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8 August 2024

Hutt City Council
30 Laings Road
Private Bag 31912
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.
Attn: Dan Kellow
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Request for more Geotechnical information – Eastern Hills Reservoir Notice of Requirement

Dear Dan,

Please find below our response to your letter dated 3 July 2024 asking us to respond to comments in the geotechnical peer review carried out by ENGEO on behalf of Hutt City Council.

1. **5.1 Ground Shaking: The Report states that the results of the 2022 NSHM have not yet been adopted into guidance document and work is underway to revise NS 1170.5 and other New Zealand Guidance documents relating to seismic hazard.**

   At the present time, the Draft Technical Specification (TS 1170.5) has been released and results are available to develop code-based response spectra based on the 2022 NSHM. It may be prudent to consider the draft TS 1170.5 response spectra in comparison with the PSHA results.

   The mean hazard calculated using NZNSHM 22 is the basis for spectra in DTS 1170.5. We expect the PSHA spectra will therefore correspond well with draft TS 1170.5. We consider no further analysis is necessary at this time.

2. **8.2.1 – Limit Equilibrium Analysis: Figure 5 shows that the pseudo-static slope stability analysis considers a horizontal seismic coefficient (*kh*) equal to the estimated 2,500-year ground acceleration (PGA).**

   In our experience, it is generally not appropriate to set *kh* equal to PGA in a pseudo-static analysis. The use of PGA usually results in overly conservative factors of safety (Seed, 1979; Chowdhury, 1978) and most current simplified methods, such as Bray and Macedo (2019), estimate *kh* using conditional ground motion models in conjunction with a displacement threshold.

   The reservoir tank performance is sensitive to movement. The use of PGA is to understand the slope set back required for confidence that there is no movement. As discussed in the report, we do not believe the LE analysis gives a reasonable assessment of slope seismic performance, hence dynamic analysis was undertaken and is considered most appropriate for this Project.

3. 8.2.2 – Dynamic Finite Element Analysis: Please provide all material properties for review.

We have provided further details of the material properties and the dynamic model described in section 8.2.2 of the geotechnical interpretive report as Attachment 1

4. 8.2.2 – Dynamic Finite Element Analysis: The report states that the Mohr-Coulomb model was used in the analysis. Low strain shear stiffness and damping has been determined iteratively.

Please provide additional details of how appropriate shear stiffness and damping were selected for each material. We also note that compared to the Mohr-Coulomb model, the Hardening Soil model with small-strain stiffness (HSsmall) is generally more appropriate for dynamic calculations as it includes strain-dependent shear stiffness and damping.

The calculated shear strains are typically low. Low Rayleigh damping has been applied conservatively. The analysis we have undertaken suggests the extent of deformation is not sensitive to damping in this case. At this stage we have insufficient information to justify using higher damping, however this can be considered further in the detailed design phase of the project, which will begin once planning approvals have been issued.

5. 8.2.3 – Earthquake Records: Please confirm that the scaled ground motion time histories were applied to the PLAXIS model in units of m/s.

We can confirm that the scaled ground motion time histories were applied to the PLAXIS model in m/s units.

6. 8.2.4 – Results: Figure 8 shows typical displacement contours from the dynamic analysis and the report notes that the magnitude of the calculated displacements vary depending on the specific characteristics of the ground motions but area typically more than 1m and could easily be greater in reality considering the brittle nature of the rock.

Please provide a displacement contour scale for interpretation of Figure 8.

We have provided a displacement contour scale as Attachment 1, but do not consider it particularly relevant to the site due to the brittle nature of the materials identified through previous ground investigations and the accuracy of these estimates at large strain. The structure is sensitive to ground displacements and displacement over 1 m is not likely to be tolerable by the structure.

Please provide estimated displacement profiles at critical locations for each ground motion time history considered.

As discussed in section 8.2.4 of the geotechnical interpretive report, displacement profiles for all records have a similar mode of deformation, primarily within the very weak to extremely weak, completely to residually weathered rock and colluvium. Further analysis will be carried out in detailed design following additional site investigations and refinement of the ground model. We are confident that the work carried out to date reasonably demonstrates that the slope hazard can be managed and is acceptably low.

Please provide the average displacement profile at critical locations considering the full suite of ground motion time histories.

This will be undertaken in the detailed design phase of the project, which will begin once planning approvals have been issued. We have only analysed one section for the purposes of understanding the slope hazard at the site. Further investigations and analysis will be undertaken during the detailed design phase of the Project. Notwithstanding this, from the investigations and modelling undertaken as part of the development of the concept, we are confident that the work carried out to date reasonably demonstrates that the slope hazard can be managed and is acceptably low.

