REPORT

Tonkin+Taylor

Construction Oversight Report

Shoal Bay Landfill - Leachate Storage Pond 3

Prepared for
City of Darwin
Prepared by
Tonkin & Taylor Ltd
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1 Introduction

1.1 Brief

Mr Anthony Kortegast of Tonkin & Taylor Pty Ltd, was engaged by the City of Darwin (Council) on 03 May 2022[1] to verify the design and then construction of Leachate Storage Pond 3 (LSP3) at the Shoal Bay Waste Management Facility, Holmes, Northern Territory. Mr Kortegast is an experienced landfill practitioner and Environmental Auditor (Industrial Facilities) currently appointed by EPA Victoria pursuant to the Environment Protection Act 2017. This report refers to the Auditor and audit related processes. While this terminology generally follows Victorian practice, it is stressed that while this is an oversight report prepared by an EPA appointed Auditor, it does not constitute a statutory audit.

The design of LSP3 was reviewed and verified[2] by Mr Kortegast in November 2022: ***Shoal Bay Landfill: Leachate Pond 3 – Design Verification, Tonkin & Taylor Pty Ltd, November 2023, ref: 1020203.V3*****.** The design verification followed a similar process to that which would apply to auditor verification of a landfill cell or cap design in Victoria, noting that in Victoria such design verifications are not required for ancillary landfill structures such as leachate ponds. The pond design was subsequently approved by the Northern Territory EPA (NT EPA) and on 29 November 2022 NT EPA issued Environment Protection Approval EPA350 which requires, inter alia:

> ***11. The approval holder must submit to NT EPA within 10 business days of completion of the facility and prior to use of the storage pond, a review of the completed activity with certification from a qualified person(s) that the works:***
>
> ***11.1 were constructed in accordance with condition 1;***
>
> ***11.2 were constructed in accordance with the final CQAP or if applicable the revised CQAP;***
>
> ***11.3 "as constructed" will deliver the intended purpose; and***
>
> ***11.4 are compliant with condition 7 of this approval.***

The cross referenced conditions are:

> ***1. The works must be completed in accordance with the approval application accepted on 26 October 2022 and additional information as per Table 1.***
>
> ***Table 1.***

Document name	***Document date***
Shoal Bay Waste Management Facility Leachate Storage Pond 3 CQA Plan (PS132636-013-R-Rev0_CQA Plan)	***23/11/2022***
Construction Environmental Management Plan Shoal Bay Waste Management Facility Leachate Storage Pond 3 (PS132636-018-RCEMP_Rev0)	***14/11/2022***

[1] Tonkin & Taylor Pty Ltd – Shoal Bay Waste Management Facility – Leachate Pond 3 Construction Audit, 24-11-2022 (Ref: 1020203.1000P v2)
[2] Non-statutory

Quality Management Plan Shoal Bay Waste Management Facility Leachate Storage Pond 3 (PS132636-009-QMP-Rev0)	***23/11/2022***
Shoal Bay Waste Management Facility Leachate Storage Pond 3 Design (PS132636-016-R-001-016_REV0)	***24/11/2022***
Shoal Bay Waste Management Facility Leachate Storage Pond 3 Technical Specification (PS132636-004-R-001_Rev0_Technical Specification)	***24/11/2022***

7. The approval holder must conduct the activity in accordance with the CQAP[3] submitted to the NT EPA.

The CQAP was prepared by WSP Golder and submitted to NT EPA in November 2022, in accordance with Condition 6. A copy of the CQAP is provided as Appendix A to this report. At Section 4.1 the CQAP identifies WSP Australia Pty Ltd (WSP Golder) as the "certifier of the works. The "Environmental Auditor" is identified as *"…the Qualified Person approved by the NT EPA and commissioned by the City of Darwin to oversee and verify whether the WUC[4] comply with the Specification…."*. Hence the aim of the Auditor oversight and this report is primarily to assess whether the works have been constructed in accordance with the Specification. Formal Certification of the works will be by others. In this regard the Auditor has considered the requirements of the other approval documents including the Construction Environmental Management Plan and the Quality Management Plan insofar as required under the oversight scope.

Hence, in summary, the Auditor role was one of periodic observation and oversight, monitoring of the progress of the works and designer responses to issues as they arose, and provision of an overall assessment of Specification compliance.

