28th March 2013

MEMORANDUM

UND-02-Memo-014

To	[redacted] s 9(2)(a)
From	[redacted] s 9(2)(a)
CC	
Date	27 March 2013
Subject	Underpass – Historic Lateral Spreading Cracks – Geological Observations

Background

Sub parallel orientated, infilled cracks are observed in surfical soils at the eastern end of the MPA Underpass site. These cracks are considered to have been formed as a result of seismic activity.

Observed Geology

Based on our observations, and the excavation of two test pits through the cracks (TPTT7 and TPTT8), the geological sequence of materials in the vicinity of the cracking can be summarised as follows:

Layer No	Material Description	Inferred Origin	Depth below pre construction surface	Thickness
1	Grey gravely SILT / silty gravel	Man Made Fill	0m	0.2m
2a	Light grey and orange mottled gravely SILT with completely weathered greywacke clasts (orange sand)	Reworked Colluvium / Alluvial Fan	0.2m	0.4m
2b	Becoming silty gravel with fine to coarse, moderately weathered sub angular gravels at base. Heavy iron staining at base. Undulating basal surface.	Less weathered Colluvium / Alluvial Fan	0.6m	0.2m
3	Uniform, brown silty SAND / sandy SILT. Undulating basal surface	Marginal Marine Environment (backwater, estuarine, lacustrine)	0.8m	0.4m
4	Silty fine to coarse GRAVEL with minor light grey plastic silt in pockets. Becoming sandier towards the base. Undulating basal surface.	Alluvial Fan	1.2m	1.0m

5	Silty, brown fine SAND. The layer is locally disturbed and deformed.	Alluvium / Marginal Marine Environment(backwater, estuarine, lacustrine)	2.2m	0.1m
6	Light grey / brown SILT with heavy iron staining at top and bottom of layer	Marginal Marine Environment (backwater, estuarine, lacustrine)	2.3m	0.2m
7	Sandy silty fine to coarse GRAVEL	Alluvial Fan	2.5m	1m?

Layers containing cracks

These layers are indicated in Photograph 1 and 2 below.

Photograph 1: Alluvium and marginal marine deposits in site excavation

Photograph 2: Alluvium and marginal marine deposits in TPTT8

Crack Description

A summary of crack information is as follows:

Extent	See attached Sketch EW-02-902. To date, cracks have only been observed at the eastern end of the underpass alignment, between approximate underpass chainage 480-520. This is the only location where the ground has been cleaned back to layers containing cracks. Other areas are either cleaned back to fills, other alluvium layers, or rock.
Width	Typically 10mm (smaller cracks) to 30mm (larger cracks)
Spacing	Smaller cracks are approximately 300-500mm spaced. Larger cracks are approximately 1.5-2m spaced.
Length	Shorter cracks are 2-3m long. Longer cracks are 10-20m long.
Distribution within geological sequence	Layer 1 – None Layer 2a – None visible Layer 2b – Large cracks only Layer 3 – All cracks Layer 4 – Small cracks terminate in the layer, larger cracks continue to base Layer 5 – Large cracks only Layer 6 – None visible Layer 7 – None visible
Colour	Smaller cracks are light grey brown with some orange iron staining on side walls Larger cracks are light grey with dark orange brown iron staining on side walls.
Infill	In layer 3 and upper layer 4, large cracks contain light grey, plastic, cohesive, clayey silt with brown organics.

