Technical Report C

Geotechnical Dam Assessment

C

Attachment 4

Geotechnical and Dam Assessment Report prepared by PDP

Redvale Ponds 5 and 6 Geotechnical and Dam Assessment Report

Prepared for

Waste Management New Zealand

November 2025

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Quality Control Sheet

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Limitations:

This report has been prepared by Pattle Delamore Partners Limited (PDP) on the basis of information provided by Waste Management New Zealand Ltd and others (not directly contracted by PDP for the work), including Tonkin and Taylor. PDP has not independently verified the provided information and has relied upon it being accurate and sufficient for use by PDP in preparing the report. PDP accepts no responsibility for errors or omissions in, or the currency or sufficiency of, the provided information.

This report has been prepared by PDP on the specific instructions of Waste Management New Zealand Ltd for the limited purposes described in the report. PDP accepts no liability if the report is used for a different purpose or if it is used or relied on by any other person. Any such use or reliance will be solely at their own risk.

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1.0 Introduction

Pattle Delamore Partners Ltd (PDP) was engaged by Waste Management New Zealand Ltd (WMNZ, the client) to undertake a dam and geotechnical engineering assessment of two existing ponds at the Redvale Landfill and Energy Park located at Dairy Flat. The assessment covers Pond 5, Pond 6 and the associated dams (termed as Dam 5 and Dam 6 in this report) to support the renewal of the resource consents (Consents 38812 for Dam 5, 38813 for Dam 6, and 38814 to take water from both dams).

2.0 Site Description

Redvale Landfill is located on Landfill Access Road, Dairy Flat. The two ponds of interest and their associated dams are located at the southern end of the property.

Pond 5 is southwest of Landfill Access Road and south of Stockpile 4. Formerly it was in line with an overland flowpath from Stockpile 4, however that flowpath has been diverted around the west side of the pond before reconnecting with its previous route up below the dam. Pond 5 contains a volume of approximately 4,800 m^3 of water (run off from stockpile 4). It has an 8 m high embankment dam comprised of low permeability clay fill. There are two smaller ponds at the base of Dam 5, one acts as a stilling basin for the dam and is connected to the second pond by a culvert.

Pond 6 is the main pond with the largest volume in the original resource consent. There are two smaller termed finger ponds located west adjacent to Pond 6. Pond 6 is situated north of Landfill Access Road and west of the Redvale Landfill main office building (which is downstream of the dam). According to WMNZ, Pond 6 has not been emptied since its construction as it provides the landfill's water supply in the emergency case of a fire. It contains a volume of approximately 11,500 m^3 of water, and its associated embankment dam has a height of 6.7 m. The dam is comprised of the same material as the dam at Pond 5.

Refer to Figure 1 for layout of the site.

3.0 Objectives and Scope

The objective of this report is to provide the engineering assessment to support the renewal of the resource consents for the pond dams.

4.0 Scope

This report includes:

- A desktop factual geotechnical summary of ground conditions;
- A summary of a site walkover and visual inspection observations;
- An assessment of compliance with dam safety guidelines;

- A stability and seepage analysis of the dam structures; and
- Recommendations for a maintenance and monitoring programme.

This report excludes any assessment of the two smaller lower ponds downstream of the main Pond 5.

5.0 Desktop Review

5.1 Published Geological Information

5.1.1 QMaps

According to the geological map of the area (Edbrooke, 2001) the site is underlaid primarily by interbedded sandstone and mudstone of the East Coast Bays Formation (Waitemata Group). There is a boundary between the Waitemata Group material and Hukerenui mudstone 30 m east of Dam 6.

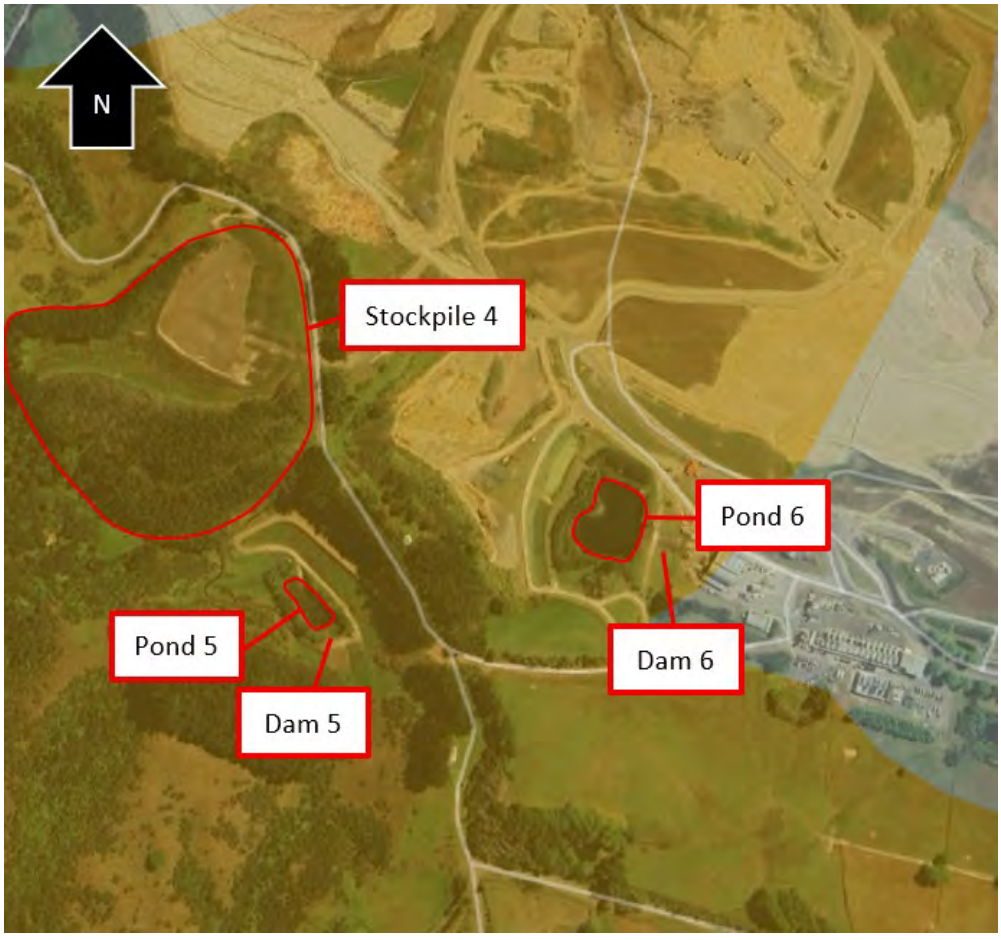

Figure 1: QMap indicating geology onsite. Orange indicates East Coast Bays Formation while the pale cream colour indicates Hukerenui Mudstone.

5.1.2 GNS Fault database

The fault database (New Zealand Active Fault Datasets, 2025) provided by GNS indicates no active faults within the entire Rodney area.

5.1.3 New Zealand Geotechnical Database (NZGD)

Three rotary core borehole logs are available north of Pond 5 (RC 71048, RC 71049, RC 71050). These logs indicate soft to firm sandy silt underlaid by interbedded, extremely weak sandstone and siltstone which becomes moderately strong at around 4 m bgl.

One test pit directly adjacent to Pond 6 (TP 124553) suggested that the ground is primarily silty clay (completely weathered mudstone) to 2 m, then soft mudstone. It also indicated that there are two sub horizontal shear zones at 1.1 and 2.4 m bgl, and another shear zone at 2.8 m bgl (90° to 30°, 60° to 340°).

Refer to Appendix A for NZGD borehole and test pit logs.

5.2 Historical Aerial Imagery Review

There are several historical image records on the Retrolens website (Te Uru Kahika - Regional and Unitary Councils Aotearoa, 2025) from the 1970s and 1980s showing the Redvale Landfill site. In these images approximately a quarter of the site appears to be excavated. Prior to 1973 it is difficult to identify the site however almost all of the Dairy Flat area is farmland.

5.3 Documentation Provided By WMNZ

WMNZ provided numerous information to inform the geotechnical assessment of the dams supporting ponds 5 and 6, these include the following key documents:

- As-built drawings for Ponds 5 and 6 (Tonkin and Taylor and Doug Hood Ltd, 1998)
- Construction certificates for Ponds 5 and 6
- Stockpile No. 4 geotechnical report (Tonkin and Taylor, 1996)
- Stockpile No. 4 earthwork specification (Tonkin and Taylor)
- Previous consenting documents
- Latest/recent survey data
- Recent Ponds 5 and 6 dam monitoring and inspection records (2022-2025)

Examination of these documents yielded key information such as the geometry, material descriptions and several strength parameters of the dam to inform the seepage and static and seismic stability analyses. The geotechnical parameters relevant to this report are presented in Table 1.

Each dam is underlaid by a toe key to stabilise the structure on the weaker organic soils. The widths of the toe keys vary, however the maximum key widths for Dams 5 and 6 are 20 m and 12 m respectively.

Table 1: Geotechnical Parameters Relevant to Dams 5 and 6

Material Type	Material Description	Parameter	Value
3B	Inorganic clay and clayey silt, high strength, low permeability.	S_u (kPa)	100
		γ (kN/m^3)	18
		c' (kPa)	5
		ϕ' (°)	25
1C	High strength structural fill (mudstone siltstone or marly limestone).	S_u (kPa)	150
		γ (kN/m^3)	19
		c' (kPa)	5
		ϕ' (°)	35

Notes:

1. *Geotechnical parameters from reference: Redvale Landfill Project Stockpile No. 4 Geotechnical Report by T&T.*
2. *Material Type 3B constitutes the embankment dams themselves.*
3. *Material Type 1C constitutes the structural fill in the shear key beneath each dam.*
4. *The remaining soil underlying the dam are organics and weathered soil.*

The Tonkin and Taylor geotechnical report summarises the geotechnical setting of the site as follows:

"Investigations including geological mapping, digger pit and drill hole investigations show that Stockpile 4 is underlain by a westerly dipping sequence of sedimentary rocks judged to belong to the Waitemata Group on the basis of lithology and structure. The sequence consists of coarse sandstones and grits with interbeds of angular clasts of soft green mudstone forming a fine breccia which, in turn, is overlain by soft weak fine sandstone and coarse siltstone which are, in places, finely interbedded. A thick lens of what appears to be volcanic tuff is mapped in the sandstone/siltstone unit forming a ridge between the two main branches of the upper drainage system.

East of Stockpile 4 site, the Waitemata Group sediments are cut off by a North to South trending fault and sheared mudstone, similar to those sub-cropping on the West Property, occur to the east of this fault."

This aligns with what was found in the QMap and NZGD logs.

6.0 Site Walkover

A PDP geotechnical engineer undertook a site walkover on Friday 12 September 2025. They were taken around the site by a client representative to observe the current conditions of the ponds and associated dams and identify any potential geohazards. Refer to Appendix B for the site visit report outlining findings from this walkover.

It was observed that the ponds and dams were generally in good condition with no clear evidence of cracking or seeps in the concrete spillway. Ponded water was present at the base of each spillway where the decant outlets. Maintenance is required to clear vegetation from the spillways of both ponds and silt from the top of the spillway of Dam 5. The need for clearing vegetation and silt has also been noted in previous site walkover inspections provided by WMNZ.

7.0 Dam and Geotechnical Engineering Assessment

7.1 Dam Classification and Safety Compliance

The Building (Dam Safety) Regulations 2022 under the Building Act 2004 defines a classifiable dam as “a dam that has a height of 4 or more metres and stores 20,000 or more cubic metres volume of water or other fluid”.

Following our site walkover inspection and discussion with WMNZ, we understood that there were no significant structural changes or damage to Ponds 5 and 6 over the years, despite several severe weather events in recent years. Review and comparison of the as-built drawings and latest/recent survey data indicates that there have been no significant changes to the overall ponds’ structures in terms of pond size and dam height since their construction.

Both dams 5 and 6 have larger heights than that specified but contain lower volumes of fluid, therefore neither dam is determined as a classifiable dam and is therefore not subject to the building (dam safety) regulations as per the New Zealand Society of Large Dams (NZSOLD) New Zealand Dam Safety Guidelines 2024.

Nonetheless, the dam structures were assessed to check the existing state is of reasonably good working conditions and geotechnically the overall structures are stable with no instability issue to mitigate any immediate risk to the safety of persons, property, or the environment.

Dam 5 is upstream of two smaller ponds including the spilling basin. Down from there are open fields and some forested area on both sides of the flow path with the nearest downstream structure being a residential property approximately 250 m distance away. Therefore, impact and risk to people and property is considered low.

Dam 6 is positioned West (and upstream) of onsite buildings and associated infrastructure which are typically manned by WMNZ Redvale landfill staff and contractors and potentially be significantly impacted if the dam structure was to have a major failure leading to uncontrolled release of the impounded water.

7.2 Geotechnical Engineering Assessment

7.2.1 Assessment Basis

The following is a geotechnical assessment of the global stability and seepage effects of the dam structures for the different loading conditions based on NZSOLD New Zealand Dam Safety Guidelines 2024.