1.2 Background

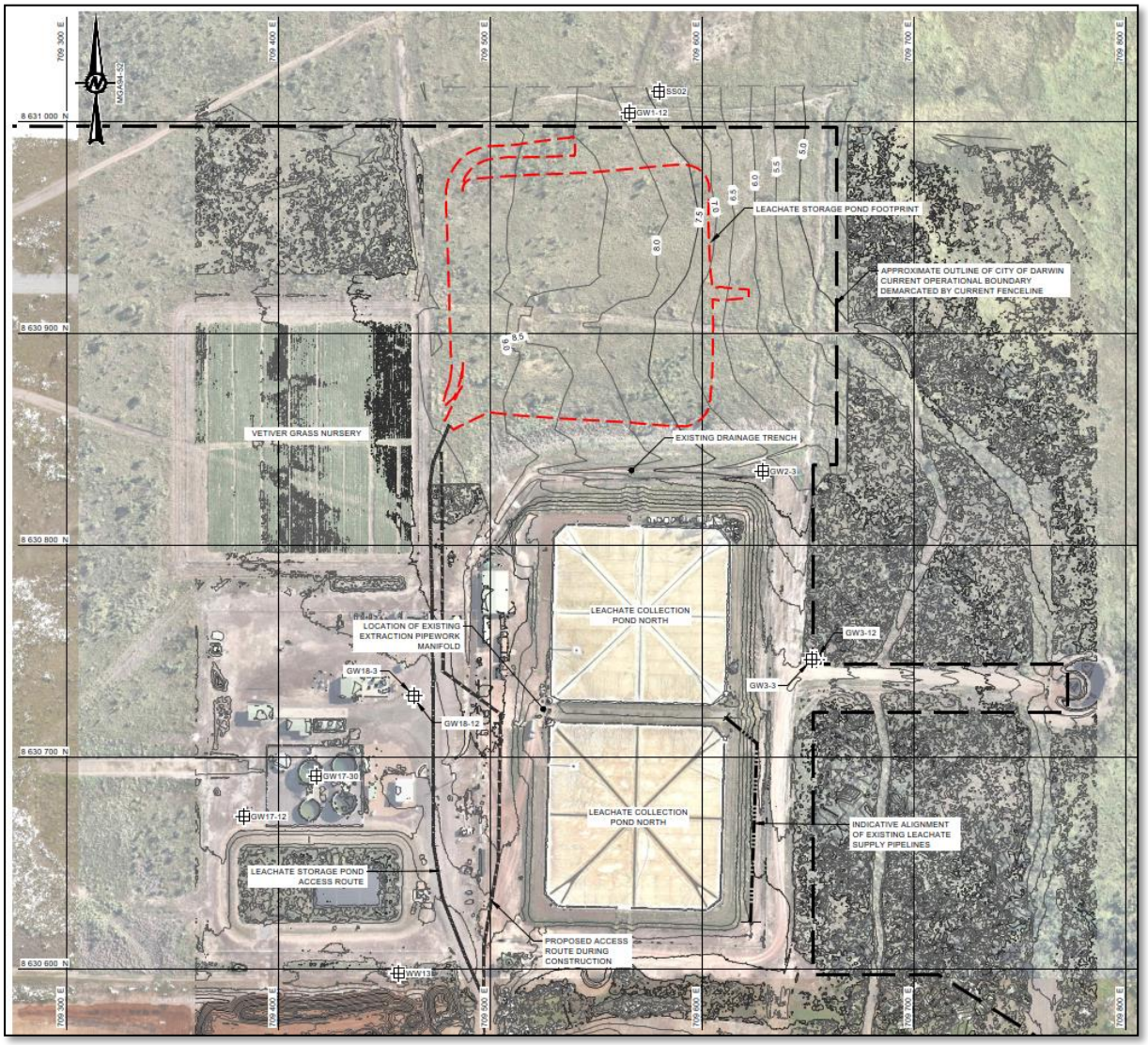
Council has the expressed aim of mitigating adverse environmental effects and moving towards implementing best practice landfill design as well as progressive rehabilitation and improvement at the Shoal Bay landfill, in line with landfill practice now being followed elsewhere in Australia. The Council is planning further cell expansions and leachate system improvements as part of its overall waste management strategy.

The Shoal Bay landfill is a conventional municipal solid waste landfill that accepts a variety of putrescible and solid inert wastes. It is subject to ***Northern Territory EPA Licence EPL 188-03*** issued on 02 July 2021. The licence requires that the site be operated in accordance with the ***Environmental Management Plan for Shoal Bay Waste Disposal Site*** (Ref: 189753-43, 13 December 2021).

LSP3 is the third leachate pond to be constructed at the site, as shown in **Figure 1.1**.

[3] Construction Quality Assurance Plan
[4] Works Under Construction (the works)

Figure 1.1: Leachate Pond Location (red dashed line)



LSP3 provides additional leachate storage and pre-treatment capacity for the landfill and is aimed at providing additional wet season storage capacity and to avoid leachate system overload. The pond measures approximately 90m x 90 m and is up to 3.2 deep from sump to 'maximum storage level' at 9.7m AHD. The total pond depth from sump to top of bund wall is 4.2m. The pond has a capacity of approximately 16ML and is designed with a freeboard of 500 mm.

The pond is located to the north of the two existing leachate storage ponds and is of similar size to those constructed previously.

2 Auditor oversight method

2.1 Scope

Following the Auditor issuing a verification report for the pond design and as part of its construction approval, NTEPA required a construction management and works certification process as described above and this was performed by WSP Golder and Council staff. Council engaged the Auditor, as required, to independently monitor construction against the Specification requirements following on from verification of the design.