7. **8.2.4 – Results: The single output of results shown for the dynamic analyses (Figure 8) appear to be inconsistent with the pseudo-static analyses, which indicate that failure (or significant displacement) extending at least 30m under the tank foundations could be expected. While we appreciate the inherent differences in how these two types of analyses are performed, the estimate displacements from dynamic analyses appear low and localised in contrast to the pseudo-static results.**

   The PLAXIS results should be reviewed in further detail once the additional requested information is provided.

   As discussed in section 8.2 of the geotechnical report provided, we do not have confidence in psuedo-static analysis results because if the inherent assumptions made with this simplified method of analysis and observed performance of similar greywacke slopes in the Kaikoura earthquake.

8. **8.3 – Platform Stabilisation Piles: We understand that 1.2m diameter bored reinforced concrete soldier piles and capping beams are proposed around sections of the tank perimeter where the reservoir foundation is on completely weathered rock that is susceptible to deformation in severe storms or earthquakes.**

   Whey were the proposed soldier piles not considered in the limit equilibrium or dynamic deformation analyses?

   We consider that the piles can be designed to constrain the foundation and therefore have not included these in the model for concept design. Further consideration of this will be undertaken in the detailed design phase of the project once the additional site investigations are completed

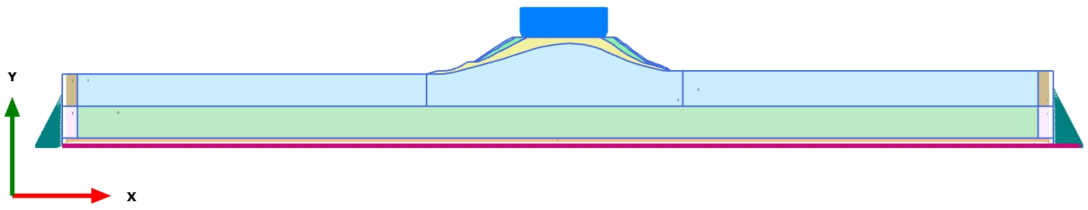
Yours sincerely

Cathy Crooks

Cathy Crooks
Principal Planner
Connect Water/WSP

PLAXIS Report

1.1.1.1 Calculation results, RSN1633_T_1_9211 [Phase_4] (4/11030), Materials plot



Materials plot

1.1.2.1.1 Materials - Soil and interfaces - Mohr-Coulomb

Identification number		1
Identification		Colluvium
Soil model		Mohr-Coulomb
Drainage type		Drained
Colour		
Comments		
γ_unsat	kN/m³	18.00
γ_sat	kN/m³	18.00
e_init		0.5000
n_init		0.3333
Input method		Direct
Rayleigh α		0.000
Rayleigh β		1.000E-3
E'_ref	kN/m²	25.00E3
ν (nu)		0.3200
G_ref	kN/m²	9470
E_oed	kN/m²	35.77E3

Identification number		1
E'_inc	kN/m²/m	0.000
y_ref	m	0.000
V_s	m/s	71.84
V_p	m/s	139.6
c'_ref	kN/m²	50.00
φ' (phi)	°	0.000
ψ (psi)	°	0.000
c'_inc	kN/m²/m	0.000
y_ref	m	0.000
Tension cut-off		True
Tensile strength	kN/m²	0.000
Determination		ν-undrained definition
ν_u definition method		Direct
ν_u,equivalent (nu)		0.4950
Skempton B		0.9755
K_w,ref/n	kN/m²	920.7E3
Classification type		Standard
Soil class (Standard)		Coarse
< 2 μm	%	10.00

Identification number		1
2 µm - 50 µm	%	13.00
50 µm - 2 mm	%	77.00
Use defaults		False
k_x	m/day	0.000
k_y	m/day	0.000
Void ratio dependency		True
c_k		1000E12
n_init		0.3333
-ψ_unsat	m	10.00E3
c_s	kJ/t/K	0.000
λ_s	kW/m/K	0.000
ρ_s	t/m³	0.000
Thermal expansion type		Isotropic
α_sv	1/K	0.000
Phase change		False
D_v	m²/day	0.000
f_Tv		0.000
Stiffness determination		Derived
Strength determination		Rigid

Identification number		1
R_inter		1.000
Consider gap closure		True
Cross permeability		Impermeable
Drainage conductivity, dk	m^3/day/m	0.000
R_thermal	m^2 K/kW	0.000
K_0 determination		Automatic
K_0,x		0.5000
K_0,z		0.5000

