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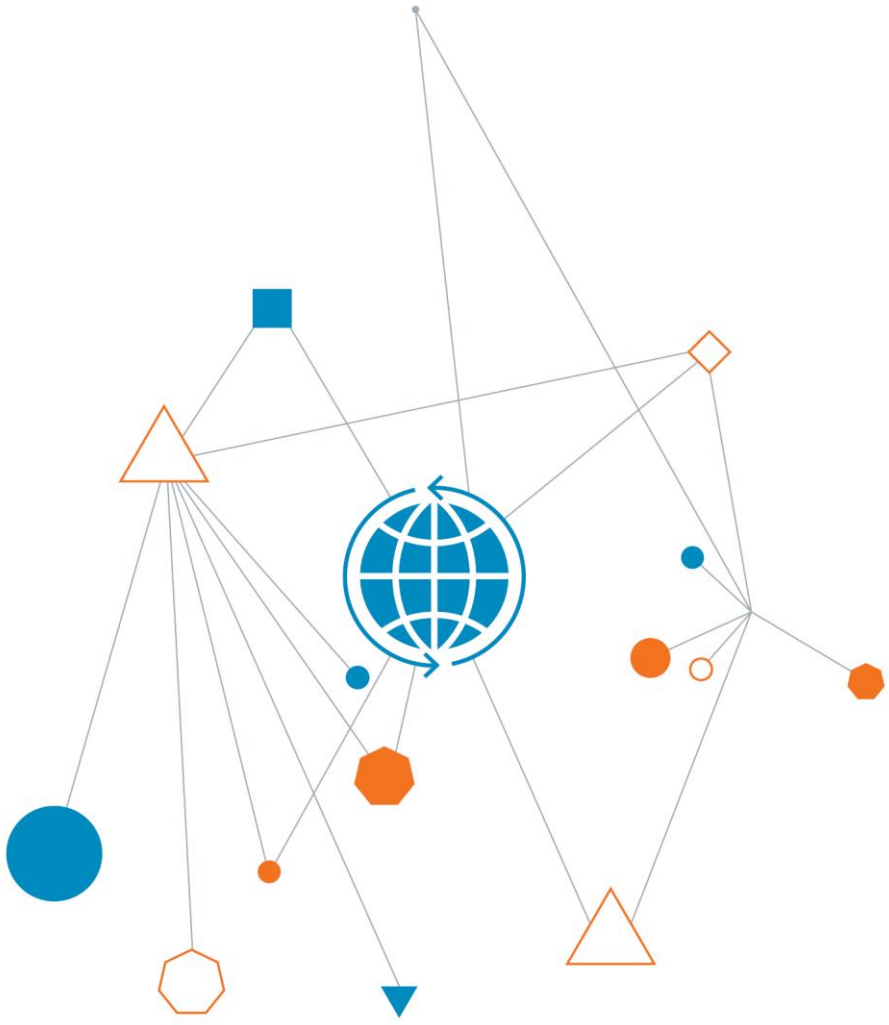
The Art Gallery of NSW

Sydney Modern Development

Geotechnical Excavation Monitoring Plan

2 April 2020



When you
think with a
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Sydney Modern Development – Geotechnical Excavation Monitoring Plan

Prepared for
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2 April 2020

Document authorisation

Our ref: SYDGE234348-G1-GEMP-Rev4

For and on behalf of Coffey

Quality information

Revision history

Revision	Description	Date	Author	Reviewer	Approver
0	Draft	14 Oct 2019	JS	RMT	Not yet approved
1	Updated Draft	30 October 2019	JS	RMT/PS	Not yet approved
2	First Issue	5 November 2019	JS	RMT	RMT
3	Second issue	29 January 2020	AE/JS	RMT	RMT
4	Third issue	2 April 2020	JS	RMT	RMT

Distribution

Report Status	Copies	Format	Distributed to	Date
Draft	1	PDF	Jesse Moss – Richard Crookes Constructions	14 October 2019
Updated Draft	1	PDF	Jesse Moss – Richard Crookes Constructions	30 October 2019
First Issue	1	PDF	Jesse Moss – Richard Crookes Constructions	5 November 2019
Second Issue	1	PDF	Jesse Moss – Richard Crookes Constructions	29 January 2020
Third issue	1	PDF	Jesse Moss – Richard Crookes Constructions	2 April 2020