While not covered by current guidance, the principles of barrier (liner) design and Manufacturing Quality Assurance/Construction Quality Assurance (MQA/CQA) that apply to landfill liners can also be applied to other related landfill infrastructure such as leachate ponds or caps.

Hence this non-statutory verification report covers the pond construction including site preparation, subgrade fill, the liner system and associated drainage and ancillary works. It excludes the floating geomembrane cover which was independently designed and installed by Fabtech Pty Ltd.

2.2 Objective

The objective of this verification is to confirm that construction of LSP3 meets the design and specification requirements and was completed generally in accordance with the CQAP. The required outcome of the assessment is a statement by the Auditor/reviewer that the construction has been verified through observation and MQA/CQA documentation as meeting the design intent and complying with the Specification.

2.3 Approach and constraints

Following Auditor verification of the design[5], the Auditor engaged with Council, its consultants and construction team ahead of, and throughout the construction of LP3. Owing to the remoteness of the site location and the onset of wet season weather, scheduling of the works, and in turn the scheduling of site visits by the audit team proved difficult. Therefore, the construction period extended and made scheduling site visits difficult. As a result, this verification relies on observations made by the Auditor's expert team members and extensive construction compliance data set provided by the designer, GITA and third-party liner installation verification consultant (also referred to in the Specification as the "contractor".

When the construction data was provided to the Auditor it was presented in a format that would not meet Victorian requirements for verification of landfill construction[6] and hence the Auditor has needed to interpret the data set as provided in order to form an opinion in relation to construction against the Specification and hence the likely environmental performance of the pond structure. In doing so the Auditor has adopted a pragmatic approach, focussing on the critical design elements: specifically, the primary environmental barrier (the bottom pond liner).

Overall, the process of design review and verification for technical compliance has followed Victorian practice for landfill construction assessment, albeit with less than perfect MQA and CQA data. This review and construction verification is based on the following:

- The verified LP3 design;
- Records of construction provided by Council and its consultants;
- On-line meetings and discussions as the work progressed;

[5] Non-statutory

[6] This has resulted in separate communication from the Auditor to Council ahead of the Stage 7 cell construction to ensure record keeping and data presentation is improved for that more critical construction work.

- Two site visits by members of the Auditor's team; and
- MQA/CQA data provided by the site team and the geomembrane verification Consultant (GVC).

The output of the verification is the provision of this report demonstrating appropriate review and verification of construction, with recommendations as appropriate.

3 Guidance documents

Some guidance for the design and construction of leachate ponds is provided in the NT EPA publication: ***Guidelines for the Siting, Design and Management of Solid Waste Disposal Sites in the Northern Territory***, January 2013.

At Page 40, Section 5, the guidance states:

- *"Prior to and during treatment, leachate must be stored and managed in a manner such that it will not escape into surface water or groundwater, will not cause offensive odours and will minimise human contact with the leachate*." Management options for leachate include evaporation, discharge to sewer, treatment, surface irrigation and dust suppression (effectively evaporation).
- *"to prevent seepage from the treatment system into groundwater,* leachate *[sic] ponds should be lined to the equivalent standard as the landfill."*
- *"Where leachate is to be evaporated, it should be within a closed system where no leachate is able to escape to the environment. Ponds are typically used to evaporate leachate."*

At page 36, Section 4, the guidance states:

- *"Composite liners are required in all medium and large Municipal Solid Waste (MSW) landfills"* (such as the Shoal Bay Facility.
- Figure 0.6 illustrating the required elements of a landfill cell composite liner includes the requirement for two forms of liner, a compacted clay liner (barrier 1) and a geomembrane liner (barrier 2).

At page 37, Section 4, the guidance states:

- *"Double liner systems consist of either two singles liners, two composite liners or a single and composite liner. The upper liner collects leachate, whilst the lower liner acts as a leak detection system and backup for the primary liner. Landfills designed with double liner system are capable of accepting Listed Wastes or a higher leachability concentration than composite liner systems."*

The approved design for LP3 includes a double liner system with two different geosynthetic barriers (a primary liner of high density polyethylene geomembrane (HDPE GM) and leakage detection system and a lower secondary liner of bituminised geomembrane (BGM).

In verifying the LP3 design, the Auditor gave consideration to the guidance and the general requirements for barriers (liner systems) being constructed for landfill leachate containment as referred to in the applicable NT EPA landfill guidance, as well as the EPA Victoria Publication 788.3: ***Best Practice Environmental Management: Siting, design, operation and rehabilitation of landfills***, August 2015 (the Victorian landfill BPEM).

The above guidance makes no reference to "construction" and hence the process of certifying the adequacy of construction is based on the requirements of EPA 350 which require the construction to be certified by a qualified person(s) as being constructed in accordance with Condition 1 of the EPA approval and in accordance with the final/revised CQAP required under Condition 6, and hence that the pond "as constructed" will deliver its intended purpose.