1.1.2.1.2 Materials - Soil and interfaces - Hoek-Brown

Identification number		2	3	4	5
Identification		Completely weathered	Highly weathered	Moderately weathered	slightly weathered
Soil model		Hoek-Brown	Hoek-Brown	Hoek-Brown	Hoek-Brown
Drainage type		Drained	Drained	Drained	Drained
Colour					
Comments					
γ_unsat	kN/m³	22.00	23.00	24.00	24.00
γ_sat	kN/m³	22.00	23.00	24.00	24.00
e_init		0.5000	0.5000	0.5000	0.5000
n_init		0.3333	0.3333	0.3333	0.3333
Input method		Direct	Direct	Direct	Direct
Rayleigh α		0.000	0.000	0.000	0.000
Rayleigh β		1.000E-3	1.000E-3	1.000E-3	1.000E-3
E_rm	kN/m²	12.76E3	284.8E3	1.676E6	5.376E6
ν (nu)		0.3000	0.2800	0.2500	0.2300
G_ref	kN/m²	4907	111.3E3	670.5E3	2.185E6
|σ_ci|	kN/m²	1000	10.00E3	30.00E3	50.00E3
Determination		Derived	Derived	Derived	Derived

Identification number		2	3	4	5
m_b		0.8647	1.478	2.229	3.186
s		0.07913E-3	0.4189E-3	1.273E-3	3.866E-3
a		0.5611	0.5223	0.5114	0.5057
m_i		18.00	18.00	19.00	19.00
GSI		15.00	30.00	40.00	50.00
D		0.000	0.000	0.000	0.000
σ_t	kN/m²	0.09151	2.835	17.13	60.67
σ_c	kN/m²	-4.995	-172.0	-992.1	-3011
Tension cut-off		False	False	False	False
ψ_max	°	0.000	0.000	0.000	0.000
σ_ψ	kN/m²	0.000	0.000	0.000	0.000
Determination		ν-undrained definition	ν-undrained definition	ν-undrained definition	ν-undrained definition
ν_u definition method		Direct	Direct	Direct	Direct
ν_u,equivalent (nu)		0.4950	0.4950	0.4950	0.4950
Skempton B		0.9783	0.9805	0.9833	0.9848
K_w,ref/n	kN/m²	478.4E3	10.87E6	65.71E6	214.5E6
Classification type		Standard	Standard	Standard	Standard
Soil class (Standard)		Coarse	Coarse	Coarse	Coarse
< 2 µm	%	10.00	10.00	10.00	10.00
2 µm - 50 µm	%	13.00	13.00	13.00	13.00
50 µm - 2 mm	%	77.00	77.00	77.00	77.00

Identification number		2	3	4	5
Use defaults		False	False	False	False
k_x	m/day	0.000	0.000	0.000	0.000
k_y	m/day	0.000	0.000	0.000	0.000
Void ratio dependency		True	True	True	True
c_k		1000E12	1000E12	1000E12	1000E12
n_init		0.3333	0.3333	0.3333	0.3333
-ψ_unsat	m	10.00E3	10.00E3	10.00E3	10.00E3
c_s	kJ/t/K	0.000	0.000	0.000	0.000
λ_s	kW/m/K	0.000	0.000	0.000	0.000
ρ_s	t/m^3	0.000	0.000	0.000	0.000
Thermal expansion type		Isotropic	Isotropic	Isotropic	Isotropic
α_sv	1/K	0.000	0.000	0.000	0.000
Phase change		False	False	False	False
D_v	m^2/day	0.000	0.000	0.000	0.000
f_Tv		0.000	0.000	0.000	0.000
Stiffness determination		Derived	Derived	Derived	Derived
Strength determination		Rigid	Rigid	Rigid	Rigid
R_inter		1.000	1.000	1.000	1.000
Consider gap closure		True	True	True	True
Cross permeability		Impermeable	Impermeable	Impermeable	Impermeable
Drainage conductivity, dk	m^3/day/m	0.000	0.000	0.000	0.000

Identification number		2	3	4	5
R_thermal	m² K/kW	0.000	0.000	0.000	0.000
K_0 determination		Automatic	Automatic	Automatic	Automatic
K_0,x		0.5000	0.5000	0.5000	0.5000
K_0,z		0.5000	0.5000	0.5000	0.5000