	In lower Layer 4, large cracks are defined by light grey clayey silt and gravel. There is no discernible crack in the lower layer 4. The silts are inferred to have washed down and accumulated into a more open texture within the gravels. This infers that layer 3 and upper layer 4 supported an open tension crack that was filled with silt, whereas lower gravel layer did not form a crack, but rather a more open texture. Smaller cracks contain sandy silt. The cracks are slightly siltier than the surrounding Layer 3. They do not contain the cohesive, plastic light grey silts like the larger cracks. A common feature is iron staining on the side walls. It is more pronounced and thicker on the larger cracks. There is also trace evidence of precipitation / layering parallel to the sidewalls.
Orientation	The cracks are generally orientated as follows: • 265-275° - at the eastern end of the temporary road (c. Chainage 500-520). • 285-295° - at approximate Chainage 480-500.
Shape	The cracks are essentially sub parallel. They are locally sinuous and also there is evidence that along the length of the larger cracks they curve round from c.270° to 290° orientation as the cracks track in a westerly direction. Some cracks bifurcate (split), both horizontally and vertically. Other cracks appear to cross cut each other. Some cracks are relatively uniform in width from top to bottom. Others are wider at the top, being 50-80mm wide, compared to 30mm wide lower down. The vertical dip of the cracks is variable, with some dipping steeply to the north, others to the south. The cracks are typically at 75-90° from horizontal. The dip of the crack varies with depth. Some are slightly sinuous, whilst others are curved.
General observations and comments	- Cracks appear to have opened from top down (some cracks do not penetrate all the way through Layer 4). - Crack infill has probably entered from the top, probably as a flood plain silt deposit. - The plasticity of the crack infill is considered to be the result of post-depositional alteration - Precipitation of the iron minerals has occurred at the interface between the sand / gravel and relatively impermeable crack infill. - Cracks follow desiccation cracking on surfaces. - The silts that infill the cracks are different to the silts that form Layer 2a. The crack infill is more plastic. - The crack infill silts also infill low spots on the upper surface of Layer 3 (i.e. into the bottom of Layer 2b).
Age	Carbon dating of organics in the cracks at eastern end of the temporary road indicates the infill is approximately 5000 years old. This is based on 1 carbon dating result. There is no dating evidence to suggest cracks of different ages. Organics in the colluvium / alluvium layers above and below the cracks (Layer 2a and Layer 6 respectively) are dated at 10,000 and 25,000 yrs respectively. The dating of Layer 6 therefore suggests it is of Pleistocene Age, and dates back to the last ice age. This infers that the cracks are younger than Layer 2a which is deposited above them. This is likely explained as Layer 2a being a reworked colluvium deposit, carrying organics in

	material that mobilised in an older event. Likewise the trace organics found in Layer 6. It is likely that the yellow brown sand and gravel deposits of this area are actually Holocene in age. And were deposited less than 12,000 years ago. Further carbon dating testing is in progress.
Environment of Deposition	Layer 3 is likely to have been deposited in a terrestrial marginal marine (e.g. estuary / backwater / lacustrine) environment. This low energy, quiet environment would have been periodically interrupted by high energy alluvial fans from the surrounding hillsides and up the valley. These alluvial fans would have been triggered by extreme storms or earthquake events. They would have deposited thick gravels (layers 4 and 7). Between these events, sands and silts (Layers 5 and 6) would have been deposited. These indicate a quieter, lower energy alluvial / marginal marine environment. Some of these deposits are disturbed. It is believed that the rapid emplacement of alluvial gravels over them (i.e. Layer 4) has caused the relatively fluid sands and silts below to deform into the overlying gravel.
Sea Level Changes and Uplift	Sea level rose rapidly up to approximately 6500 years ago, and since then it has remained relatively constant (give or take 1m or so). In conjunction with sea level rise, the area has been subject to uplift from fault movements for a long time, including the last 6500 years. Raised beaches around the coast of Wellington (i.e. Turakirae Head) indicate that there have been multiple events in the last 6500 years that have raised the ground level in the region. Uplift at Turakirae Head in the 1855 and 1460 earthquakes is measured to be approximately 2.5m and 6m respectively. Older uplifts are also recorded here, with three beaches recording uplift of 8.2m (approx 3,100 years ago), 5.5m (approx 4,900 years ago) and 2.7m (approx 6,500 years ago). 24.9m of uplift has therefore occurred over 6500 years, equating to approximately 5m per event. This is why the marginal marine deposits are elevated above sea level despite no significant sea level change in the last 6500 years.