4 Risk context

Leachate ponds differ significantly to landfills in terms of the stresses that the barrier is subject to. Landfill bottom liners are often deeply buried and under high load. Also, they are inaccessible once cell filling starts. In contrast, leachate ponds are lightly loaded and as they are surface containment structures they can be drained and repaired should the need ever arise. The barrier system in a leachate pond is generally subject to much lower stresses and temperatures than occur with landfill cell bottom liners. Furthermore, as they are accessible, the condition of leachate pond liner components can be regularly assessed by direct inspection and their containment performance is better able to be monitored. This type of monitoring usually occurs both visually (as part of regular site oversight) and as part of site environmental monitoring (in relation to discharges to surface water and groundwater).

In practice, the main risk elements in relation to how the leachate pond will ultimately perform are:

- The integrity and performance of the liner system;
- The effectiveness of the intermediate leak detection and drainage system;
- The quality of the subgrade in terms of supporting the liner system and managing differential settlement; and
- The performance of the floating cover in reducing rainfall contribution to leachate volumes.

5 Documents Reviewed

As part of this verification the following documents were referenced and reviewed:

- Shoal Bay Waste Management Facility – Leachate Storage Pond 3 CQA Plan: PS132636-013-R-Rev0
- Shoal Bay Landfill LP3 design documents including:
  - PS132636-004-R-RevB_Technical Specification.pdf
  - PS132636-016-R-001-016_RevA.pdf (design drawings)
- Shoal Bay Waste Management Facility – Leachate Storage Pond 3 Construction Environmental Management Plan: PS132636-018-RCEMP-Rev0
- Shoal Bay Waste Management Facility – Leachate Storage Pond 3 Quality Management Plan: PS132636-00-QMP-Rev0
- MQA/CQA data including:
  - Week ending 17 Decphoto montage.doc
  - NCR001_Site Won Material_Rev0.pdf
- Site third party construction quality assurance reporting including[7]:
  - PS132636-028-RevA Manufacturers Report – Main Doc.pdf
  - PS132636-028-RevA Manufacturers Report – Appendix B.pdf
  - PS132636-028-RevA Manufacturers Report – Appendix C.pdf
  - PS132636-028-RevA Manufacturers Report – Appendix D.pdf
  - PS132636-028-RevA Manufacturers Report – Appendix E.pdf
  - PS132636-028-RevA Manufacturers Report – Appendix G.pdf
  - PS132636-028-RevA Manufacturers Report – Appendix I.pdf

[7] The following Appendices were not provided to the Auditor but were substituted in part with Auditor team photographs and records from site visits: Appendix A - construction photographs, Appendix F - completed ITP's and ITRs records, and Appendix H - CQA for the floating cover (out of scope).

6 Assessment of pond construction elements

The design of LP3 was informed by prior experience with LP1 and LP2, in particular in relation to the management of wet season conditions. The ponds are designed to accommodate heavy duty floating covers that are designed to minimise the risk of damage during cyclones and to manage wet season rainfall by separating and decanting this from the top of the floating cover system. Verification of the construction of this design element is outside the scope of this report.

The construction period for LP3 was significantly impacted by weather. This mean that the construction as somewhat stop-start. Consequently, scheduled inspections proved difficult to coordinate and 3 scheduled visits by the design verification specialist were either cancelled or needed to be undertaken by other members of the team.

In addition, the site team provided photographic reports and updates as work re-commenced between periods of wet weather. Site visits carried out were:

- 17 March 2023 – Subgrade works.
- 02 & 03 May 2023 – Completion of HDPE GM liner and floating cover installation

Overall, the Tonkin & Taylor team is considered to have observed enough of the critical aspects of the works to form the view that the works have been completed generally in accordance with the Specification and CQAP. The critical work elements observed include:

Site visit 1

- Unit 2 Select Fill - Observed completion of placement of Unit 2 select fill for lots 1 and 2, and portion of lot 5 (floor). Cited samples of QA records, ITP, field inspection checklist, as built data for lots 1 and 2.
- Unit 7 Rip Rap - Construction of the external spillway had commenced to base level which include the spillway, chute, dissipation basin. Cited construction method statements and construction management plans, and ITP associated with this unit.
- Unit 8 Pavement Material – Construction of the crest access had commenced and observed that pavement material (unit 8) had been placed on the southern, western, and northern embankments (Lots 1, 2 and 4). Cited construction method statements and construction management plans, and ITP associated with this unit.
- Unit 19 Overflow Pipe- The emergency pipe and well had been installed at the time of the site visit/inspection and observed the construction method statement for this unit.
- Unit 20 - Concrete - The concrete overflow chamber had been installed at the time of the site visit/inspection and observed the construction method statement for this unit.

Site visit 2

- HDPE GM panel and seam layout.
- Evidence of seam and repair non-destructive testing (vacuum box and needle pressure testing).
- Evidence of seam destructive testing process (patches and repairs).
- Reduced wrinkles during early morning HDPE GM contracted state.
- Anchor trench construction and restraint.
- Leachate extraction sum construction.
- Spill way dimensions and vehicle crossing slab construction.
- Leachate inlet pipe and method of securing to the side wall liner.