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Appendices

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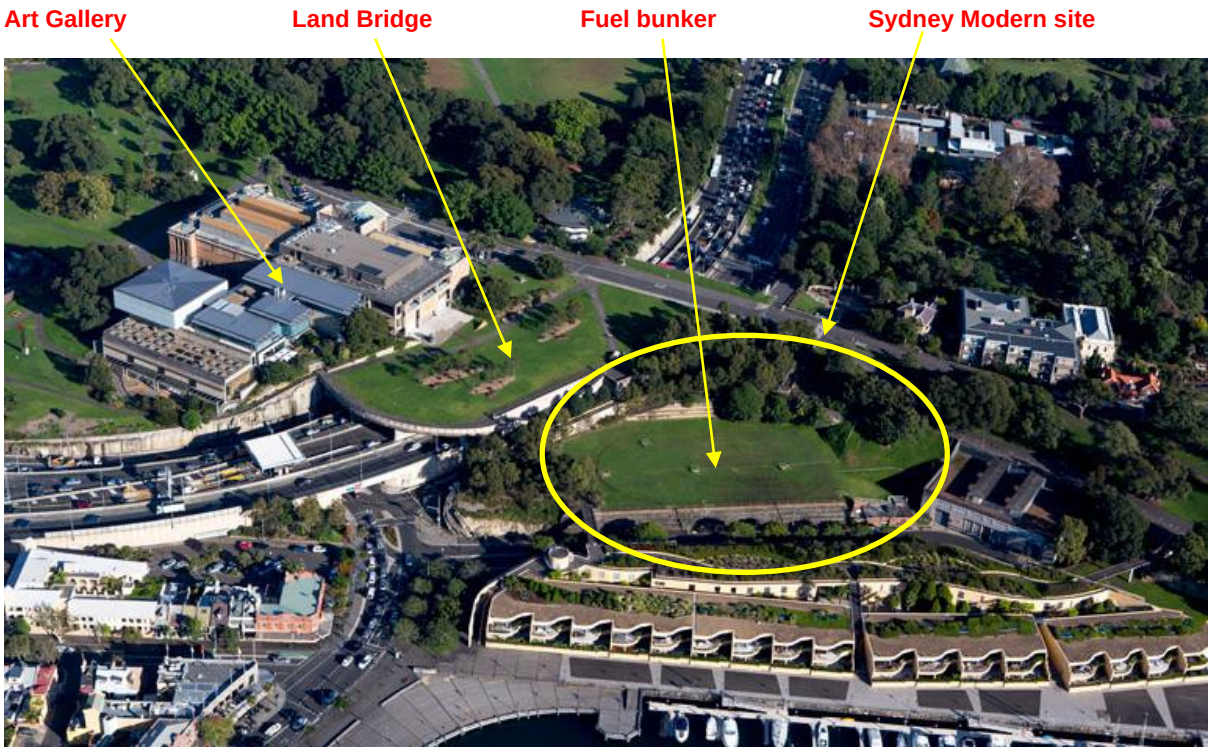
1. Introduction

Coffey Services Australia Pty Ltd (Coffey) has prepared this Geotechnical Excavation Monitoring Plan (GEMP) to support the construction of the proposed Sydney Modern Gallery (SMG) by Principal Contractor, Richard Crookes Construction. This work follows on from geotechnical investigation and design services that Coffey conducted for the project on behalf of The Art Gallery of NSW (AGNSW) during the design development prior to Contract Award.

The Sydney Modern Project is a proposed major expansion of the existing Art Gallery adjacent to the Phillip Precinct of the Domain. The expansion is a separate building located north of the Eastern Distributor Motorway (EDM) in an area largely occupied by a disused Navy fuel bunker that was excavated into the hillside in the 1940's. The proposed gallery building will include several levels, each with a different footprint, and will involve further excavation west of the bunker adjacent to the EDM.

Figure 1.1 – Sydney Modern location relative to existing Art Gallery and Eastern Distributor



Coffey Consolidated Geotechnical Report reference GEOTLCOV25037AA-AV dated 28 August 2018 (referred to herein as the Coffey Geotechnical Report) was issued at Tender Stage. It contained the outcomes of the various geotechnical investigation episodes consolidated into a single report.

As part of our services to AGNSW, Coffey prepared a draft preliminary Geotechnical Excavation Monitoring Plan (GEMP) reference SYDGE210394-BB dated 19 October 2018, which was issued to tenderers for information only.

This GEMP provides an updated plan specific to planned RCC construction methods and schedules, outlining further investigation and construction monitoring activities and recommendations on hold points for construction of the Sydney Modern Gallery.

2. The Development

2.1. Proposed Development

The proposed SMG will be a multi-level structure. The entry level and Gallery 1 will be located over the existing EDM land bridge (RL 22.9m). The remaining four levels of galleries will be located north of the land bridge and will incorporate part of the disused fuel bunker but will also require further excavation into the hillside to the west of the fuel bunker. Gallery levels LL1, LL2, LL3 and LL4 will be formed at RL 16m, RL 9.7m, RL 4.5m and RL 1.15m respectively.