1.1.2.1.3 Materials - Soil and interfaces - Linear Elastic

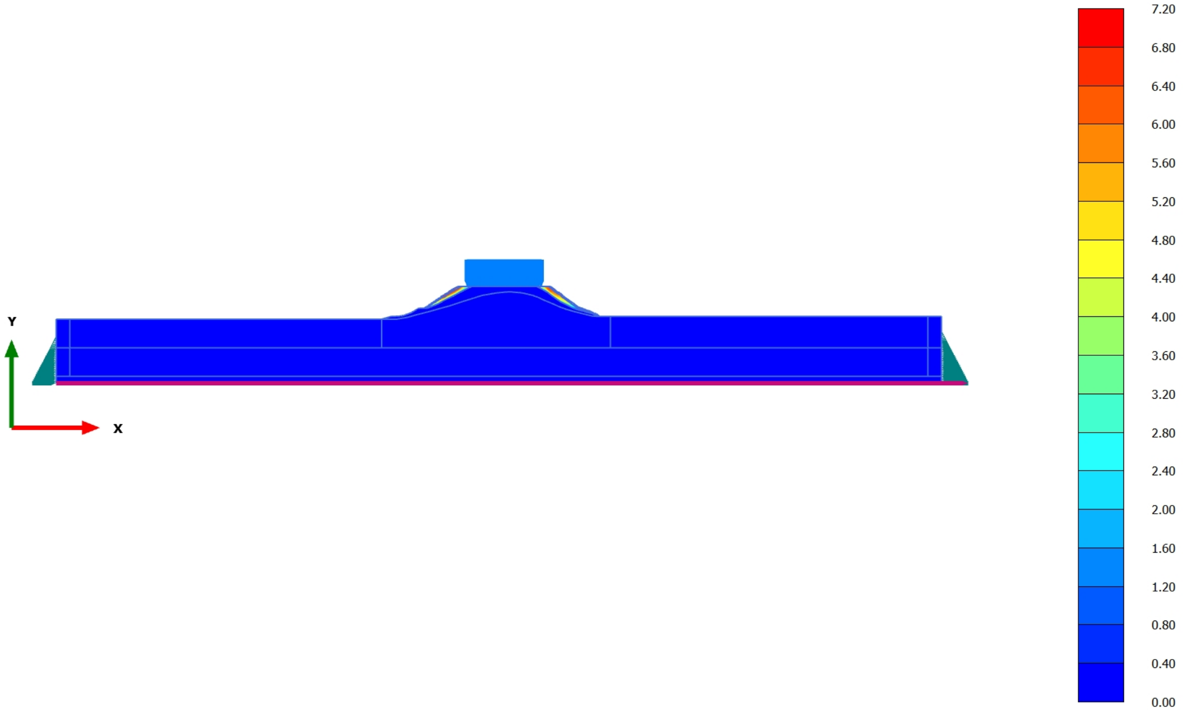
Identification number		6	7	8
Identification		bedrock	Moderate-Boundary	Slightly-Boundary
Soil model		Linear Elastic	Linear Elastic	Linear Elastic
Drainage type		Drained	Drained	Drained
Colour				
Comments				
γ_unsat	kN/m³	25.00	24.00	24.00
γ_sat	kN/m³	25.00	24.00	24.00
e_init		0.5000	0.5000	0.5000
n_init		0.3333	0.3333	0.3333
Input method		Direct	Direct	Direct
Rayleigh α		0.000	0.000	0.000
Rayleigh β		0.000	1.000E-3	1.000E-3
E'_ref	kN/m²	13.88E6	4.213E6	6.635E6
ν (nu)		0.2100	0.2500	0.2300
G_ref	kN/m²	5.734E6	1.685E6	2.697E6
E_oed	kN/m²	15.62E6	5.056E6	7.692E6

Identification number		6	7	8
E'_inc	kN/m²/m	0.000	0.000	0.000
y_ref	m	0.000	0.000	0.000
V_s	m/s	1500	830.0	1050
V_p	m/s	2476	1438	1773
Determination		ν-undrained definition	ν-undrained definition	ν-undrained definition
ν_u definition method		Direct	Direct	Direct
ν_u,equivalent (nu)		0.4950	0.4950	0.4950
Skempton B		0.9860	0.9833	0.9848
K_w,ref/n	kN/m²	563.5E6	165.2E6	264.7E6
Classification type		Standard	Standard	Standard
Soil class (Standard)		Coarse	Coarse	Coarse
< 2 μm	%	10.00	10.00	10.00
2 μm - 50 μm	%	13.00	13.00	13.00
50 μm - 2 mm	%	77.00	77.00	77.00
Use defaults		False	False	False
k_x	m/day	0.000	0.000	0.000
k_y	m/day	0.000	0.000	0.000
Void ratio dependency		True	True	True
c_k		1000E12	1000E12	1000E12