- The pond surface water diversion system dimensions and re-vegetation.
- Leachate sump riser pipes and concrete headwall construction.
- Emergency leachate overflow weir box.

6.1 Subgrade

6.1.1 Subgrade material compliance assessment

The objective of the subgrade and base fill Specification is to ensure that a stable foundation is provided for the pond liner system. The Auditor team observed completion of placement of Unit 2 select fill for lots 1 and 2, and portion of lot 5 (floor). The Auditor also received photographs, QA records, ITP, field inspection checklists, and as-built data for lots 1 and 2.

Although there were some testing method substitutions, and although the oversight team was unable to validate some of the testing frequencies, the Auditor considers that there is sufficient evidence of testing and compliance for Units 1-8 and the results were generally compliant with Specification requirements. Some minor variations and non-compliances were dealt with the by the designer/certifier, and these are discussed in variation memoranda included in the GITA reporting.

The construction was recorded by way of multiple surveys (noting the stop/start nature of the work owing to inclement weather).

Overall, the Auditor considers the Specification requirements in relation to subgrade and embankment fill quality were met. Given the low loadings and the tolerance of the liner system to minor differential settlement, the oversight team's efforts were focussed on ensuring the quality of the overlaying liner system which is the primary environmental barrier.

6.2 BGM secondary liner

6.2.1 BGM material compliance assessment

The project Technical Specification requires the following:

- *Quality control (MQC) test results conducted on samples proposed for the Works. MQC data shall demonstrate the proposed material will meet the requirements of Table 16 with regards to material property values and testing frequencies.*
- *The Designer will review manufacturers information and assess whether independent testing is required based on the MQC results presented' and "the GITA may recover samples from the geomembrane rolls delivered to site and arrange independent testing of the samples to confirm the material meets the requirements of the Specification.*

The manufacturer quality assurance testing data supplied by WSP to the Auditor indicates the key performance requirements of the specification were tested for during the manufacturing process. Thickness, mass per unit area, tensile, tear and puncture resistance testing were performed with results at or above the minimum standard required by the project Technical Specification.

The designer and third party construction quality assurance consultant (WSP) elected to undertake sampling of a number of rolls representative of the batch of materials supplied to site, and arranged for independent testing by NATA accredited testing laboratory TRI Australasia Pty Ltd. The testing results for these samples from 8 non-sequential rolls met and exceeded the minimum performance standards set out in the project Technical Specification. The material properties tested for were thickness, mass, tear resistance, tensile strength, elongation, and puncture resistance.

Evidence has been provided demonstrating that BGM liner quality has been tested, both as part of a manufacturer quality control system, and again independently upon delivery to site, and the results confirm minimum material performance standards have been achieved.

6.2.2 Installation methods and records compliance assessment

The liner installation contractor and TPCQA (WSP) put in place a system of construction inspection and testing hold points and provided the Auditor with their Inspection Test Plan Register (ITPR) which sets out the forms to be filled out upon inspection. The TPCQA provided a register to the Audit team that set out the following:

- The item to be inspected (e.g., "*BGM vacuum box testing");*
- The responsible party;
- Any relevant test method or specification reference;
- Acceptance criteria;
- The frequency of testing;
- Verifying document/forms/records to be used; and
- Whether it was a hold point, witness point, visual observation, test, or surveillance.

The Auditor was provided with a register of Requests for Information (RFI's) related to material approvals, compiled by EAC. These forms contained requests for review, acceptance, and approval of materials as being compliant with project specifications, by the TPCQA. Although not formally signed, these are considered to be a reliable record of TPCQA having agreed that materials were compliant with specification requirements. The Auditor was not provided with these documents or the TPCQA's assessment prior to material being installed, but this is deemed acceptable as the Auditor was not responsible for certifying construction of the works.

The Auditor has been provided with evidence of the installation contractor (Fabtech Australia Pty Ltd) certification of membership with the International Associated of Geosynthetic Installers (IAGI).

Also provided were the certificates of calibration for pressure gauges for non-destructive testing equipment, and for tensiometers used in destructively testing trial weld and as-built seam samples. All calibration certification was within 12 months of the date of Pond 3 liner installation works.

A register of materials (Roll number, Serial number, and length) was provided to the Auditor by the TPCQA post installation, for HDPE GM materials.

The Auditor was provided with completed Inspection and Testing Plan documentation (ITPR's) for liner installation by Eastern Arm Civil Pty Ltd (EAC) the earthworks contractor and Fabtech Pty Ltd the lining installer, and WSP Pty Ltd (The TPCQA). These records are considered evidence of a system of review and approval of installation against design required methods, standards and performance requirements including:

- Proposed liner installation layout plans;
- Suitability of subgrade for placement of liner materials;
- Liner installation works (panel, seam, repair location/testing record sheets);
- Trial welds, destructive and non-destructive testing of as-built liner; and
- Liner panel, seam, and repair layout plans.