Currently there is a relatively thin pillar of rock between the southern bunker wall and the Eastern Distributor Woolloomooloo off-ramp tunnel, which is cut into rock, as shown in Figure 2.1. Rock pillar heights refer to the proposed excavation face. Heights along the EDM are lower.

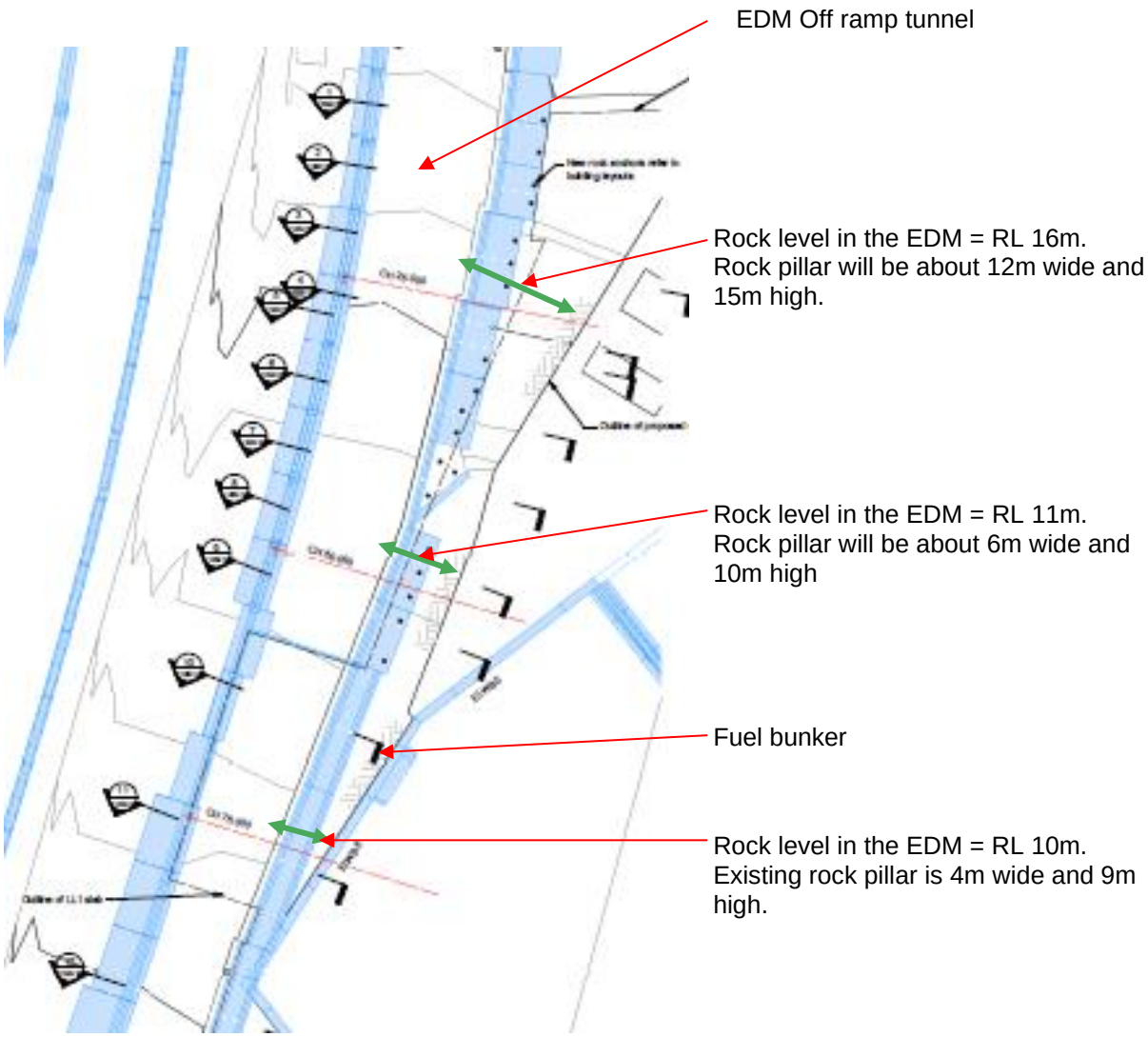
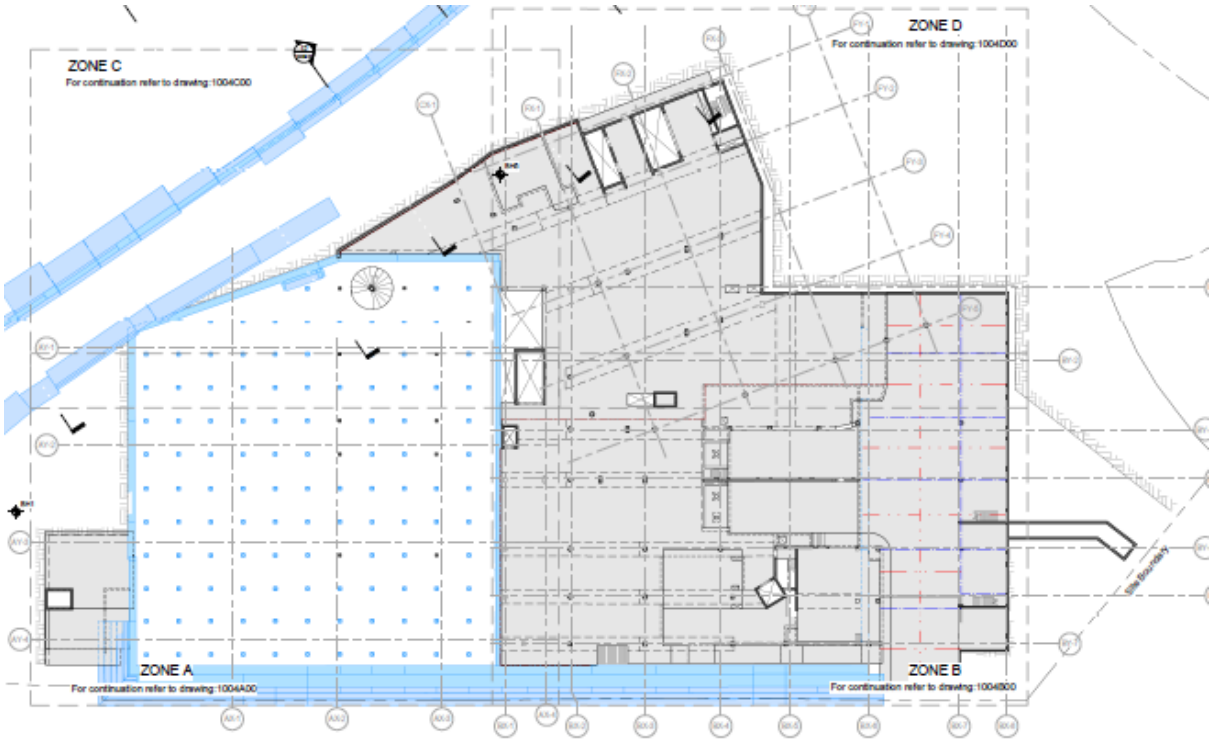