The following loading conditions are considered for the assessment:

- Normal Loading Conditions – Normal designed full stored pond water level conditions with seepage analysis.
- Note: Each pond has a riser connected to a pipe running underneath the dam to prevent the pond from overflowing unnecessarily. The top of the riser sits approximately less than 1 m below the spillway level.
- Unusual Loading Conditions – Rapid drawdown of the ponds.
- Extreme Loading Conditions – Significant seismic event e.g. earthquake with low Annual Exceedance Probability (AEP) for ultimate limit states.

7.2.1.1 Seismic Event

For Dam 6, based on the location and usage of the buildings located downstream, the following seismic loading would be used in the assessment in accordance with NZS 1170.0. The dam structure is assumed an Importance Level (IL) 3 with a 100-year design life. The same IL and design life is conservatively assumed for Dam 5.

An IL 3 structure with a 100-year design life has the following earthquake AEP, Ultimate Limit State (ULS): 1 in 2500 years and Serviceability Limit State (SLS): 1 in 25 years. According to Appendix A, Table A1 of the Earthquake geotechnical engineering practice Module 1 (MBIE 2021) appropriate design PGAs are ULS 0.28 g and SLS 0.05 g with magnitude of 5.9 for both cases. It should be noted that a 1 in 2500 year earthquake is extremely conservative.

7.2.1.2 Rapid Drawdown

Rapid drawdown was considered in the stability review of the Ponds 5 and 6 earth dams. Several drawdown rates (e.g. 0.1 m/day to 2 m/day) were studied and the analyses results are presented to show the dams' response to drawdown. Rapid drawdown is unlikely to occur under the current operation for both Pond 5 or Pond 6. However, if drawdown is required (e.g. maintenance, cleaning purpose), it should be carried out at an appropriate drawdown rate to maintain stability of the dam. Discussion and recommendation based on the detailed stability assessment results are presented in the following sections.

7.2.1.3 Assumptions and Limitations

The review and assessment were based on analysis model with the adopted dam geometry, ground profile, and design parameters from the original dam embankment design, as presented in the Geotechnical Report for Stockpile No. 4 by Tonkin & Taylor Ltd (Ref.: 13872 dated 5th July 1996).

No intrusive ground investigation was carried out to determine current site-specific parameters, such as measured hydraulic conductivity and soil strength.

7.2.2 Static, Seepage and Drawdown Stability Analysis

7.2.2.1 Fully coupled flow-deformation analysis

A seepage and stability analysis were conducted using PLAXIS 2D (Bentley Systems) to evaluate the seepage behaviour through the dam embankment and assess structural stability under various hydraulic loading conditions. The analysis incorporated the strength reduction method (SRM) to estimate the factor of safety of the dam under both steady-state and transient seepage scenarios.

Four different cases of seepage and stability analyses had been analysed for the earth dam as follows:

- Case 1 - Full stored pond water level condition at approximately RL 75.5 m for Pond 5 and RL 67.9 m for Pond 6.
- Case 2 - Water drawdown at a rate of 2.0 m/day.
- Case 3 - Water drawdown at a rate of 1.0 m/day.
- Case 4 - Water drawdown at a rate of 0.1 m/day.

The design water level is 67.9 m RL on the dam for Pond 5 and 75.5 m RL for Pond 6. The level of each riser is less than 1 m lower than the spillway for both dams.

Within the pond the water level declines at an approximate 1:4 slope. Water exits the dam at the toe of the slope for Ponds 5 and 6.

7.2.2.2 Geotechnical Parameters

The geotechnical design parameters are taken from the Geotechnical Report for Stockpile No. 4 by Tonkin & Taylor Ltd (Ref.: 13872, dated 5th July 1996). The analysis parameters, such as the hydraulic conductivities of the different soil materials within the constructed dam, were derived based on the respective material types. For the purpose of the seepage analysis model, the parameters in Table 1 were used in addition to those listed in Table 2 below.

Table 2: Additional Geotechnical Parameters for Seepage Analysis			
Material ID	**Material Description**	**Parameter**	**Value**
3B	Inorganic clay and clayey silt, high strength, low permeability.	E'_{ref}, Young Modulus (kPa)	20,000
		v', Poisson Ratio	0.3
		K_x / K_y, Permeability (m/day)	$8.60E^{-05}$
1C	High strength structural fill	E'_{ref}, Young Modulus (kPa)	35,000
		v', Poisson Ratio	0.3
		K_x / K_y, Permeability (m/day)	$8.60E^{-03}$
-	Organic weathered soil layer	γ, Density (kN/m^3)	18
		c', Effective Cohesion (kPa)	2
		ϕ', Effective Friction Angle (°)	28
		E'_{ref}, Young Modulus (kPa)	8,000
		v', Poisson Ratio	0.3
		K_x / K_y, Permeability (m/day)	$8.60E^{-02}$
-	ECBF sandstone	γ, Density (kN/m^3)	20
		c', Effective Cohesion (kPa)	20
		ϕ', Effective Friction Angle (°)	40
		E'_{ref}, Young Modulus (kPa)	50,000
		v', Poisson Ratio	0.1
		K_x / K_y, Permeability (m/day)	$8.60E^{-06}$

7.2.2.3 Results and Discussion

The seepage analysis demonstrates that:

- The phreatic surface within the dam embankment shown corresponds to the transient conditions for different rates of pond drawdown and shows only minor variation compared with the steady-state condition at the full pond level.
- Due to the low permeability of the dam embankment material, seepage through the dam occurs very slowly and typically takes a long time to reach steady-state conditions.

- As a result, a rapid drawdown condition can have an impact on dam stability, as the phreatic surface adjusts and excess pore water pressure builds up, which takes time to dissipate.
- Under the most critical drawdown rate of 2.0 m/day simulated at Pond 5, the factor of safety (FOS) decreases to 1.1, which is below the minimum requirement of FOS = 1.2 according to the NZSOLD Guidelines (summarised in Table 3 below). However, such a rapid drawdown rate is unlikely under normal operating conditions.
- No significant seepage is expected that could reasonably cause damage to the dam when the pond is at the riser level (near full). The factors of safety achieved for Ponds 5 and Pond 6 are both greater than 1.5.
- The results from the seepage and stability analysis are considered reasonable, as site inspections indicated no visible seepage on the dam surface, except for localised ponding in the stilling basin.

The factors of safety for the various cases are summarised in Table 3 below. Outputs from the seepage and static stability analysis are available in Appendix C.

Table 3: Static, Seepage and Drawdown Analysis Results

Dam	Case	Minimum Factor of Safety [1]	Analysis Global Stability Factor of Safety
Pond 5	Full Water Level Static	1.5	1.63
	Water Drawdown 2.0 m / day	1.2 to 1.3	1.12
	Water Drawdown 1.0 m / day		1.22
	Water Drawdown 0.1 m / day		1.64
Pond 6	Full Water Level Static	1.5	1.70
	Water Drawdown 2.0 m / day	1.2 to 1.3	1.66
	Water Drawdown 1.0 m / day		1.70
	Water Drawdown 0.1 m / day		1.74

Note:

1. *Slope stability acceptance criteria referred to Table 6.3 NZSOLD Guideline (Module 3) 2024*

If water drawdown is expected due to operation or maintenance requirement, it is recommended that the water drawdown rate be limited to rate no more than 1 m/day to maintain the required minimum FOS, in particular for Pond 5.

7.2.3 Seismic Stability Analysis

A seismic analysis was undertaken to determine the global stability of the Ponds 5 and 6 dams under seismic loading. The modelling for this was done using Slope/W by Geostudio. While Plaxis is suitable for seepage analysis it was deemed that Slope/W would be a more appropriate software for seismic slope modelling given it is widely used and accepted by the industry. Undrained parameters are typically used in a seismic model. However drained parameters were used in this assessment as they were more conservative and provided a more robust review and analysis of the dam structure and its resilience during seismic events.

Cross sections for seismic models used the same geometry and phreatic surface assumptions as the static and seepage analysis. The ULS and SLS PGAs mentioned in Section 7.2.1.1 were used for this analysis.

Seismic displacement was estimated using the software Slammer by the United States Geological Survey.

7.2.3.1 Results and Discussion

The seismic analysis demonstrates that:

- Under SLS conditions both dams achieved a FOS >1.
- Both dams achieved a FOS less than 1 for ULS conditions, however the estimated displacements were found to be negligible (<25 mm) and not likely to cause either dam to fail catastrophically, releasing the impounded water from the ponds downstream.

Outputs from the analysis can be found in Appendix D and the results are summarised in Table 4.

Table 4: Seismic Analysis Results

Dam	Case	Minimum Factor of Safety [1]	Analysis Global Stability Factor of Safety
Pond 5	SLS	1.0	1.4
	ULS	1.0	0.8 (<25 mm Displacement)
Pond 6	SLS	1.0	1.5
	ULS	1.0	0.9 (<25 mm Displacement)

Note:

1. *Slope stability acceptance criteria referred to Table 6.4 NZSOLD Guideline (Module 3) 2024 using Operating Basis Earthquake and Safety Evaluation Earthquake conditions which are not exactly the same but are equivalent/similar to typical slope stability assessment under seismic SLS and ULS conditions.*

8.0 Monitoring and Maintenance Plan

According to the inspection and maintenance documentation provided by WMNZ, Pond 5 was inspected in 2022, 2023, 2024 and 2025; Pond 6 was inspected in 2025. The extent of these site walkover inspections, the observations made about dam conditions and the recommendations made regarding maintenance all appeared to be reasonably appropriate for records as part of the monitoring and maintenance plan.

Regular monitoring has been undertaken in the form of a yearly visual inspection of Pond 5, Pond 6 and their associated dams. Observations shall be made regarding the dam overall structure and spillways, drainage, overgrowth and anything else that may impact and compromise the operational functions and structural integrity of the dams.

Additional inspections should also be carried out after significant natural hazard events (significant storm/flooding event, earthquake, etc) which have potential impacts and cause damage to the dam structure integrity and operational functions.

The primary maintenance tasks are as follows: the dams and associated structures shall be maintained so that they remain structurally sound and stable throughout their operational life. No trees or vegetation other than grass shall be allowed to grow on or near the embankment as these could weaken either dam's structural stability. The spillways and their access ways shall be protected from becoming restricted by debris.

WMNZ should consider developing and implementing a Dam Safey Management System (DSMS) with reference to NZSOLD New Zealand Dam Safety Guideline 2024 Modules 5 and 6. The DSMS is purely for WMNZ in-house operational purposes and not measures to mitigate an effect on the environment.

9.0 Conclusions and Recommendations

- As-built records and geotechnical design information provided by WMNZ, including T&T geotechnical report and earthwork specification, are adopted for the dam stability assessment.
- The PDP's site visit inspection showed that both Ponds 5 and 6 and associated dams were generally in good condition with no clear evidence of movement, cracking or instability of the dam structure. Maintenance is recommended to clear vegetation from the spillways of both ponds and silt from the top of the spillway of Dam 5.

- Following our site walkover inspection and discussion with WMNZ, we understood that there were no significant structural changes or damage to Ponds 5 and 6 over the years, despite several severe weather events in recent years. Review and comparison of the as-built drawings and latest/recent survey data indicates that there have been no significant changes to the overall ponds' structures in terms of pond size and dam height since their construction.
- Both Dams 5 and 6 are determined as not being a "Classifiable Dam" according to the Building (Dam Safety) Regulations 2022 under the Building Act 2004. Therefore, both dams are not subject to the building (dam safety) regulations as per the New Zealand Society of Large Dam (NZSOLD) New Zealand Dam Safety Guidelines 2024.
- Based on the geotechnical assessment of the dam stability, both dams have been deemed to be structurally sound and stable and pose no undue risk to life, property or the natural environment under their normal operations and in unusual and extreme events such as water drawdown, significant storm/flooding, and seismic conditions.
- According to the inspection and maintenance records provided by WMNZ, Pond 5 was inspected in 2022, 2023, 2024 and 2025; Pond 6 was inspected in 2025. The site inspections including observations of the dam conditions and recommendations made regarding maintenance all appeared to be reasonably appropriate for records as part of the monitoring and maintenance plan.

10.0 References

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Appendix A: NZGD Logs

TONKIN & TAYLOR LTD.