The Audit team has reviewed the installation records and considers them to be generally compliant with the project specification requirements as they are relatively complete, without significant data gaps, and with quality assurance test results that meet the required performance standards for destructive and non-destructive testing of seams and repairs.

The Auditor is satisfied that a reasonable quantity of construction verification data has been collected during installation of the primary BGM liner compliant with intent of the project Technical Specification. There is good evidence that effort was taken to reduce the amount of welding and increase the area of large intact panels of BGM to form the liner over the pond's internal surface.

Panels were joined using flame torch and application of pressure roller. Third party records verify that the seams between panels were subject to both non-destructive (vacuum box and air lance testing) and destructive testing (using a calibrated tensiometer) with results indicating significantly greater weld strength and integrity was achieved than the minimum standard required by the project specification.

The number of repairs per unit area of liner is considered industry average (in the Auditor's experience) with a total of 76 repairs, 22 of which relating to repairs at locations where samples of seam were taken for destructive testing.

When first observed by the Auditor's representative on 02 May 2023, the liner was in a relaxed state due to low sun exposure, and the HDPE geomembrane liner covered the BGM. Due to the heat in the liner some wrinkles were felt in the BGM through the HDPE geomembrane in particular across the floor. Upon repeat inspection the next morning prior to direct sun exposure, the liner had contracted to a taut, smooth condition with no wrinkles being felt beneath the HDPE Geomembrane.

Overall, the Auditor is satisfied that the lower bituminous barrier was installed in accordance with the Specification.

6.3 Leak Detection System

6.3.1 Geonet material compliance assessment

The design utilised a drainage geocomposite in the form of a geonet, to intercept any leakage through minor defects in the primary liner and drain that leachate to a sump for extraction. The Specification required the geonet achieve a specific minimum performance in terms of:

- The thickness density and compressive strength of the core;
- The mass per unit area, CBR burst strength and tensile strength of the geotextile layers; and
- The flow rate per unit width of the finished geocomposite.

The manufacturer quality assurance (MQA) testing data supplied by WSP to the Auditor indicates:

- The HDPE core of the geonet was tested for thickness and density with compliant performance but the thickness was tested at a significantly reduced pressure than required (2kPa not 50kPa). The compressive strength was not tested but given the low normal loads this is not a concern.
- The geotextile fabric was tested for its mass (indicator of strength and infiltration performance) and CBR burst strength, but not tensile strength. Mass and CBR burst strength results were below the minimums required.
- The total geocomposite (finished geonet) was tested for flow rate in accordance with the required testing methods. The results of the testing demonstrate the material met the required standard with exception of compressive strength which again was not tested (see above).

The designer and third-party construction quality assurance consultant (WSP) elected to undertake sampling of a number of rolls representative of the batch of materials supplied to site and arranged for independent testing by NATA accredited testing laboratory. Testing was performed on the HDPE core (thickness and density of HDPE) and on the completed composite (flow rate).

The testing results for these samples met and exceeded the minimum performance standards set out in the Specification, with the exception of one marginally under thickness result. However, the thickness result (4.95mm instead of 5mm) was measured at a pressure significantly greater than that required by the Specification (200 kPa instead of 50 kPa) and it can therefore be considered a passing result.

The Auditor notes that while the compressive strength of the geonet core was not tested by the manufacturer, the results of the independent laboratory testing of thickness under significant confining pressure, are a good indicator of material strength under the simulated field conditions. On this basis the absent MQA compressive strength testing is considered a minor non-compliance.

It is noted that the flow rate achieved by the samples subject to independent testing are more than 4 times the minimum flow rate required by the Specification. Flow rate and core thickness under pressure are the key performance requirements for this material.

The Auditor considers that sufficient evidence has been provided to demonstrate the geocomposite quality has been tested and adequately demonstrated, both as part of a manufacturer quality control system, and again independently upon delivery to site. The results confirm minimum material key performance requirements as specified have been achieved. In addition to the drainage geocomposite material and installation compliance, the Auditor's team observed sufficient installation quality verification documentation to demonstrate that the leak detection drainage layer is graded to a single point on the floor where leachate can be removed by pump(s) lowered down HDPE sump riser pipes that travel down the inside of the pond side wall. The sump, riser pipe and associated materials appear to have been installed as per design drawings with some minor modification during construction to allow for unforeseen site conditions.

6.4 HDPE GM primary liner

6.4.1 HDPE GM material compliance assessment

The HDPE GM material manufacturer quality assurance testing data (MQA) and independent laboratory quality assurance testing data (IQA) provided to the Auditor demonstrate that the geomembrane met the Specification requirements for:

- Basic physical properties (density and thickness) for both MQA and IQA;
- Strength parameters (tensile strength, elongation, tear, and puncture resistance) for both MQA and IQA; and
- All of the durability performance indicator parameters (carbon black content and dispersion, oxidative induction time, oven aging, stress crack resistance and UV resistance) for MQA but only carbon black content and dispersion.