Figure 2.1 – Plan showing Existing Rock Pillar between Art Gallery and Eastern Distributor

Excavation adjacent to EDM will need to comply with RMS Technical Direction – Excavation adjacent to RMS Infrastructure (Ref File GEO4364 included in Appendix B). In the event of any discrepancy between this GEMP and the RMS Technical Direction, then RCC shall perform the procedure requiring the more frequent or more stringent monitoring, or the stricter tolerances.

The structural drawings divide the SMG into 4 Zones as shown in Figure 2.2 below.

Figure 2.2 – Plan showing Structural Zones A to D



Zone A: south tank of existing fuel bunker that will remain as part of the gallery forming the bulk of LL4.

Zone B: north tank of existing bunker that will be partially demolished with excavation to LL3 north of fuel bunker.

Zones C and D: contain deep excavation to LL4 to west of fuel bunkers, closest to the EDM.

Zone E: EDM Land bridge

2.2. Excavation Staging

The construction sequence is summarised below:

Table 1: Construction staging

Stage	Zones	Description
1	A, B, C, D, E	- Remove vegetable soil. - Install vibration monitors (Where accessible) - Demolition of existing structures and finishes. - Partial demolition of Northern oil tank - Removal of topsoil over EDM Land Bridge
2	A, B, C, D	- Install shoring piles to allow excavation to LL2 (RL9.2m) - Bulk excavation from Entry level (RL 23.0) to LL2 (RL9.2) within the SMG footprint to EDM Wall 5 footing. Batter excavation per Geotech advice and continue excavation across the site to LL4. - Progressively survey monitor shoring walls - Progressively expose EDM Wall 5 Footing and anchor footing (between CH0.000 – 75.000). - Once anchors are installed, begin survey monitoring EDM Wall 5, install tilt meters and crack meters.