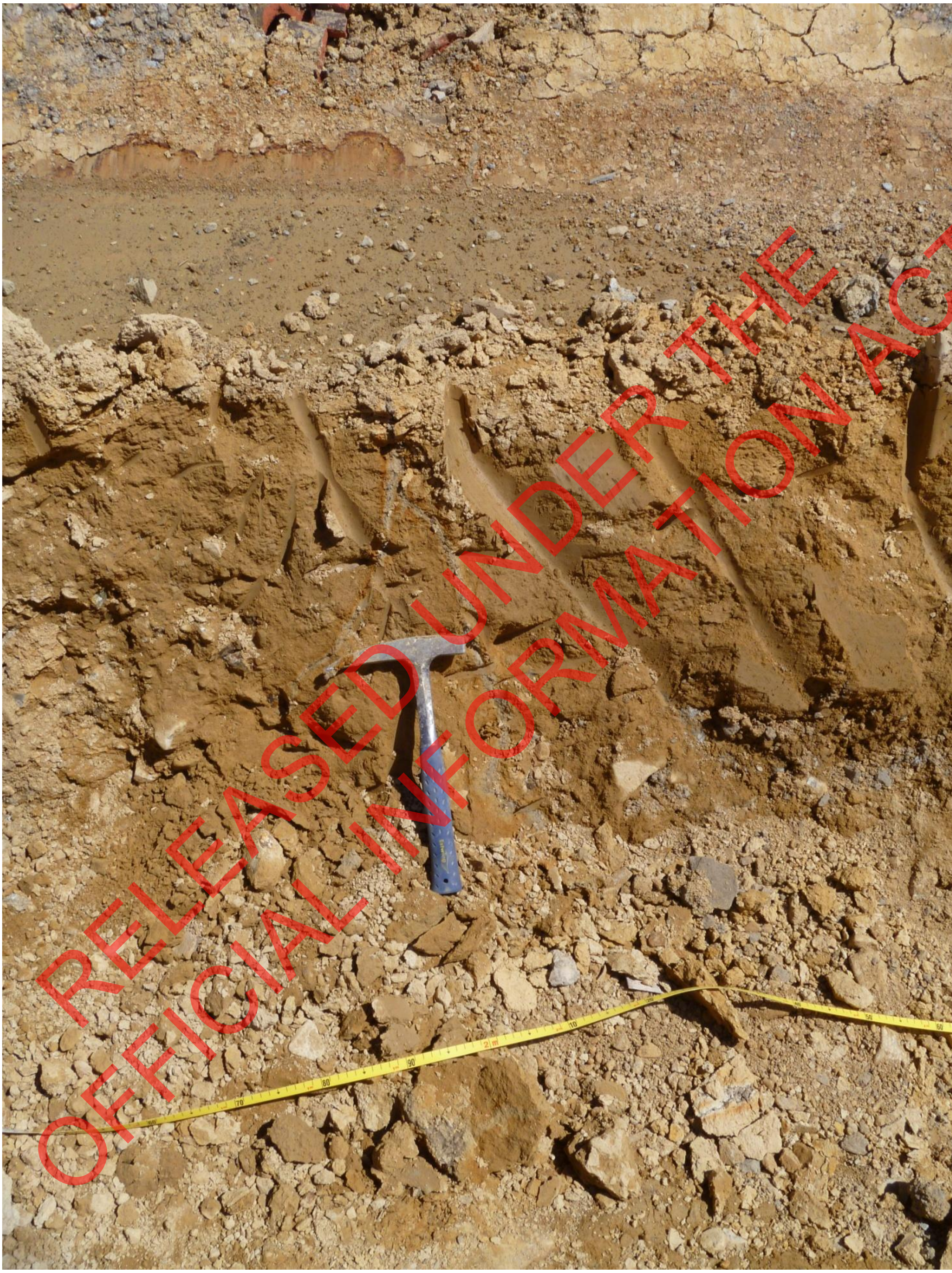
Photograph 3: Example of a marginal marine environment (Cloudy Bay)