14978

DRILL HOLE LOG

DRILL HOLE No: W28
Hole Location: West Abutment of Proposed Toe Key.
SHEET 1 OF 2

PROJECT: Redvale Landfill | LOCATION: Redvale, Auckland | JOB No: 13872

CO-ORDINATES mN 723781.4 mE 287291.8 | DRILL TYPE: | HOLE STARTED: 12/03/96

DATUM: | HOLE FINISHED: 13/03/96

DIRECTION: ------ | R.L. GROUND: m 88.9 | DRILLED BY: PRODRILL LTD

ANGLE FROM HORIZ.: -90.00 ° | R.L. COLLAR: m 89.6 (pvc) | LOGGED BY: BDH CHECKED: SAC

DESCRIPTION OF CORE | ROCK DEFECTS

GEOLOGICAL UNIT	ROCK OR SOIL TYPE, WEATHERING, HARDNESS, STRENGTH, COLOUR, LITHOLOGICAL FEATURES (bedding, cement, foliation, mineralogy, texture, etc...);	ROCK WEATHERING (UW SW MW HW)	ROCK STRENGTH (R4 R3 R2 R1 R0)	PT LOAD / UCS TEST (MPa)	CORE LOSS / LIFT (%) (3 10 30 100)	METHOD, CORE & CASING	TEST SYMBOL	DEPTH (m)	GRAPHIC LOG	DEFECT LOG	FRACTURE LOG spacing of natural fractures (cm) (50 10 1)	SIGNIFICANT JOINTS, BEDDING, CRUSHED AND SHEARED ZONES/SEAMS; DEFECT TYPE, SHAPE, ROUGHNESS, APERTURE, INFILLING, SPACING; ANGLES ARE RELATIVE TO CORE AXIS	DATE / DEPTH	RQD (%)	WATER	DRILL WATER LOSS (%) (25 50 75)	WATER PRESSURE TESTS Lugeons or Permeability (10^{-7}m/s) (0.01 0.1 1 10 100 1000)	CORE BOX RL (m)
	Pale grey with brown tints (Fe-st), extremely weak, extremely soft, slightly clayey SILTSTONE					TUBE		1				ON GTGS						
						TUBE		2										
	Orange with grey tints, soft, wet, sandy, SILT					TUBE		3 4 5 6										
	Grey, very soft, very weak (R0-R1) SILTSTONE with thin SANDSTONE interbeds							7										
	Dark grey, soft, weak to moderately strong (R1-R2) weakly cemented SANDSTONE, with SILTSTONE laminae					SPT		8				SPT 50 for 150mm						
								9 10				B15° B15°						
	Grey, soft, weak (R0-R1), fine SANDSTONE and coarse SILTSTONE (R1-R2)							11 12 13 14 15				J45°, planar						

GROUNDWATER A.R.W.B.
W.R. No .....
NAME Waste Mgmt
TECHNICAL FILES
1 / CS12-12-1740
ACTIONED
BORE LOG .....
PUMP TEST .....
COMPUTER .....
WATER QUAL .....

BC - 5220.

RL 13872 14/06/96

TONKIN & TAYLOR LTD.

DRILL HOLE LOG

DRILL HOLE No: W28
Hole Location: West Abutment c Proposed Toe Key.
SHEET 2 OF 2

PROJECT: Redvale Landfill	LOCATION: Redvale, Auckland		JOB No: 13872
CO-ORDINATES mN 723781·4 mE 287291·8	DRILL TYPE:	HOLE STARTED:	12/03/96
	DATUM:	HOLE FINISHED:	13/03/96
DIRECTION: ------	R.L. GROUND: m 88·9	DRILLED BY:	PRODRILL LTD
ANGLE FROM HORIZ.: -90.00 °	R.L. COLLAR: m 89·6	LOGGED BY: BDH	CHECKED: SAC

DESCRIPTION OF CORE | ROCK DEFECTS

GEOLOGICAL UNIT	ROCK OR SOIL TYPE, WEATHERING, HARDNESS, STRENGTH, COLOUR, LITHOLOGICAL FEATURES (bedding, cement, foliation, mineralogy, texture, etc...);	ROCK WEATHERING (UW, SW, MW, HW)	ROCK STRENGTH (R4, R3, R2, R1, R0)	PT LOAD / UCS TEST (MPa)	CORE LOSS / LIFT (%) (3, 30, 100)	METHOD, CORE & CASING	TEST SYMBOL	DEPTH (m)	GRAPHIC LOG	DEFECT LOG	FRACTURE LOG spacing of natural fractures (cm) (50, 10, 5, 1)	SIGNIFICANT JOINTS, BEDDING, CRUSHED AND SHEARED ZONES/SEAMS DEFECT TYPE, SHAPE, ROUGHNESS, APERTURE, INFILLING, SPACING ANGLES ARE RELATIVE TO CORE AXIS	DATE / DEPTH	RQD (%)	WATER	DRILL WATER LOSS (%) (25, 50, 75)	WATER PRESSURE TESTS Lugeons or Permeability (10^{-7}m/s) (0.01, 0.1, 1, 10, 100, 1000)	CORE BOX
												B20°						
	END OF BOREHOLE @ 15.5m.							16 17 18 19 20 21 22 23 24 25 26 27 28 29										

RL 13872 14/06/

TONKIN & TAYLOR LTD.

DRILL HOLE LOG

DRILL HOLE No: W29
Hole Location: Centreline of Proposed Toe Key.
SHEET 1 OF 1

PROJECT: Redvale Landfill | LOCATION: Redvale, Auckland | JOB No: 13872

CO-ORDINATES mN 723802.6 mE 2877321.2 | DRILL TYPE: | HOLE STARTED: 08/03/96

DATUM: | HOLE FINISHED: 08/03/96

DIRECTION: —— | R.L. GROUND: m 76.3 | DRILLED BY: PRODRILL LTD

ANGLE FROM HORIZ.: -90.00 ° | R.L. COLLAR: m 76.7 | LOGGED BY: BDH CHECKED: SAC

DESCRIPTION OF CORE | ROCK DEFECTS

GEOLOGICAL UNIT	ROCK OR SOIL TYPE, WEATHERING, HARDNESS, STRENGTH, COLOUR, LITHOLOGICAL FEATURES (bedding, cement, foliation, mineralogy, texture, etc...);	ROCK WEATHERING UW SW MW HW	ROCK STRENGTH R4 R3 R2 R1 R0	PT LOAD / UCS TEST (MPa)	CORE LOSS / LIFT (%) 3 30 100	METHOD, CORE & CASING	TEST SYMBOL	DEPTH (m)	GRAPHIC LOG	DEFECT LOG	FRACTURE LOG spacing of natural fractures (cm) 50 10 1	SIGNIFICANT JOINTS, BEDDING, CRUSHED AND SHEARED ZONES/SEAMS; DEFECT TYPE, SHAPE, ROUGHNESS APERTURE, INFILLING, SPACING; ANGLES ARE RELATIVE TO CORE AXIS	DATE / DEPTH	RQD (%)	WATER	DRILL WATER LOSS (%) 25 50 75	WATER PRESSURE TESTS Lugeons or Permeability (10^{-7}m/s) 0.01 0.1 1 10 100 1000	CORE BOX (1) (m)
	Grey brown, soft to firm, clay SILT, moist							1										
	Grey extremely weak (R0), fine SANDSTONE - drilling breaks throughout						SPT	2 3					SPT 36 for 150mm		100			
	Grey soft, weak to moderately strong (R1-R2), fine SANDSTONE, interbedded (laminae) SILTSTONE Grey, fine SANDSTONE to coarse SILTSTONE (R2-R3)							4 5 6 7							90 75 100 100			
	END OF BOREHOLE @ 8.0m.							8 9 10 11 12 13 14										

ON GTGS

GROUNDWATER A.R.W.B.
W.R. No.....
NAME Waste Mgmt.
TECHNICAL FILES
CS1:2-12-1749
ACTIONED
BORE LOG .....✓.....
PUMP TEST.....
COMPUTER .....✓.....
WATER QUAL .....

BC - 5309.

RL 13872 14/06/9

TONKIN & TAYLOR LTD.

DRILL HOLE LOG

DRILL HOLE No: W30
Hole Location: East Abutment of Proposed Toe Key.
SHEET 1 OF 1

PROJECT: Redvale Landfill	LOCATION: Redvale, Auckland		JOB No: 13872
CO-ORDINATES mN 723837.1 mE 287344.0	DRILL TYPE:	HOLE STARTED:	11/03/96
	DATUM:	HOLE FINISHED:	12/03/96
DIRECTION: -----	R.L. GROUND: m 89.2	DRILLED BY:	PRODRILL LTD
ANGLE FROM HORIZ.: -90.00 °	R.L. COLLAR: m 89.9	LOGGED BY: BDH	CHECKED: SAC

DESCRIPTION OF CORE

GEOLOGICAL UNIT	ROCK OR SOIL TYPE, WEATHERING, HARDNESS, STRENGTH, COLOUR, LITHOLOGICAL FEATURES (bedding, cement, foliation, mineralogy, texture, etc...);	ROCK WEATHERING (UW SW MW HW)	ROCK STRENGTH (R4 R3 R2 R1 R0)	PT LOAD / UCS TEST (MPa)	CORE LOSS / LIFT (%) (0 30 100)	METHOD, CORE & CASING	TEST SYMBOL DEPTH (m)	GRAPHIC LOG
	Brown, soft to firm, clayey sandy SILT, moist to wet			TUBE			1	
	Colour grading to pale grey			TUBE			2	
				TUBE			3	
	Grey, very soft, very weak (R0), fine to medium SANDSTONE						4	
				SPT			5	
	Weakly cemented (R2/R3) SANDSTONE						6	
							7	
							8	
							9	
	Dark grey, soft, weak to medium strong (R2/R3), fine SANDSTONE						10	
							11	
							12	
	END OF BOREHOLE @ 12.5m.						13	
							14	

ROCK DEFECTS

DEFECT LOG	FRACTURE LOG spacing of natural fractures (cm) (50 10 1)	SIGNIFICANT JOINTS, BEDDING, CRUSHED AND SHEARED ZONES/SEAMS DEFECT TYPE, SHAPE, ROUGHNESS, APERTURE, INFILLING, SPACING ANGLES ARE RELATIVE TO CORE AXIS	DATE / DEPTH	RQD (%)	WATER	DRILL WATER LOSS (%) (25 50 75)	WATER PRESSURE TESTS Lugeons or Permeability (10^{-7}m/s) (0.01 0.1 1 10 100 1000)	CORE BOX RL (m)
		SPT 6/11/18						
		SPT 40 for 150mm						

GROUNDWATER A R W B
W.R.No
NAME waste Mgmt
TECHNICAL FILES
J25° / C.S.1.2-12-17 4D
ACTIONED
BORELOG ✓
PUMP TEST
COMPUTER
WATER QUAL

BL 5310

ON GTGS

RL 13872 14/06/96

EXCAVATION LOG

EXCAVATION No: TP94
Location:

SHEET 1 OF 1

PROJECT:	Redvale Landfill	LOCATION:	Redvale, Auckland	JOB No:	13872
CO-ORDINATES	723790.20 mN 287669.90 mE	EXPOSURE TYPE:	Pit	HOLE STARTED:	20/02/96
		EQUIPMENT:	Kobelco 120	HOLE FINISHED:	20/02/96
R.L.	66.22m m	OPERATOR:	BROUGHTON EXCAV.	LOGGED BY:	BDH
DATUM		DIMENSIONS:		CHECKED BY:	SAC

EXCAVATION TESTS						ENGINEERING DESCRIPTION					GEOLOGICAL
PENETRATION 1 2 3	SUPPORT	WATER	SAMPLES, TESTS	R.L. (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	SOIL NAME, PLASTICITY OR PARTICLE SIZE CHARACTERISTICS, COLOUR, SECONDARY AND MINOR COMPONENTS	MOISTURE CONDITION	STRENGTH / DENSITY CLASSIFICATION	ESTIMATED SHEAR STRENGTH 50 100 150 200	ORIGIN TYPE, MINERAL COMPOSITION, DEFECTS, STRUCTURE
					0			Orange grey, soft to firm, silty CLAY (CW MUDSTONE)				CW MUDSTONE
			•56/17kPa		1			Subhorizontal shear zone				
					2			Dark grey, soft MUDSTONE				
								Subhorizontal shear zone				
					3			Shear zones @ 90° to 30°, 60° to 340°				SW MUDSTONE, sheared throughout
								END OF PIT 3.0m.				
					4							
					5							

SKETCH

Appendix B: Site Walkover Report

Site Visit Report

PROJECT: Redvale Ponds 5 and 6 Reconsenting	JOB NO: A046070004
CLIENT: WMNZ (Najam Saqib)	DATE: 12/09/2025
WEATHER: Overcast with light showers	

GENERAL SITE OVERVIEW
⁘ Refer to Photo 1 for a markup schematic of Ponds 5 and 6 operation.
⁘ Pond 5 is currently acting as a sediment/settlement pond for the Stockpile 4 area.
⁘ Potable water on site is pumped from a borehole upslope of Pond 5 to storage tanks.
⁘ Grey Water is pumped from Pond 5 and 6 to storage tanks.

POND 5 WALKOVER
⁘ Refer to Photo 3 for markup notes and Photos 6 to 11 for representative site photos.
⁘ Water pump at Pond 5 has been unused for approximately 3 years as there has been sufficient water pumped from Pond 6.
⁘ Pond 5 was emptied, cleaned and a new decant was installed approximately 2 years ago.
⁘ Some instabilities observed upslope of the road in the cut slope. A small slump previously recorded at the northwest end of the pond is now fully grassed over.
⁘ The road drain discharges onto the grassed dam face.
⁘ The clean water diversion discharges onto the concrete spillway. This was flowing during the site inspection.
⁘ No evidence of cracking or seeps in the concrete spillway.
⁘ Moss and vegetation growing on spillway and silting at the top of spillway.
⁘ No instabilities or seeps observed on grassed sections of dam face, due to recent heavy rainfall the ground was wet but firm.
⁘ The Pond 5 decant was closed during the site inspection to maximise storage for the summer. The level was above the decant and close to overtopping.
⁘ Ponded water present at the base of the spillway where the decant outlets.