Stage	Zones	Description
3	A, B, C, D	- Core hole investigation rock pillar and install inclinometers - Demolition of Western oil tank wall. - Remaining excavation from LL2 – LL4 - Survey monitor rock faces and inspect for defects.
4	A, B, C, D	- Demolition of existing southern stairs. - Progressively expose EDM Wall 5 Footing and anchor footing (between CH100.00 – 125.000). - Excavation to Reduced levels.
5	A, B, C, D	- New structure
6	Land bridge	- Removal of topsoil and new external finishes
7	A, B, C, D	- Building fit out and completion.

3. Geotechnical Excavation Monitoring Plan

3.1. Objectives

Coffey provided geotechnical interpretation of the ground conditions to be encountered in the SMG excavation and impacts of excavation on the EDM in the Coffey Geotechnical Report. Those boreholes encountered variable rock conditions particularly to the west and north of the bunker.

The accurate prediction of ground behaviour and impact of excavation on the movement of the retaining structures, adjacent structures and services can be difficult and is related to:

- The variability of the ground conditions and the extent of geotechnical investigation that can be reasonably conducted prior to construction, and
- Assumptions about the in-situ stress regime and ground conditions adopted for the design.
- Influence on stress redistribution due to previous adjacent excavations including the EDM.

To validate the estimated movements of the excavated faces and shoring walls, it is appropriate to adopt an observational construction monitoring programme during excavation and construction works to assess actual movements against predicted movements and tolerances of affected structures. Construction works need to be modified if the monitoring data indicates that the observed movement values could exceed the tolerances of the neighbouring structures.

The objective of the GEMP is to:

- Identify **elements** of the development and/or neighbouring properties and infrastructure that are at risk from ground movements arising from the excavation or vibrations arising from the methodologies to achieve the excavation.
- Identify **systems** to monitor the extent of ground movements that occur, or the level of vibrations that are generated at the element location.
- Establish **tolerance limits** for each element and prescribe **criteria** at which work will cease so that tolerance limits are not exceeded.

This GEMP does not address noise associated with construction activities. Noise monitoring will be undertaken with the noise and vibration management plan (prepared by White Noise Acoustics).

3.2. Elements at risk

The following elements may be at risk with respect to the proposed excavation:

- The land upslope of the fuel bunker to Art Gallery Road will be immediately adjacent to deep excavation. Geotechnical investigation revealed variable rock strength and defect conditions in this area. The stability of shoring pile walls (supporting soil strength and low rock strength materials) and unsupported rock excavations could be at risk due to variable ground conditions and unfavourably oriented rock defects. Workers and plant within and adjacent to the excavation could be in danger if rocks fall or instability occurs.
- EDM Wall 5 and pavement surfaces that are within the likely zone of influence of the excavation. These elements could be affected by instability of the pillar of rock that will remain between the EDM and the SMG, or by ground movements associated with stress relief in the rock under the EDM. Vibration may also impact on these elements.
- The exterior and interior of the existing Art Gallery of NSW. This building is likely outside the zone of influence of the SMG excavation. The principal concern is the potential impact of vibrations that may affect delicate exhibition items, or that may affect the heritage building.
- The Botanic Gardens entry frontage and administration building may be within the zone of influence of ground movements arising from stress relief in the underlying rock and could be affected by vibrations.
- The Wharf Terrace apartments and residences are not expected to be affected by ground movements arising from the excavation but could be affected by vibrations.
- The electrical substation to the north of the site is expected to be founded below the level of adjacent excavation (about RL 4.5m) but this is not confirmed. It is expected that the structure is founded on rock so the structure, or infrastructure within the substation, could be affected by vibrations.

In order to assess whether the various elements at risk have suffered damage as a result of the excavation activities, it is necessary to record the pre-construction state of the element. This is achieved through dilapidation surveys.

3.3. Risk management strategy

The risk management strategy relies on the following categories of monitoring activities that will be conducted prior to, during and for certain periods after the excavation works:

1. Preconstruction dilapidation surveys of adjacent structures, properties, infrastructure and roads to provide a baseline condition assessment for excavation monitoring and risk management of the works.

2. Geotechnical observation of shoring pile construction to better identify variations in ground conditions.

3. Survey monitoring of excavation shoring walls, excavated rock face walls and exposed EDM Wall 5 as excavation progresses and until permanent support is provided.

4. Instrumentation monitoring relating to EDM Wall 5 by installation of:

    - Inclinometers in the Rock Pillar between EDM Wall 5 and the SMG excavation. A plan showing proposed inclinometer locations is presented in Appendix A.
    - Tilt meters along EDM Wall 5 where it abuts the proposed SMG excavation.
    - Crack meters on concrete structure elements of EDM Wall 5 where cracks exist or develop. (The Arup Level 3 Bridge Survey issued 10/01/2020 notes that “No serious structural defects were observed in the superstructure or substructure”). Regular inspections will be carried out by Arup to identify possible cracks under the stone cladding. Arup and RCC will develop a management strategy based on the results of these inspections.

