION TEMPLATE

1.0 Executive summary

2.0 Introduction

3.0 Visual examination

4.0 Metallographic examination

5.0 Discussion

6.0 Conclusions