POND 6 WALKOVER
⁘ Refer to Photo 5 for markup notes and Photos 12 to 19 for representative site images
⁘ Pond 6 is never emptied as this serves as an emergency fire reservoir (has not been cleaned)
⁘ No evidence of cracking or seeps in the concrete spillway.
⁘ Some vegetation growing on spillway.
⁘ Some silt and grass on top of spillway with ponded water in vehicle tracks.
⁘ Ground on dam face either side of the spillway vegetated in long grass potentially obscuring observations. No instabilities observed. Ground wet due to recent heavy rainfall but firm underfoot.
⁘ Ponded water at base of spillway where decant outlets and then flows into wingwalled culvert.
⁘ Fence along base of dam partially failing on the southern side of spillway – based on discussions with Najam it is inferred this is related to age or damage from machinery rather than related to ground movement.

Site Visit Report

DISCUSSIONS/INSTRUCTIONS TO CONTRACTOR	
⁘ The following information was requested from Najam during the walkover and will be located next week – Any geotechnical field investigations, factual or interpretive reports for Pond 5/6 – Pond 5 and 6 Design Reports – Earthworks specification for the construction of Ponds 5 and 6 – Any information on a documented maintenance and monitoring programme or previous inspection – records	
⁘ Drone survey of Ponds 5 and 6 discussed. Surveyor to capture general Pond 5 and 6 area and provide the DEM and aerial imagery. Some oblique images of each pond would also be useful.	
	SIGNED: Brodie Maxwell

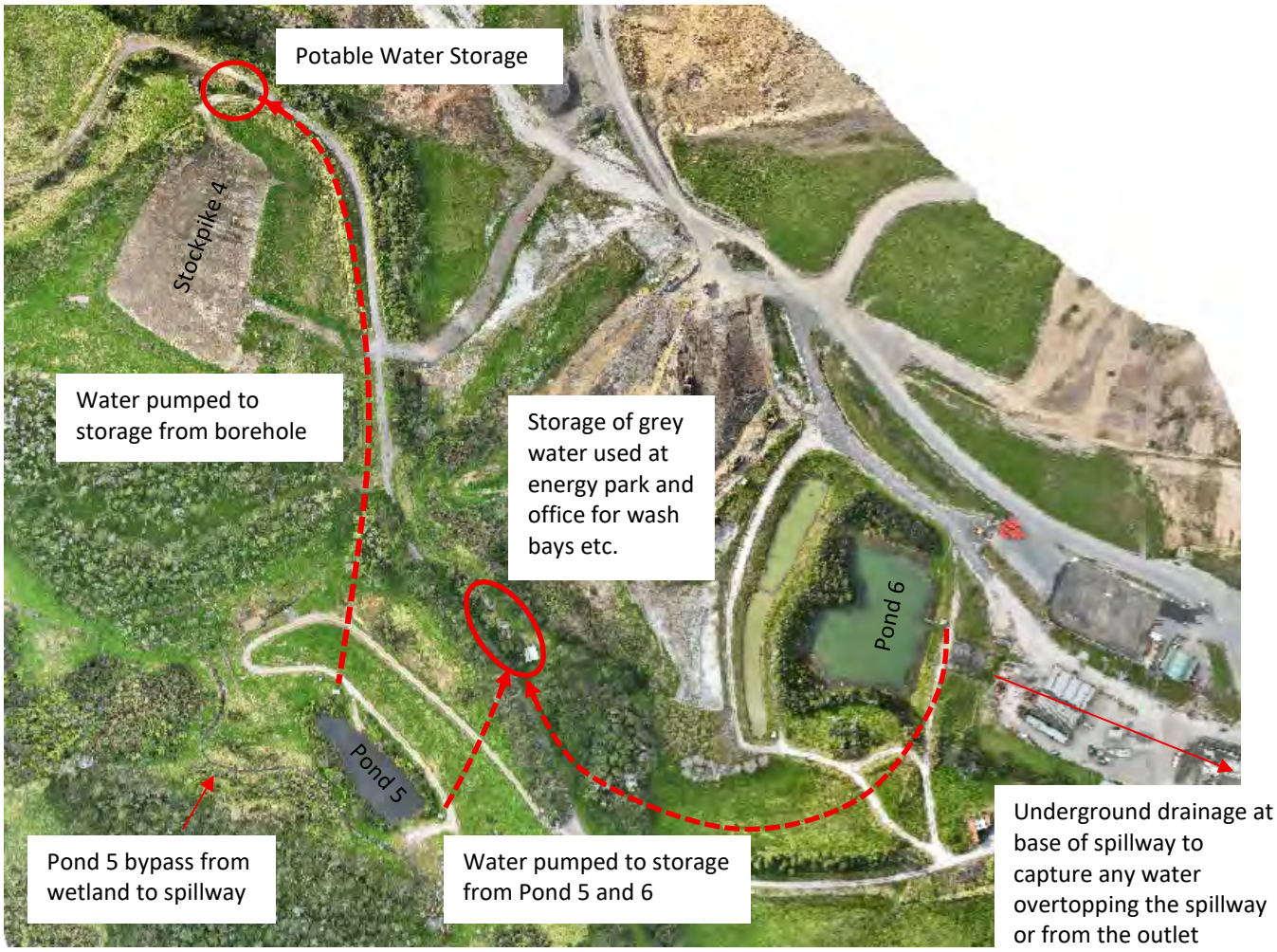


Photo 1 – General markup of Pond 5 and 6 based on discussions with Najam.

Site Visit Report

Photo 2 – Pond 5 Aerial.

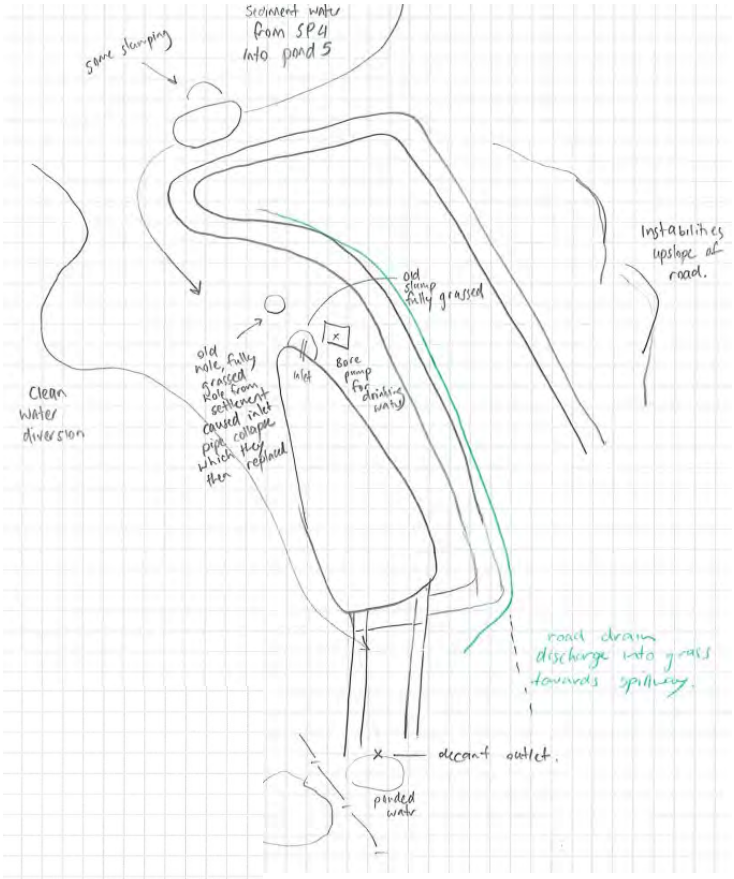


Photo 3 – Pond 5 Markup Notes.

Site Visit Report

Photo 4 – Pond 6 Aerial.

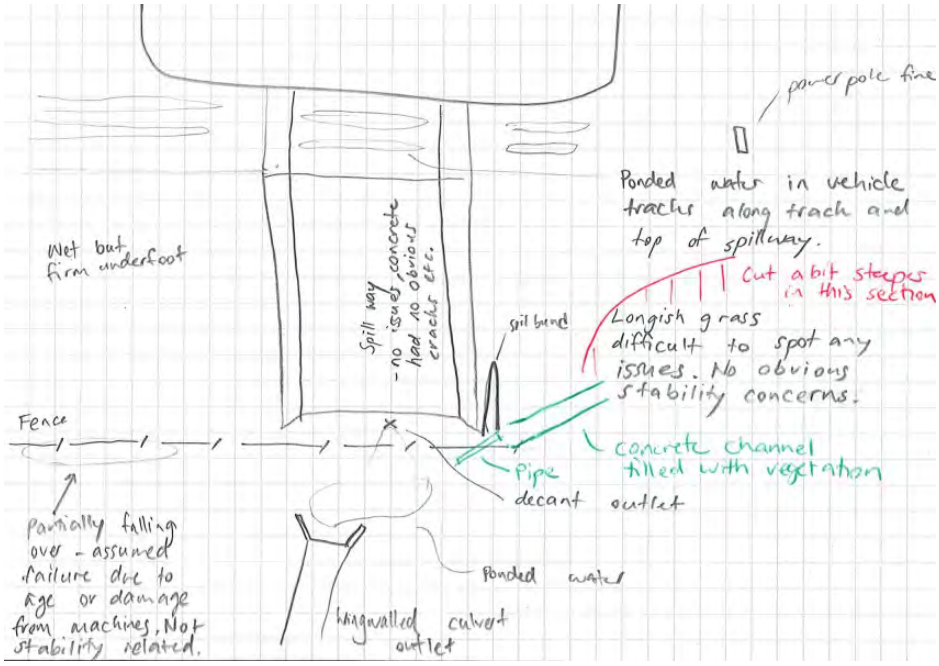


Photo 5 – Pond 6 Markup Notes.

Site Visit Report

Photo 6 – Pond 5 dam crest spillway with silting and ponded water, looking west.

Photo 7 – Pond 5 spillway vegetated with moss and some grasses, looking west.

Photo 8 – Outlet of clean water diversion onto the Pond 5 spillway.

Photo 9 – Pond 5 spillway looking north, ponded water at base of spillway.

Photo 10 – Bottom of Pond 5 spillway, looking west.

Photo 11 – Pond 5, looking southeast, cut slope instabilities visible in background.

Site Visit Report

Photo 12 – Track along top of Pond 6 dam, looking north.

Photo 13 – Pond 6 spillway looking south, with silting and ponded water on crest.

Site Visit Report

Photo 14 – Pond 6 spillway with some minor vegetation, looking south.

Photo 15 – Pond 6 spillway, looking south, ponded water at base (LHS of fence) draining out the culvert (marked with arrow).

Photo 16 – Bottom of Pond 6 spillway, looking northeast.

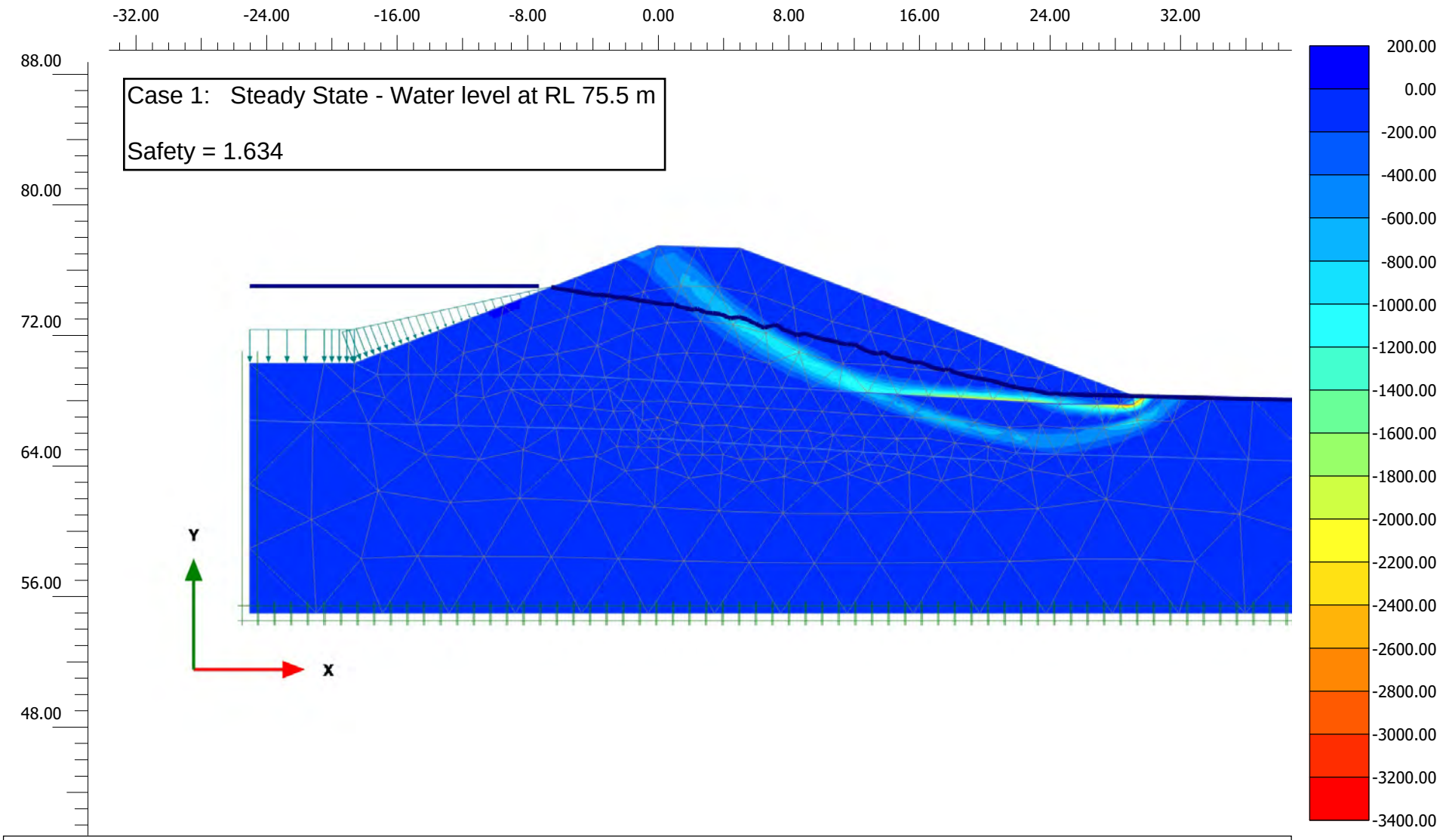
Photo 17 – Pond 6 dam with steepened slopes and concrete drainage on north side of spillway.