5. Continuous vibration monitoring during rock excavation at:
    - Selected locations on EDM Wall 5.
    - Selected locations on or inside the existing Art Gallery of NSW building.
    - Selected locations on Wharf Terrace buildings and Botanic Gardens administration building.
6. In situ testing by drilling rock cores to RL -1.5m AHD to identify rock strength and bedding defects at minimum **5** locations along EDM Wall 5 alignment. This would be conducted during the proposed anchoring of the Wall 5 L-sections.
7. Geological Mapping and Inspection to map exposed rock faces at 1.5m depth intervals for all excavation faces.

3.4. Stakeholders and their responsibilities

Stakeholders for the GEMP include:

- RCC, including parties commissioned by RCC as subcontractors or consultants
    - Structural/Civil – Arup
    - Geotechnical/Contamination – Coffey
    - Noise/Vibration – White Noise Acoustics
- Art Gallery of NSW.
- Independent Certifier – BG&E
- RMS and EDM Operator – Transurban

The responsibilities of each party throughout the excavation/monitoring phase are outlined in Table 2.

Table 2 - Responsible parties

Monitoring System	Task		
	Installation	**Monitoring**	**Review**
Level 3 Bridge Condition Report	Arup	Arup	RCC / Arup / IC / RMS / EDM Operator
Shoring Pile Observations	RCC / Pilling Contractor / Coffey	RCC /Pilling Contractor/Coffey	RCC / Arup / Coffey
Survey	RCC	RCC	Coffey / Arup / EDM Operator
Excavation geological monitoring	-	Coffey	RCC / Coffey / Arup / IC / RMS / EDM Operator
Rock coring beneath EDM Wall 5	RCC	Coffey	RCC / Coffey / Arup / IC / RMS / EDM Operator
Inclinometers	Coffey	Coffey	RCC / Coffey / Arup / IC / RMS / EDM Operator
Vibrograph	RCC /Coffey	RCC / Coffey	RCC / Coffey / Arup / IC / RMS / EDM Operator
Crack and tilt meters on EDM Wall 5	RCC	Coffey	RCC / Coffey / Arup / IC / RMS / EDM Operator

3.5. Referenced documents

The following documents are to be read in conjunction with this GEMP:

1. RMS Technical Direction – Excavation adjacent to RMS Infrastructure (Ref: File GEO4364), previously referenced in Section 2.1 of this GEMP.

2. Arup Environmental Impact statement – Acoustics Report Revision H dated 28 February 2018, pertaining to noise and vibrations, mainly as they affect people and artefacts (rather than structures and infrastructure).

3. White Noise Acoustics – Construction Noise and Vibration Management Plan-Rev2 dated 8 January 2020.

4. Dilapidation Surveys

Pre-construction Dilapidation Reports are to be prepared prior to construction works in accordance with Clause B51 of the Development Consent, as stated below:

> The Applicant is to engage a suitably qualified professional(s) to prepare a Pre-Construction Dilapidation Report detailing the current structural condition of all retained existing and adjoining buildings, infrastructure and roads within the 'zone of influence'. The report must be submitted to the Certifying Authority prior to issue of the Construction Certificate or any works commencing whichever is earlier. A copy of the report must be forwarded to the affected landowners.
>
> The Pre-Construction Dilapidation Report must also include a photographic recording of the public domain site frontages and must be prepared to the satisfaction of the PCA. The recording must include clear images of the footpath, nature strip, kerb and gutter, driveway crossovers and laybacks, kerb ramps, road carriageway, street trees and plantings, parking restriction and traffic signs, and all other existing infrastructure along the street. The form of the recording is to be as follows:
>
> a) a PDF format report containing all images at a scale that clearly demonstrates the existing site conditions;
>
> b) each image is to be labelled to identify the elements depicted, the direction that the image is viewed towards, and include the name of the relevant street frontage;
>
> c) each image is to be numbered and cross referenced to a site location plan;
>
> d) a summary report, prepared by a suitable qualified professional, must be submitted in conjunction with the images detailing the project description, identifying any apparent existing defects, detailing the date and authorship of the photographic record, the method of documentation and limitations of the photographic record.

Typically, a dilapidation survey would include structural and architectural condition assessment and would be conducted by a structural engineer or architect, not a geotechnical engineer. Whilst the GEMP will rely on the dilapidation reports produced with respect to damage tolerance, the preparation of dilapidation reports is a separate exercise to the implementation of this GEMP.