Photograph 4: Geological sequence in TPTT8 with large crack through middle of face

Cracking Photographs

Photograph 5: Large bifurcating crack passing through Layer 2b (gravel) and 3 (sand)

Photograph 6 & 7: Indicative spacing and distribution of large cracks (1.5-2m)



Photograph 8: Vertical bifurcation of cracks in Layer 3

Photograph 9: Crack infill also infilling low spots in top of Layer 3

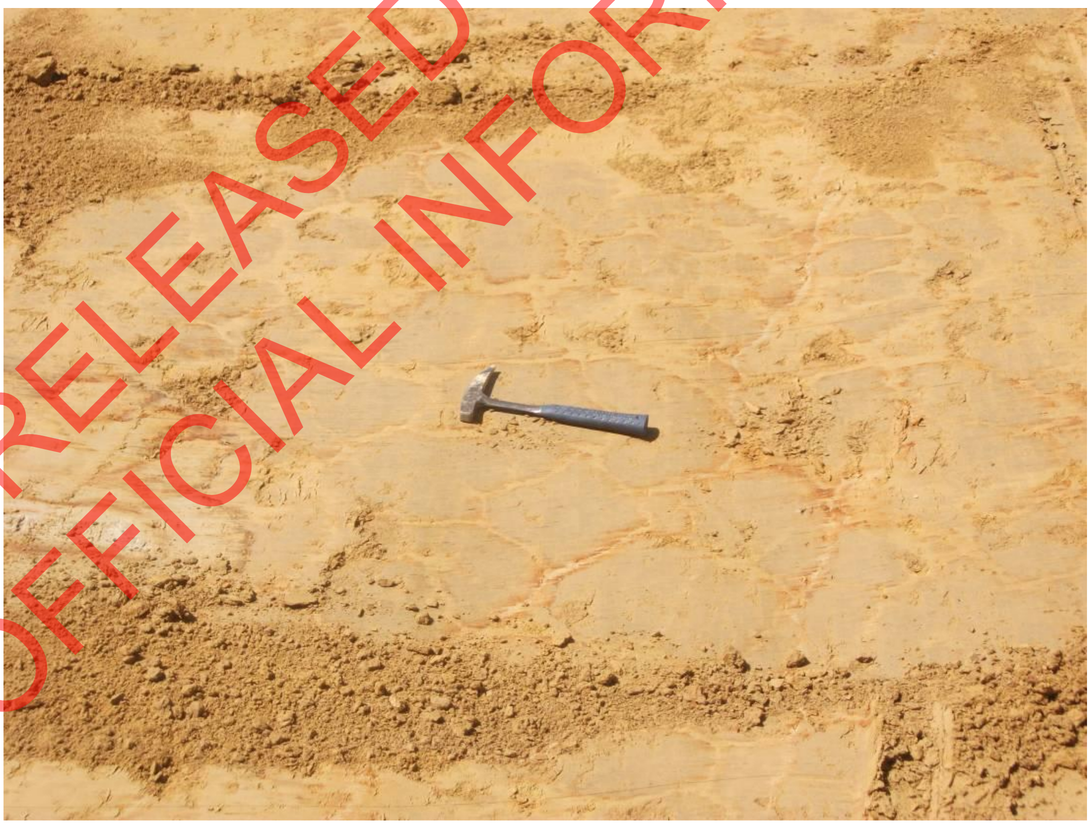
Photograph 10: Large crack extending into Layer 4

Photograph 11: Large crack extending from Layer 3 into Layer 4

Photograph 12: Bifurcating / cross cutting cracks

Photograph 13: Large cracks

Photograph 14: Clay infill at top of Layer 3



Photograph 15: Clay infill around desiccation cracks at top of Layer 3

Photograph 16: Bifurcating cracks

Photograph 17: Cross cutting cracks

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