Site Visit Report

Photo 18 and 19 – Damaged fence at base of Pond 6 dam on southern side of spillway.


Pond 5 now serving as sediment pond for SP4
Wetland
emptied, cleaned, new decants 2 yrs ago

Appendix C: Stability Analysis Output



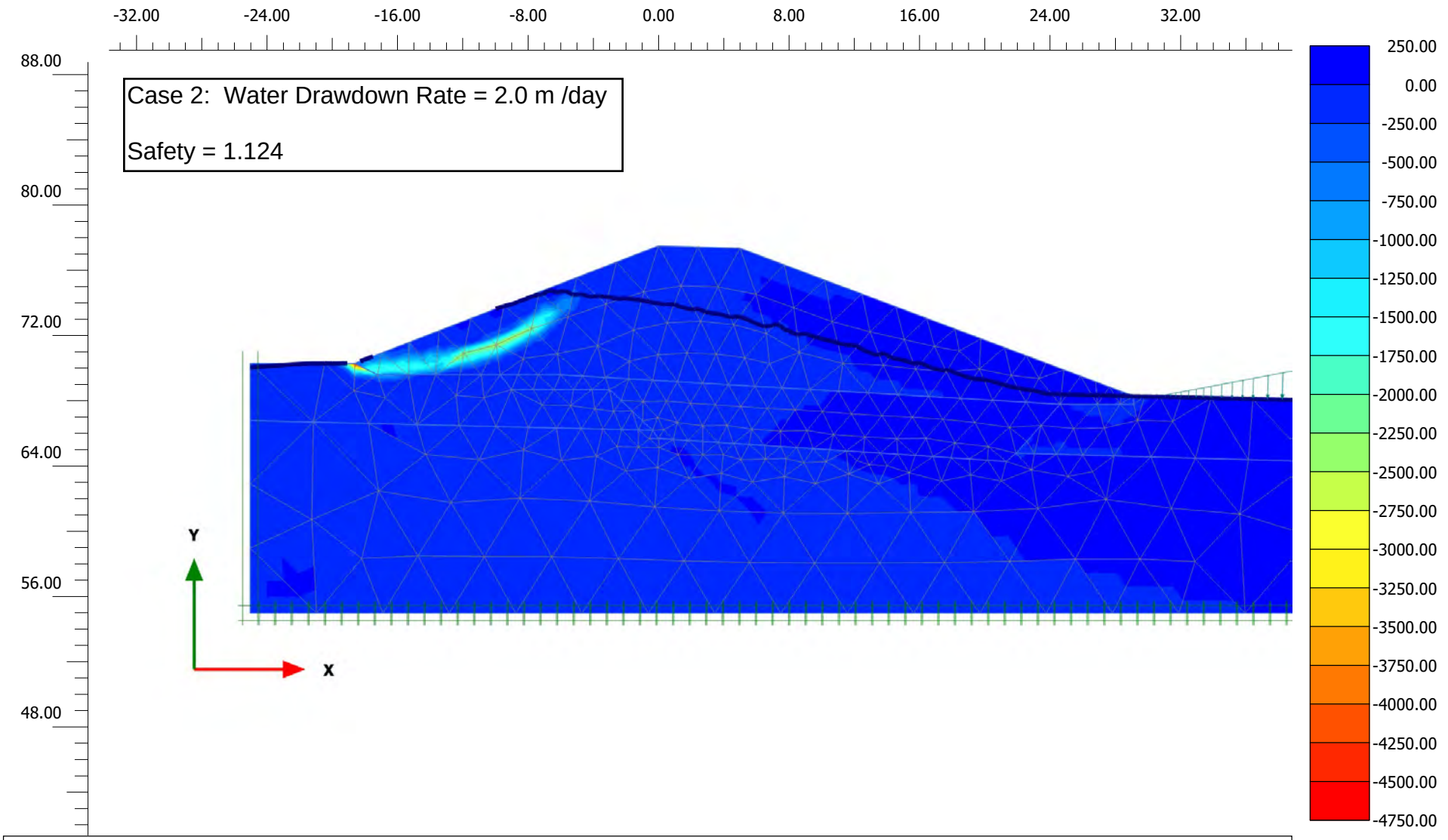
Total principal strain ε_1 (scaled up $0.500*10^{-3}$ times)

Maximum value = $2.060*10^{-18}$ (Element 10 at Node 4109)

Minimum value = -3315 (Element 310 at Node 56)

PLAXIS® 2D

Project description		Date
Redvale		6/11/2025
Project filename	**Step**	**Company**
Redvale Pond 5	319	Pattle Delamore Partners Limited



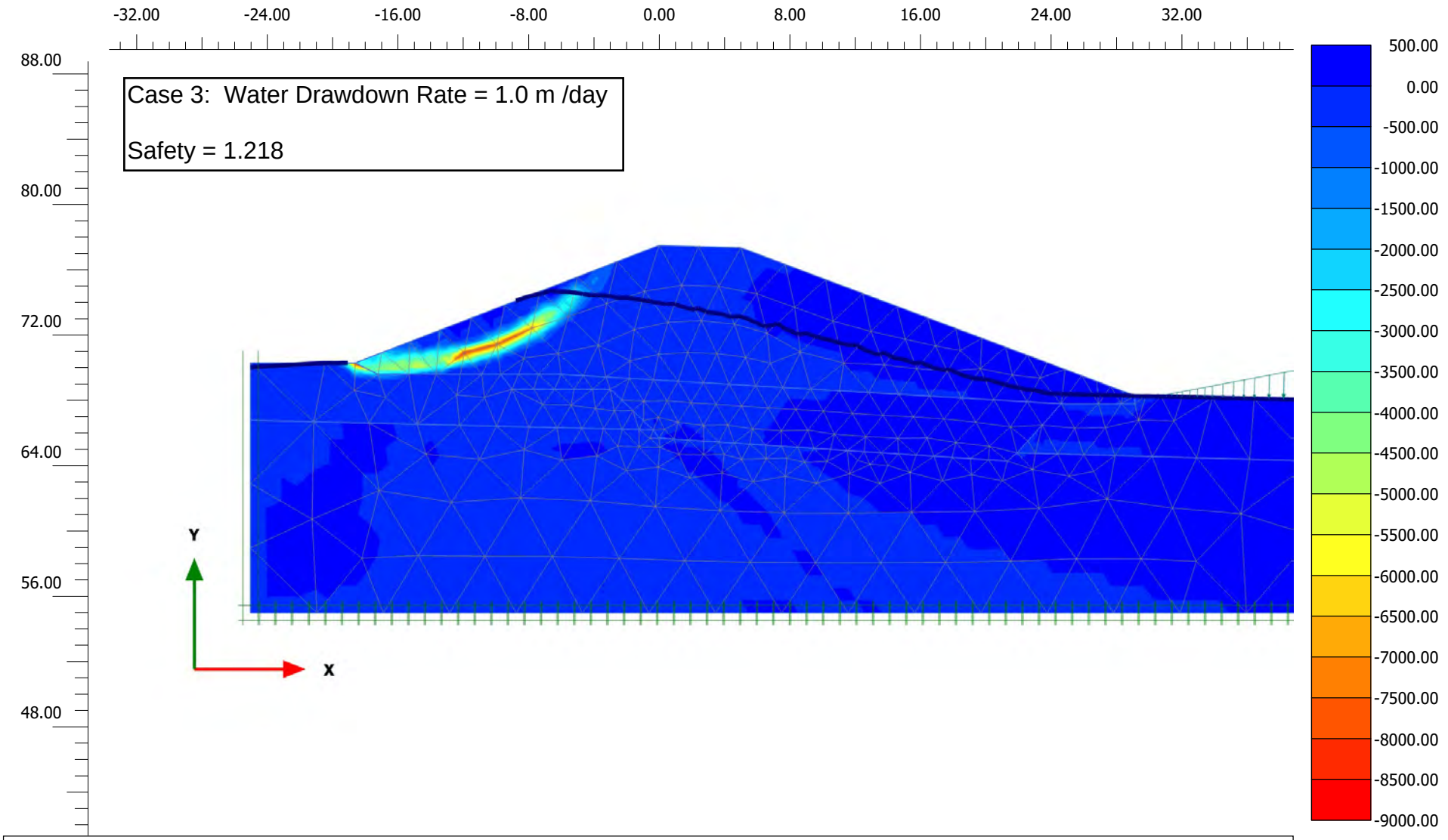
Total principal strain ε_1 (scaled up $0.500*10^{-3}$ times)

Maximum value = $0.05878*10^{-9}$ (Element 58 at Node 3877)

Minimum value = -4608 (Element 133 at Node 3457)

PLAXIS® 2D

Project description		Date
Redvale		6/11/2025
Project filename	**Step**	**Company**
Redvale Pond 5	108	Pattle Delamore Partners Limited



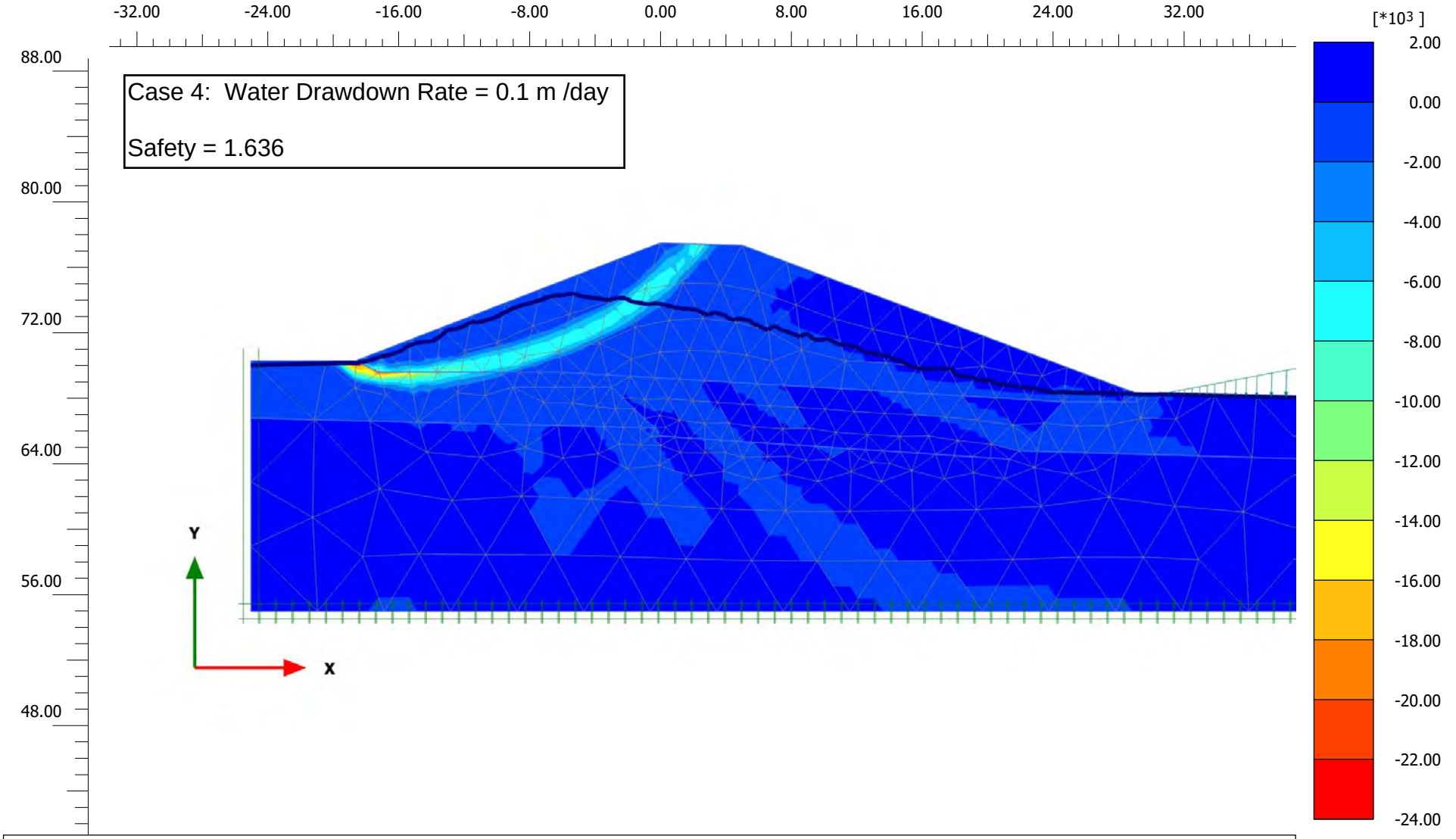
Total principal strain ε_1 (scaled up $0.200*10^{-3}$ times)