It is imperative that all dilapidation reports are completed prior to commencement of Stage 1A construction works, or as soon as safe access to the asset of interest is possible, and expected that follow-up dilapidation reports for specific receptors will generally be required following Stage 3 completion, although some receptors such as the EDM asset may require periodic dilapidation observations.

The asset owners should be given the opportunity to review the survey results and confirm that it is a true record of current conditions and the conditions at the end of constructions.

5. Further geotechnical boreholes

5.1. EDM Wall 5 (Necessary)

Geotechnical conditions of the rock pillar that will separate the EDM and the SMG excavation have been based on extrapolation of geological mapping and remote borehole information since the pillar location was inaccessible. Further boreholes are required to provide improved data along the EDM Wall 5 excavation zone.

Cored boreholes to RL -1.5m AHD at three locations along EDM Wall 5 alignment to be conducted progressively during Stage 2 works.

5.2. Shoring pile alignment (Recommended)

Geotechnical boreholes during planning phases along the shoring pile alignment have yielded variable conditions of material to be supported and depth to rock. Further boreholes have since been drilled along the shoring wall alignment by JK Geotechnics to provide further data for design. The boreholes encountered poorer quality rock conditions towards the north of the site and Arup have revised their design to suit these conditions.

5.3. Bunker Floor (Optional)

Optional 3m deep boreholes could be drilled through the bunker floor to provide data on foundation conditions, alternatively these could be completed during construction phase, as proof cores.

6. Monitoring systems for elements at risk

6.1. Shoring wall piling observations

Purpose

The purpose is to monitor ground conditions and rock levels encountered during shoring pile construction relative to the investigation boreholes to better understand and develop the ground model, particularly in Zone D where variable ground conditions were detected. Inspection of the pile installation will also be required to confirm the pile foundation design requirements.

Requirements

Pilling observations shall be conducted on a full-time basis during the pilling works. This may be conducted by Coffey, or the Pilling Contractor and Head Contractor can assign designated personnel to fulfil this function, with the geotechnical consultant to attend site if variations are detected.

Timing

This work will be conducted to confirm ground conditions during shoring pile wall construction during Stage 2 prior to excavation to LL2.

Assessment

Coffey will use this information to progress the geotechnical ground model prior to excavation.

6.2. Geological assessment of rock exposures

Purpose

The purpose of progressive geological mapping of rock exposures in excavation is to identify potentially unfavourable rock conditions that could lead to local or more widespread instability in the unsupported rock faces. This may include joint and bedding defects that could form unstable wedges, or shear zones where more than localised rock bolt support is required.

Requirements

An experienced geologist will visit the site to progressively map the exposed rock to progress the excavation ground model. The exposures will supplement the existing geotechnical information.

Timing

These visits will be conducted at not greater than 1.5m depth intervals of excavation from first encounter of top of rock in Stage 2 (and more frequent whenever deemed appropriate by the Geologist).

Visits will continue until the excavation is completed to LL4. The outcome of each periodic inspection will constitute a **Hold Point**. No excavation will occur within 5m of the excavation perimeter/boundary until the Hold Point is released.

Assessment

Coffey will use this information to progress the geotechnical ground model. Responsible Review Parties (refer to Table 2) will be consulted and the Hold Point will be:

- released if there is agreement that it is reasonable to proceed;
- conditionally released if there is concern over a localised instability issue; or
- not released until precautionary stabilisation works are conducted by RCC.

6.3. Survey monitoring of shoring walls & rock faces

Purpose

The purpose of the survey is to monitor and measure vertical and lateral shoring wall and rock face movements during and following SMG excavation work.

Requirements

Survey markers are to be installed at the following locations:

- The top of shoring walls or capping beams at nominal 6m lateral spacing, then at 1.5m vertical spacing to the bottom of the shoring walls.
- On exposed rock faces at nominal 6m lateral spacing, then at 1.5m vertical spacing to the bottom of the excavation.

The markers should be installed immediately after excavation reaches the nominated levels. Setting out of the survey markers on site shall be carried out in consultation with the Geotechnical Consultant.

A position on the top of the former oil bunkers will be used as a central/control survey point. As the excavation progresses a number of positions on remote rock ledges (i.e. in positions not expected to move) will be utilised to supplement the central/control survey point for the rock faces below the EDM footing and to survey the western end of EDM Wall 5. Survey targets and/or mini prisms, which require little maintenance, will be used. Should maintenance be required access will be via a platform ladder or EWP.