Identification number		6	7	8
n_init		0.3333	0.3333	0.3333
-ψ_unsat	m	10.00E3	10.00E3	10.00E3
c_s	kJ/t/K	0.000	0.000	0.000
λ_s	kW/m/K	0.000	0.000	0.000
ρ_s	t/m^3	0.000	0.000	0.000
Thermal expansion type		Isotropic	Isotropic	Isotropic
α_sv	1/K	0.000	0.000	0.000
Phase change		False	False	False
D_v	m^2/day	0.000	0.000	0.000
f_Tv		0.000	0.000	0.000
Stiffness determination		Derived	Derived	Derived
Strength determination		Rigid	Rigid	Rigid
R_inter		1.000	1.000	1.000
Consider gap closure		True	True	True
Cross permeability		Impermeable	Impermeable	Impermeable
Drainage conductivity, dk	m^3/day/m	0.000	0.000	0.000
R_thermal	m^2 K/kW	0.000	0.000	0.000
K_0 determination		Automatic	Automatic	Automatic
K_0,x		0.5000	0.5000	0.5000

Identification number	6	7	8
K_0,z	0.5000	0.5000	0.5000

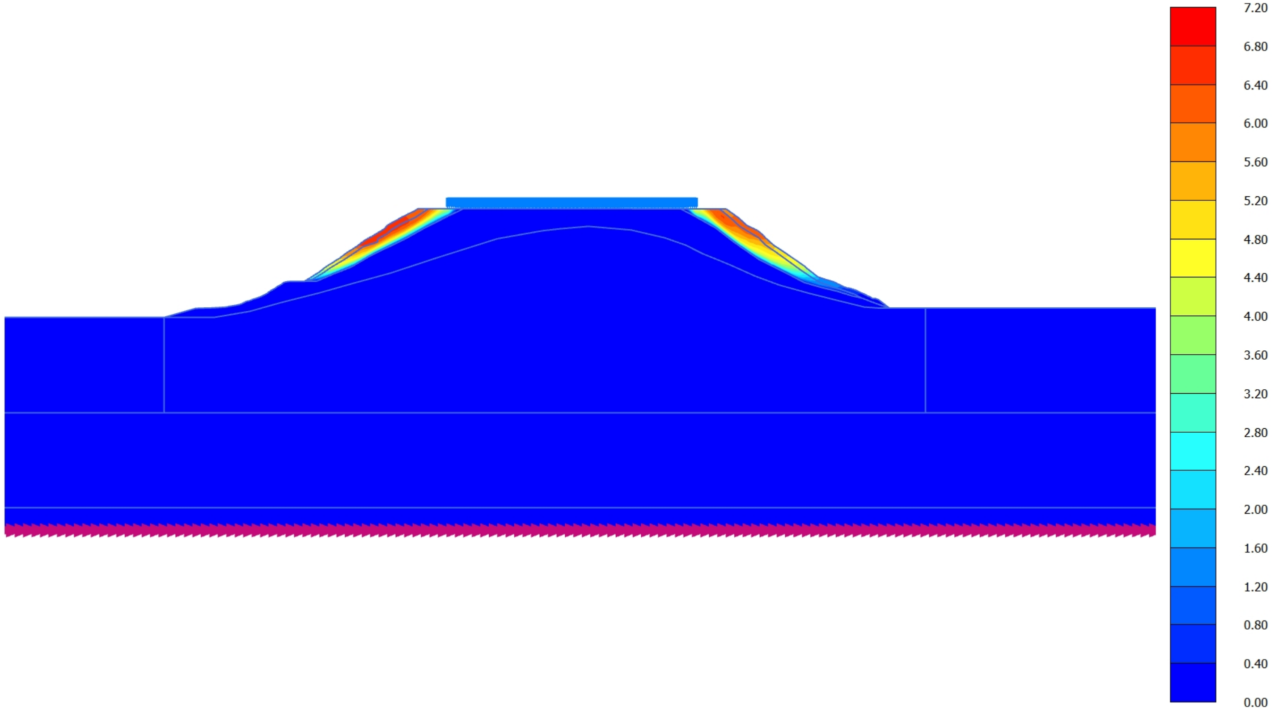
2.1.1.1.1 Calculation results, RSN1633_T_1_9211 [Phase_4] (4/11030), Total displacements |u|



Total displacements |u| (at true scale) (Time 46.00 s)

Uniform value of 0.000 m

4.1.1 Calculation results, RSN1633_T_1_9211 [Phase_4] (4/11030), Total displacements |u|



Total displacements |u| (scaled up 5.00 times) (Time 46.00 s)

Maximum value = 6.796 m (Element 542 at Node 20384)