Maximum value = $2.501*10^{-12}$ (Element 58 at Node 3877)

Minimum value = -8539 (Element 133 at Node 3457)

PLAXIS® 2D

Project description		Date
Redvale		6/11/2025
Project filename	**Step**	**Company**
Redvale Pond 5	212	Pattle Delamore Partners Limited



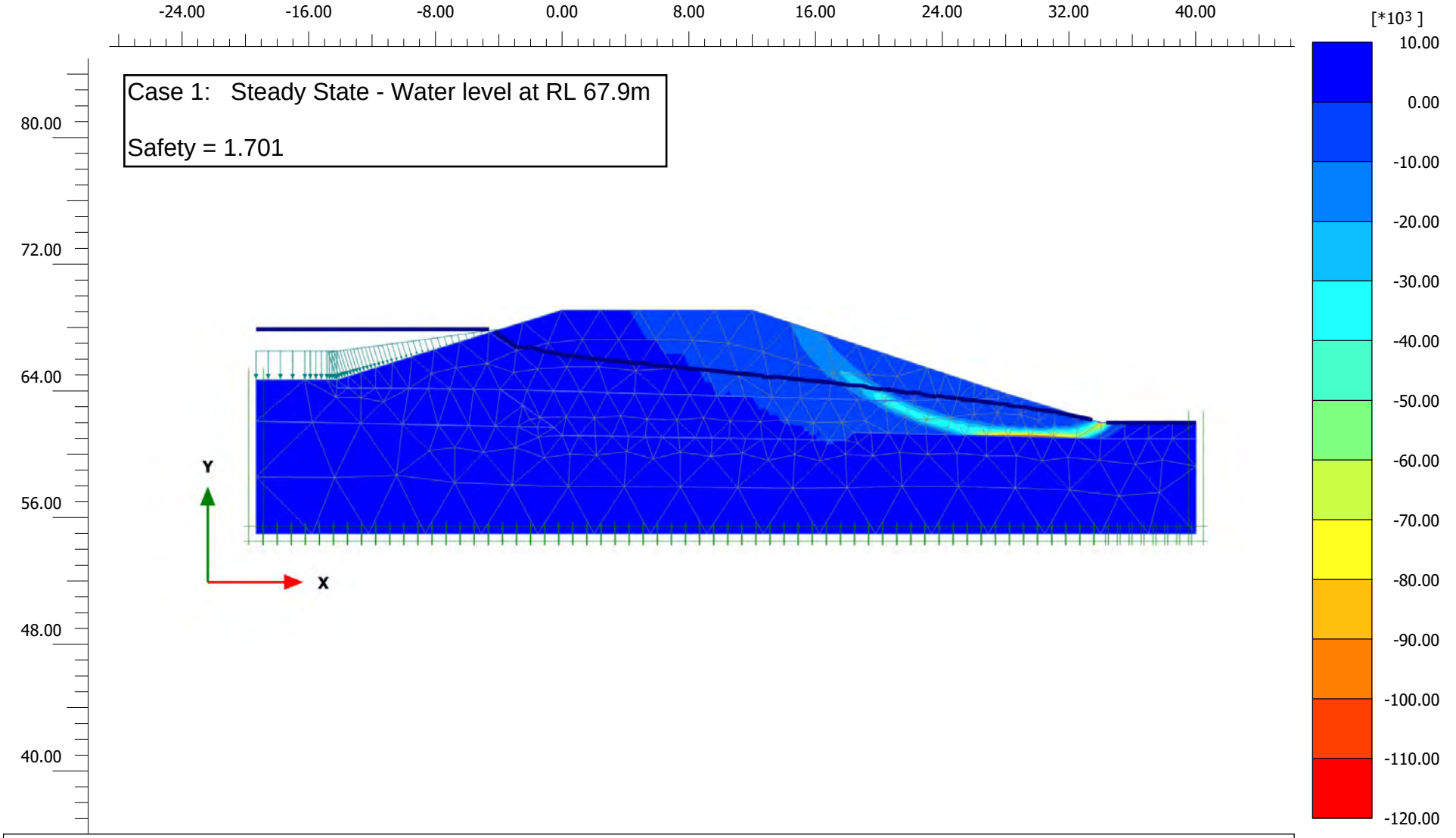
Total principal strain ε_1 (scaled up $0.0500*10^{-3}$ times)

Maximum value = $0.1137*10^{-12}$ (Element 10 at Node 4089)

Minimum value = $-23.25*10^{3}$ (Element 133 at Node 3457)

PLAXIS® 2D

Project description Redvale			*Date* 6/11/2025
Project filename Redvale Pond 5	*Step* 419	*Company* Pattle Delamore Partners Limited	



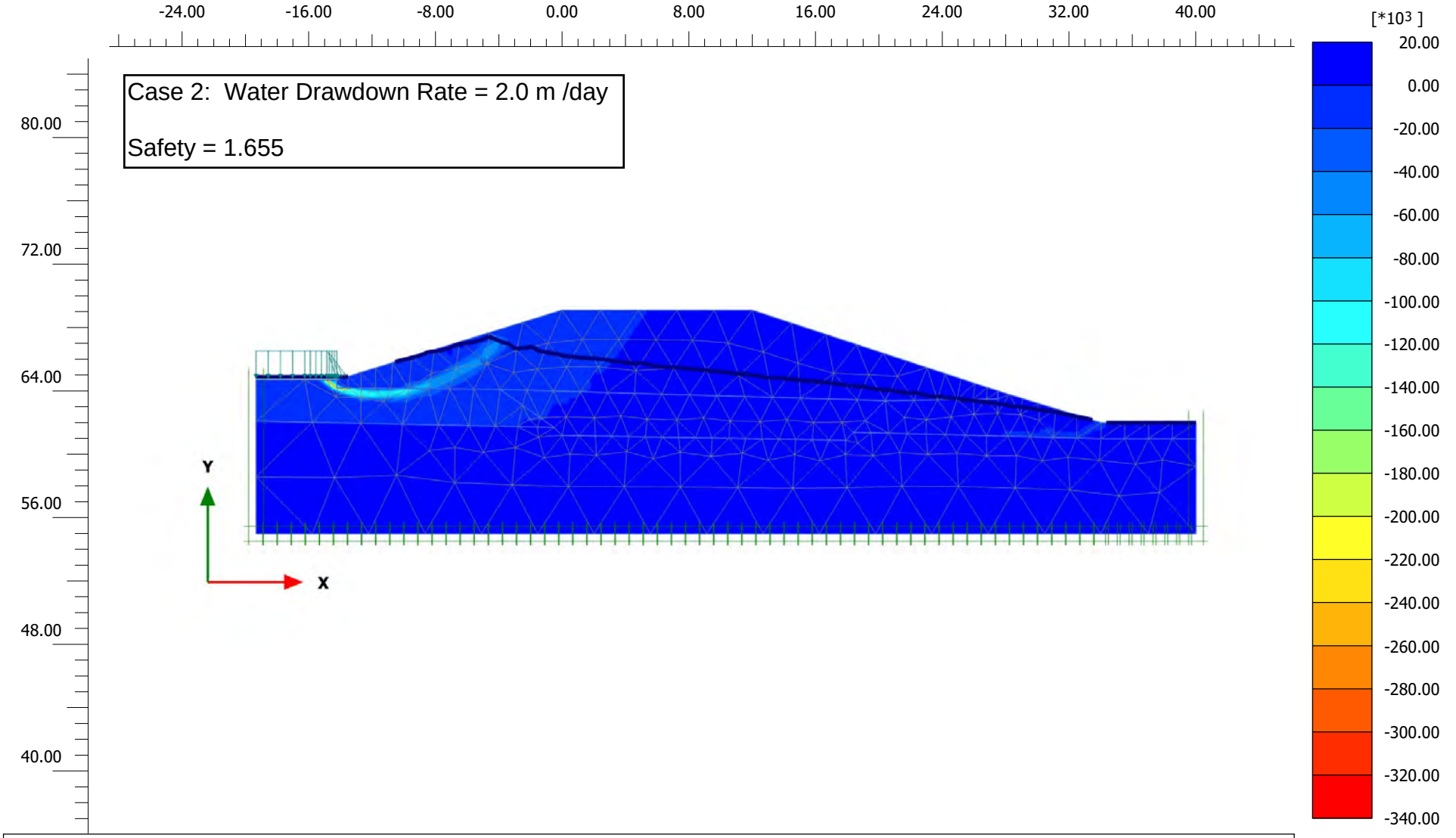
Total principal strain ε_1 (scaled up $0.0200*10^{-3}$ times)

Maximum value = $0.05421*10^{-18}$ (Element 172 at Node 2033)

Minimum value = $-116.9*10^{3}$ (Element 208 at Node 2907)

PLAXIS® 2D

Project description		Date
Redvale Pond 6		6/11/2025
Project filename	**Step**	**Company**
Redvale Pond 6	415	Pattle Delamore Partners Limited



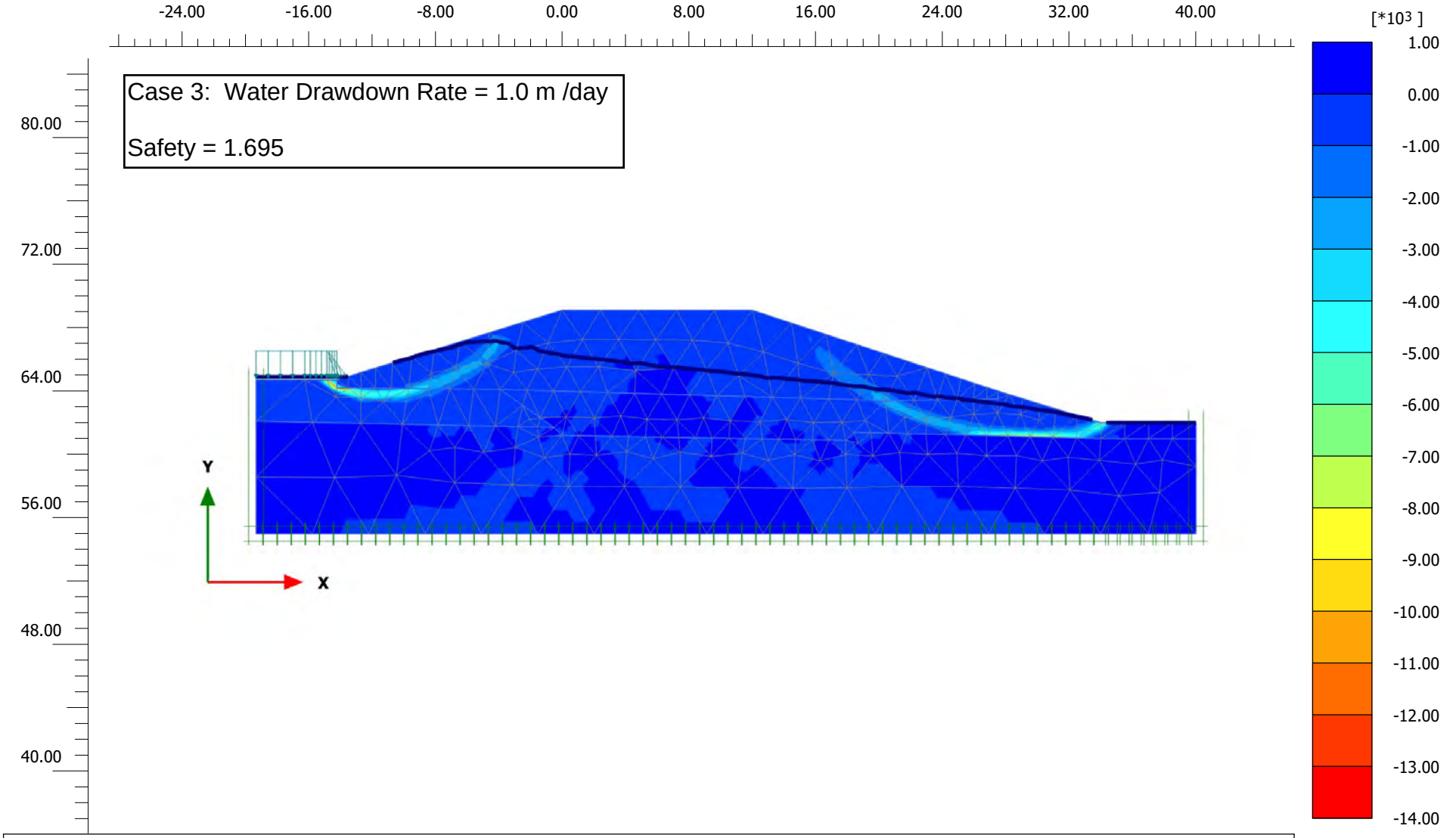
Total principal strain ε_1 (scaled up $5.00*10^{-6}$ times)