The Specification states that testing for other durability indicators (oxidative induction time, oven aging, stress crack resistance and UV resistance) was only required by the manufacturer and IQA testing was only needed if the designer considered it necessary. This was not commented on by the TPCQA, but no IQA testing was undertaken for these parameters at the designer/certifier's discretion.

Roll number E3K137184R was retested for all tensile properties in cross machine direction as break elongation failed. However, there is also no mention of failures and retests. This is considered a minor non-compliance considering the low load situation under which the geomembrane is placed.

Although the frequency of IQA testing was reviewed and confirmed compliant, no assessment of MQA testing frequency was provided to the Audit team.

MQA summary data was provided, but only for 15 rolls which the Auditor understands to be the rolls that were sampled for IQA testing.

It is difficult to confirm the frequency of testing used by the manufacturer as each roll has a result for a test, but it is unclear which rolls actually underwent testing.

In summary, the evidence provided by the TPCQA supports the conclusion that an adequate manufacturer testing program was undertaken, in general compliance with the Specification, with all the primary material performance parameters tested. Given the low design load situation in the pond, the testing approach adopted, while less rigorous that would be required for a landfill bottom liner, is considered adequate and the field performance of the material as represented by the testing data is considered to meet the Specification requirements.

6.4.2 Installation methods and records compliance assessment

The liner installation contractor and third party construction quality assurance consultant (TPCQA) put in place a system of construction inspection and testing hold points and provided the Auditor with their Inspection Test Plan Register (ITPR) which sets out the forms to be filled out upon inspection. The TPCQA provided a register to the Audit team that set out the following:

- The item to be inspected (e.g., "*trial weld process for geomembrane panel joinery");*
- The responsible party;
- Any relevant test method or specification reference;
- Acceptance criteria;
- The frequency of testing;
- Verifying document/forms/records to be used; and
- Whether it was a hold point, witness point, visual observation, test, or surveillance.

The Auditor was provided with a register of Requests for Information (RFI's) related to material approvals, compiled by EAC. These forms contained requests for review, acceptance, and approval of materials as being compliant with project specifications, by the TPCQA. Although not signed, these are considered to be a formal record of TPCQA having agreed that materials were compliant with specification requirements. The Auditor was not provided with these documents or the TPCQA's assessment prior to material being installed, but this is deemed acceptable as the Auditor was not responsible for certifying construction of the works.

As stated in Section 6.3, the Auditor has been provided with evidence of the installation contractor's certification of membership with the IAGI and certificates of calibration of both destructive and non-destructive testing equipment. All calibration certification was within 12 months of the date of Pond 3 liner installation works.

A register of materials (Roll number, Serial number, and length) was provided to the Auditor by the TPCQA post installation, for HDPE GM materials.

The Auditor was provided with completed Inspection and Testing Plan documentation (ITPR's) for liner installation by Eastern Arm Civil Pty Ltd (EAC) the earthworks contractor and Fabtech Pty Ltd the lining installer, and WSP Pty Ltd (The TPCQA). These records are considered evidence of a system of review and approval of installation against design required methods, standards and performance requirements including:

- Proposed liner installation layout plans;
- Suitability of subgrade for placement of liner materials;
- Liner installation works (panel, seam, repair location/testing record sheets);

- Trial welds, destructive and non-destructive testing of as-built liner; and
- Liner panel, seam, and repair layout plans.

The Audit team has reviewed the installation records and considers them to be generally compliant with the project specification requirements as they are relatively complete, without significant data gaps, and with quality assurance test results that meet the required performance standards.

The Auditor is satisfied that a reasonable quantity of construction verification data has been collected during installation of the primary HDPE GM liner. There is good evidence that effort was taken to reduce the amount of welding and increase the area of large intact panels of geomembrane to form the liner over the pond's internal surface.

Panels were joined using fusion dual track wedge welding (the more robust of the two available welding methods) with only minor extrusion welding. Third party records verify that the seams between panels were subject to both non-destructive and destructive testing with results indicating significantly greater weld strength and integrity was achieved than the minimum standard required by the project specification.

The number of repairs per unit area of liner is considered relatively low and the Auditor's representative noted only one issue during site inspection that required further attention. The issue noted was relatively minor (some small sign of weld overheating) which was advised to the site personnel for actioning, along with other repair work scheduled for the days after the site visit. Two other areas of damaged geomembrane were noted but confirmed to be already identified by the TPCQA and scheduled for repair.

When first observed by the Auditor's representative on 02 May 2023, the liner was in a relaxed state due to low sun exposure, with induced thermal expansion resulting in some minor wrinkles across the floor and lower sections of the side walls. Upon repeat inspection the next morning prior to direct sun exposure, the liner had contracted to a taut, smooth condition with only very minor small relatively disconnected wrinkles. The Auditor's representative advised site representatives that the pond should be first filled with care during the cool part of the morning so that the risk of wrinkles becoming trapped and folded by hydrostatic loading is minimised. Once the weight and thermal mass of the leachate has weighed down the geomembrane in its most contracted state, the risk of wrinkles being trapped and pinched reduces significantly.