Maximum value = $0.03181*10^{-6}$ (Element 68 at Node 236)

Minimum value = $-322.0*10^{3}$ (Element 103 at Node 66)

PLAXIS® 2D

Project description Redvale Pond 6			*Date* 6/11/2025
Project filename Redvale Pond 6	*Step* 106	*Company* Pattle Delamore Partners Limited	



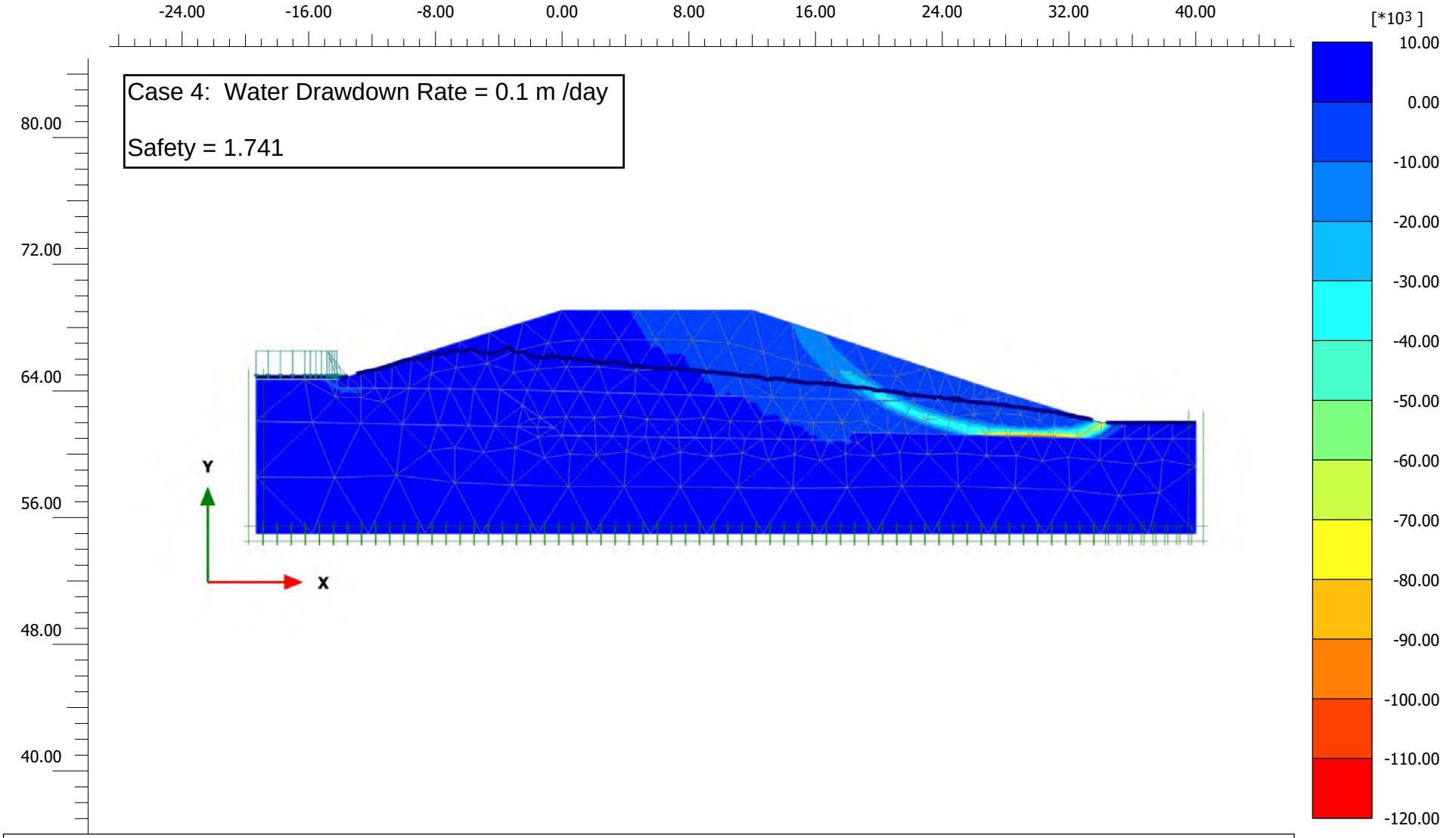
Total principal strain ε_1 (scaled up $0.100*10^{-3}$ times)

Maximum value = $0.5684*10^{-12}$ (Element 16 at Node 266)

Minimum value = $-13.78*10^{3}$ (Element 103 at Node 66)

PLAXIS® 2D

Project description Redvale Pond 6			*Date* 6/11/2025
Project filename Redvale Pond 6	*Step* 209	*Company* Pattle Delamore Partners Limited	



Total principal strain ε_1 (scaled up $0.0200*10^{-3}$ times)

Maximum value = $0.4337*10^{-18}$ (Element 390 at Node 2229)

Minimum value = $-117.4*10^{3}$ (Element 208 at Node 2907)

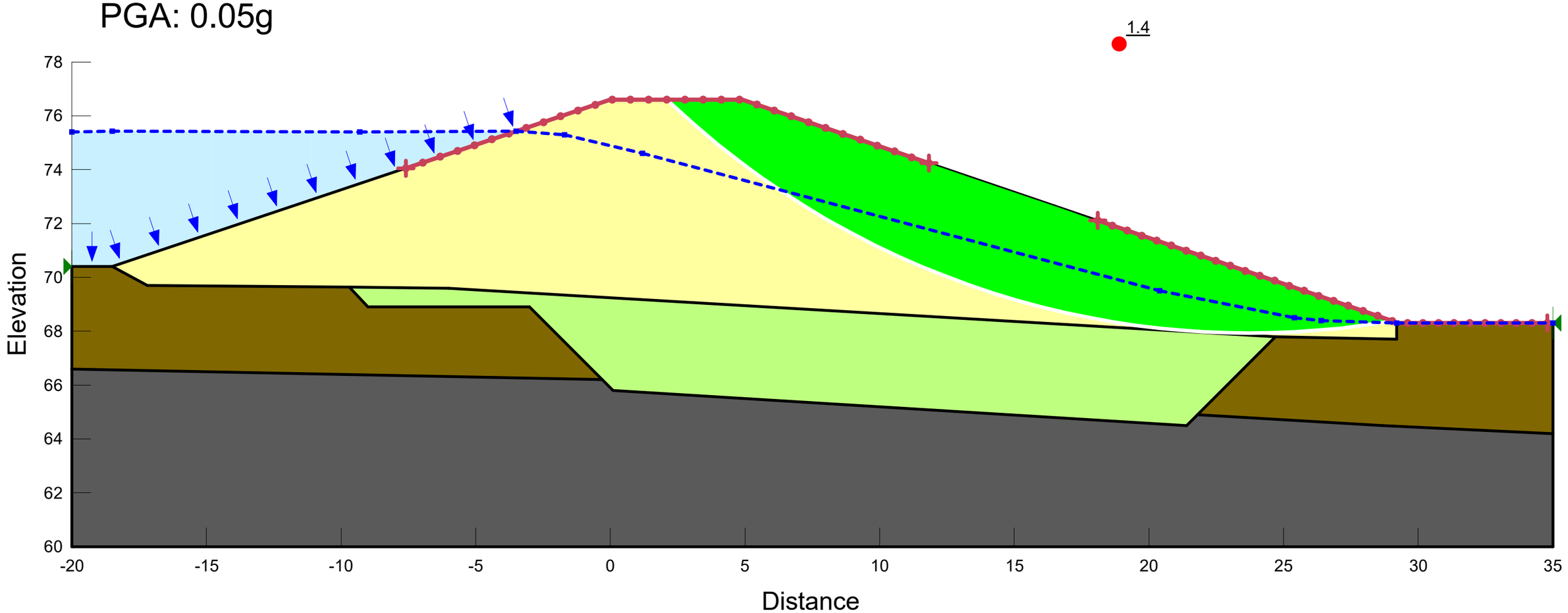
PLAXIS® 2D

Project description		Date
Redvale Pond 6		6/11/2025
Project filename	**Step**	**Company**
Redvale Pond 6	315	Pattle Delamore Partners Limited

Appendix D: Seismic Analysis

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)
	Bedrock	Mohr-Coulomb	20	20	40
	Organic Soil (Drained)	Mohr-Coulomb	17	2	28
	Type 1C (Drained)	Mohr-Coulomb	19	5	35
	Type 3B (Drained)	Mohr-Coulomb	18	5	25

PGA: 0.05g



NOTES:

REVISION	DATE	APP
A	16/10/2025	

CLIENT: Waste Management New Zealand Ltd

PROJECT: Redvale Landfill Reconsenting Geotech

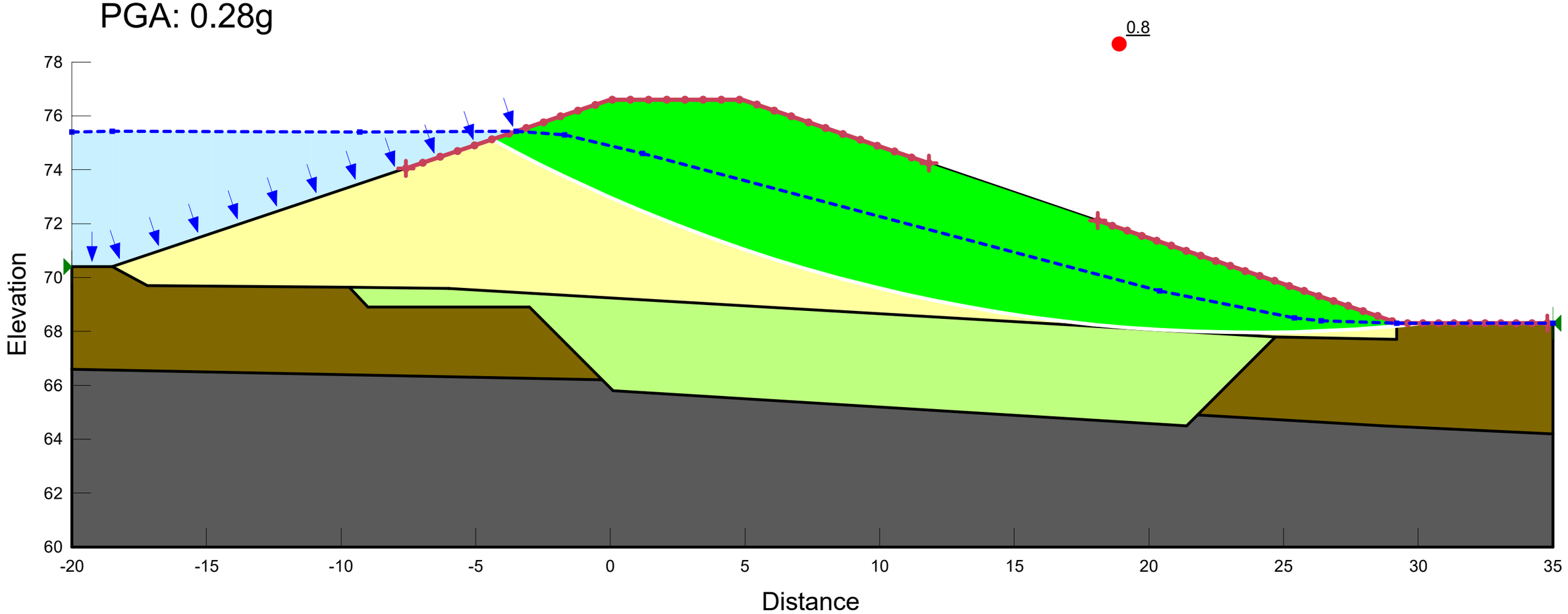
TITLE: 01 Seismic_SLS_Pond 5

PROJECT NO:		ANALYSIS BY:	FIGURE NO:	REV:
A046070004	SCALE: 1:150 @ A3	JE	1	A

Directory: J:\A04600_A04699\A04607 Redvale Landfill\A046070004_Redvale Pond 5 & 6 Reconsenting Geotech\007_Work\Design\02 Stability n Seepage\03 Slope W Mo\

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)
	Bedrock	Mohr-Coulomb	20	20	40
	Organic Soil (Drained)	Mohr-Coulomb	17	2	28
	Type 1C (Drained)	Mohr-Coulomb	19	5	35
	Type 3B (Drained)	Mohr-Coulomb	18	5	25

PGA: 0.28g



NOTES:

REVISION	DATE	APP
A	16/10/2025	

CLIENT: Waste Management New Zealand Ltd

PROJECT: Redvale Landfill Reconsenting Geotech

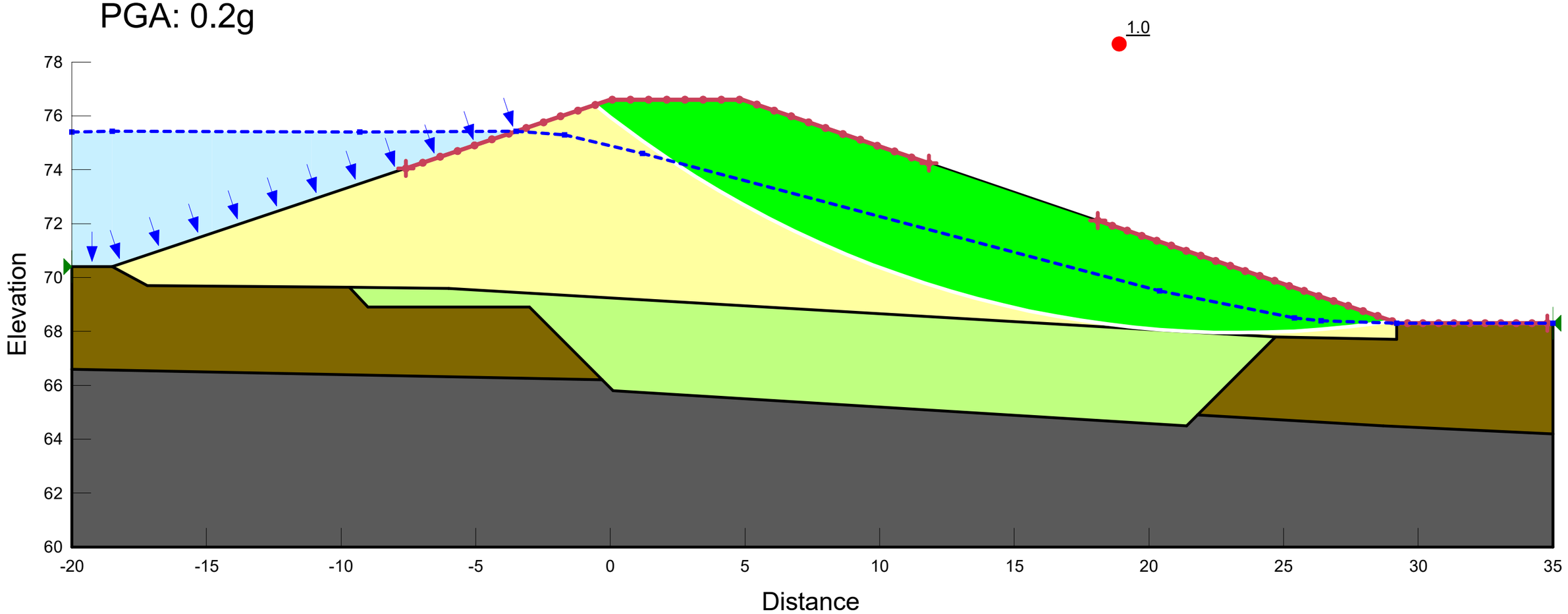
TITLE: 02 Seismic_ULS_Pond 5

PROJECT NO:	SCALE:	ANALYSIS BY:	FIGURE NO:	REV:
A046070004	1:150 @ A3	JE	1	A

Directory: J:\A04600_A04699\A04607 Redvale Landfill\A046070004_Redvale Pond 5 & 6 Reconsenting Geotech\007_Work\Design\02 Stability n Seepage\03 Slope W Mo\

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)
	Bedrock	Mohr-Coulomb	20	20	40
	Organic Soil (Drained)	Mohr-Coulomb	17	2	28
	Type 1C (Drained)	Mohr-Coulomb	19	5	35
	Type 3B (Drained)	Mohr-Coulomb	18	5	25

PGA: 0.2g



NOTES:

REVISION	DATE	APP
A	29/10/2025	

CLIENT: Waste Management New Zealand Ltd

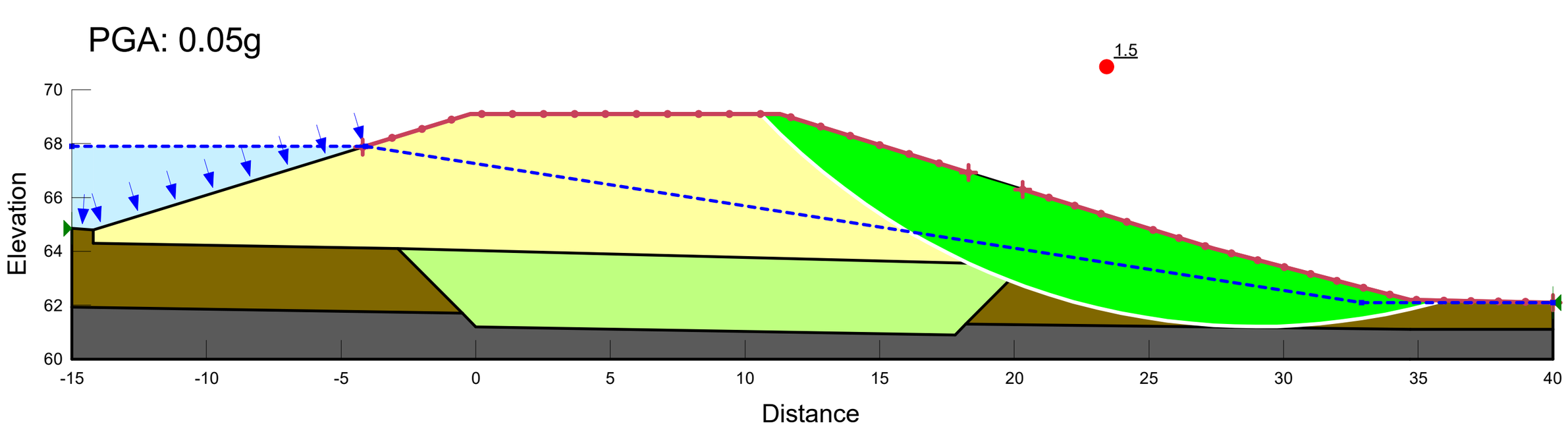
PROJECT: Redvale Landfill Reconsenting Geotech

TITLE: 03 Seismic_Yield_Pond 5

PROJECT NO:		ANALYSIS BY:	FIGURE NO:	REV:
A046070004	SCALE: 1:150 @ A3	JE	1	A

Directory: J:\A04600_A04699\A04607 Redvale Landfill\A046070004_Redvale Pond 5 & 6 Reconsenting Geotech\007_Work\Design\02 Stability n Seepage\03 Slope W Mo\

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)
	Bedrock	Mohr-Coulomb	20	20	40
	Organic Soil (Drained)	Mohr-Coulomb	17	2	28
	Type 1C (Drained)	Mohr-Coulomb	19	5	35
	Type 3B (Drained)	Mohr-Coulomb	18	5	25



NOTES:

REVISION	DATE	APP
A	29/10/2025	

CLIENT: Waste Management New Zealand Ltd

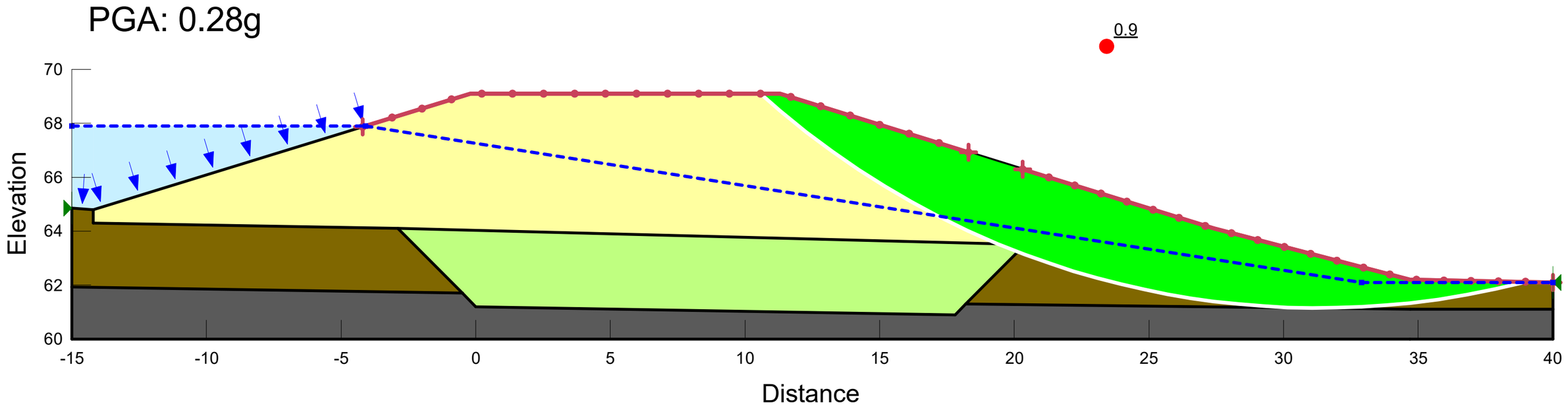
PROJECT: Redvale Landfill Reconsenting Geotech

TITLE: 04 Seismic_SLS_Pond 6

PROJECT NO:	SCALE:	ANALYSIS BY:	FIGURE NO:	REV:
A046070004	1:150 @ A3	JE	1	A

Directory: J:\A04600_A04699\A04607 Redvale Landfill\A046070004_Redvale Pond 5 & 6 Reconsenting Geotech\007_Work\Design\02 Stability n Seepage\03 Slope W Mo\

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)
	Bedrock	Mohr-Coulomb	20	20	40
	Organic Soil (Drained)	Mohr-Coulomb	17	2	28
	Type 1C (Drained)	Mohr-Coulomb	19	5	35
	Type 3B (Drained)	Mohr-Coulomb	18	5	25



NOTES:

REVISION	DATE	APP
A	29/10/2025	

CLIENT: Waste Management New Zealand Ltd

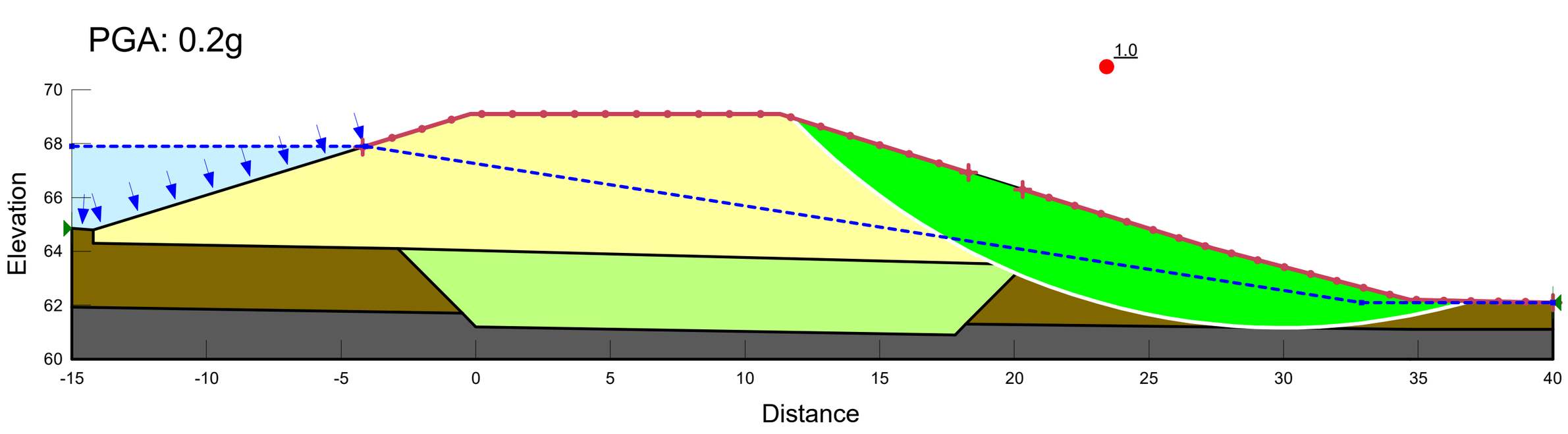
PROJECT: Redvale Landfill Reconsenting Geotech

TITLE: 05 Seismic_ULS_Pond 6

PROJECT NO:	SCALE:	ANALYSIS BY:	FIGURE NO:	REV:
A046070004	1:150 @ A3	JE	1	A

Directory: J:\A04600_A04699\A04607 Redvale Landfill\A046070004_Redvale Pond 5 & 6 Reconsenting Geotech\007_Work\Design\02 Stability n Seepage\03 Slope W Mo\

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)
	Bedrock	Mohr-Coulomb	20	20	40
	Organic Soil (Drained)	Mohr-Coulomb	17	2	28
	Type 1C (Drained)	Mohr-Coulomb	19	5	35
	Type 3B (Drained)	Mohr-Coulomb	18	5	25



NOTES:

REVISION	DATE	APP
A	29/10/2025	

CLIENT: Waste Management New Zealand Ltd

PROJECT: Redvale Landfill Reconsenting Geotech

TITLE: 06 Seismic_Yield_Pond 6

PROJECT NO:	SCALE:	ANALYSIS BY:	FIGURE NO:	REV:
A046070004	1:150 @ A3	JE	1	A

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