The Auditor team did note some trapped water between the two liner layers in one area. This was related to the weather during construction and any trapped water would ultimately drain through the secondary drainage system. This is not uncommon in such situations and is not considered problematic. In practice, the water being trapped indicates that the bottom liner was well seamed and watertight, even without vertical surcharge.

Overall, the Auditor is satisfied that the primary geomembrane barrier was installed in accordance with the Specification.

6.5 Emergency spillway and overflow systems

The Auditor was provided with the following evidence of spillway and overflow system construction in relation to compliance with design requirements:

- Pipe, concrete, geotextile, inlet grating, and aggregate material quality testing results for comparison with project Technical Specification requirements.
- Survey of pipes and ground levels for comparison with design drawing levels, grades, and thicknesses.
- Photos of pre/post installation works.

6.5.1 Spillway

Spillway construction verification included:

- Survey confirmation of the base of spillway levels and the volume of excavated of material from the bund wall to create the base of spillway level
- Confirmation of subgrade conformation pre-spillway concrete, filter geotextile and aggregate placement
- Survey of rip-rap volume and layer thickness
- Survey conformation of riser pipe, inlet pipe and spillway slab extraction and blinding volumes
- Post-spillway slab survey
- Pre and post pour inspections and checklist
- Concrete compressive strength report.

The Auditor has reviewed the evidence of compliance with design requirements and considers the information provided is sufficient to provide assurance the spillway materials and installation standard meets the design intent.

The spillway subgrade excavation, extent of filter geotextile, thickness and extent of concrete and aggregate works are all in accordance with the design drawings. Concrete, aggregate and geotextile testing generally conforms to the requirements of the project Specification as supported by the compliance testing presented in Appendix G of the WSP manufacturers' data reports.

The finished surface condition is of a high standard with the concrete spillway works blending smoothly into the anchor trench backfill and water should flow unimpeded across from the concrete apron over and into the aggregate-lined chute down the side of the pond and into the energy dissipation basin.

6.5.2 Overflow Weir Box and Solid Overflow Pipe

The weir box and overflow pipe construction verification included:

- As-constructed survey confirmation of weir box and pipe trench alignment, levels, and grades
- Survey confirmation of stabilized sand, blinding, and backfill thickness and volumes
- Welding of pipes and weir box
- Trench backfill compaction (density and moisture content) testing
- Pre and post-pour inspections and checklists
- Concrete compressive strength report.

The Auditor has reviewed the evidence of compliance with design requirements and considers that the information provided is sufficient to provide assurance that the weir box and overflow pipe materials and installation records demonstrate that the design intent was achieved.

The subgrade excavation, thickness and extent of blinding, concrete, no-fines concrete, and backfill works were all in accordance with the design drawings. Concrete strength and backfill compaction testing generally conform to the requirements of the project Specification, as shown by the compliance testing presented in Appendix G of the WSP manufacturers' data reports.

The dimensions of the weir box, the pipe material and diameter, along with the grade of the pipe generally match those set out in the detailed design drawings.

The finished condition of the exposed outer face of the weir box was inspected by the Auditor's representative during a site visit. The WSP representative and Auditor noted that some of the protective plastic shims that were to be installed between the corners of the metal weir box lid and

the geomembrane were missing and the WSP representative noted this as a corrective action to be followed up on. Other than this issue, the Auditor's representative noted the weir box and pipe outlets appeared in good condition as per the design drawing details.

6.6 Floating cover

The design, installation, CQA and certification of the floating cover construction was outside the scope of the Auditor verification.

7 Conclusions and Recommendations

7.1 Conclusions

The Auditor concludes that the construction of LP3 generally meets the Specification and design intent. The Auditor is satisfied that the Pond, as constructed, will perform in line with design expectations.

While the process of oversite and data recording was disrupted by weather and records were in some instances incomplete, the general volume of data provided was extensive and Auditor is satisfied that non-conformances were minor overall and that the works as constructed are likely to perform satisfactorily. Aspects of the Specification requirements were relaxed or varied at the discretion of the designer and works certifier, but as noted, the Auditor considers that the overall process met the Specification intent.

7.2 Recommendations

The Auditor makes the following recommendations:

- Nil.

8 Applicability

This report has been prepared for the exclusive use of our client, the City of Darwin, with respect to the particular brief given to us. This report may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

This report has been prepared by Mr Kortegast as an experienced landfill practitioner. **It does not constitute a statutory auditor verification conducted in accordance with EPA Victoria guidance and regulation**. The conclusions and recommendations (if any) provided within this report have been based on information provided to the Auditor by the audit team and third parties.

This verification and does not constitute construction verification. The Auditor has assessed the general form of the application of the construction against the design and specification at the site based on experience, relevant guidance and field records, but this does not extend to confirming the absolute validity of construction methods or underlying design assumptions.

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