Frequency

Survey will be carried out to an accuracy of ±1mm and conducted every 1.5m depth of excavation or weekly, whichever is more frequent. Following completion of bulk excavations, survey to be carried out weekly until three consecutive measurement sets indicate no change.

Assessment

Surveyed wall movements will be checked against project deformation trigger movements discussed in Section 8 of this GEMP. Verification by the Responsible Parties shall constitute a 'Hold Point'.

6.4. Inclinometers

Purpose

The purpose of the inclinometer monitoring is to measure lateral ground movement in the rock pillar beneath EDM Wall 5 during excavation.

Locations are to be selected based on the outcomes of the cores in Item 5.1.1, which will also determine whether down hole imagery should be conducted (contingency item) to better identify detected defects prior to installing the inclinometers.

Requirements

Borehole inclinometer casing is to be installed by Coffey at **three** locations inside EDM Wall 5. These locations are to remain accessible and unaffected by construction activities throughout the construction period. RCC must ensure that the inclinometers are secure.

Inclinometer casing is to extend to minimum 3m depth below the bulk excavation level so that casing toe is below the zone of influence of the excavation works. One set of running grooves is to be oriented perpendicular to the excavation face; the other set parallel to the face. Instrumentation installation and measurement is to be carried out by Coffey.

Equipment

The system will satisfy the following general requirements:

- Repeatability ± 0.01% of full scale
- Resolution: ± 0.025 mm per 500 mm
- Total System Accuracy: ± 6 mm per 30 m
- Range: ± 53 degrees.

Timing and frequency

Inclinometer casing is to be installed and baseline readings taken at least 1 week before Stage 2 commences. Take two sets of baseline measurements to check consistency. Subsequently measure:

- Per 1.5 m depth of excavation (minimum weekly) until one week after excavation completion;
- Fortnightly after excavation completion until 3 consecutive measurements indicate no change.

Assessment

Measured ground movements will be checked against the project deformation trigger criteria. Coffey will verify that the indicated movements of the excavated face and structures are consistent with expectations for the current depth of excavation and within tolerances. This verification constitutes a 'Hold Point' for each depth increment (1.5m) of excavation. If trigger levels have been reached or exceeded, action shall be taken in accordance with the monitoring plan.

6.5. Tilt Meters

Purpose

The purpose of tilt meters is to monitor change in inclination of selected panels of EDM Wall 5 where it abuts the proposed SMG excavation.

Requirements

Tiltmeters consist of gravity-sensing transducers with an appropriate housing either fixed in place or arranged as a portable device by mating with reference points permanently attached to the structure.

The tilt meters will continually record sensor temperature and local environment factors such as temperature, rainfall etc. (from a local weather station) will be used to correlate data to environmental conditions.

It is important that when setting limits for the alerts, the limit considers the range of potential movement from all causes. It possible that thermal movement could exceed ground movement. The interpretation of results and placement of sensors, needs to avoid triggering false alerts which may lead to the site teams ignoring alerts

Equipment

Six tiltmeters are to be installed by RCC at Wall 5 locations listed below, as approved by Arup, RMS, Transurban, and IC.

- 5B to 5D joint
- 5D to 5E joint
- 5E to 5G joint
- 5H to 5J joint
- Intermediate point along 5J
- Joint at East end of 5J

The tilt meters will be fixed into the EDM structure using 30mm deep, 6mm knock-in anchors, drilled with a rotary hammer drill only – no core drilling is permitted.

If reinforcement is encountered, the holes will be prepared with an epoxy primer and patched with structural repair mortar (to be specified by Arup, if required).

Timing and frequency

Tilt meters to be installed before Stage 3C commencement and monitored whenever inclinometer readings are taken (1.5m depth increments in excavation, or weekly whichever is more frequent). Additional readings should be conducted if ground movement or vibration Alarm Limits occur. Each reading constitutes a ‘Hold Point’ for each depth increment (1.5m) of excavation. If trigger levels have been reached or exceeded, action shall be taken in accordance with the monitoring plan.

6.6. Crack Gauges

Purpose

The purpose of tilt meters is to monitor change in inclination of the EDM wall is to detect whether existing cracks or construction joints in the EDM structure incur additional cracking during excavation.

Requirements

The Arup Level 3 Condition Report notes that there were no cracks that require monitoring on the EDM side. Regular inspections will be carried out by Arup to identify possible cracks under the stone cladding. Arup and RCC will develop a management strategy based on the results of these inspections.

Subject to advice from the Arup and the Independent Certifier, crack gauges may be required at:

- Locations where new and/or pre-existing cracks are identified.
- Construction joints in EDM Wall 5.
- Other locations (whether concrete or rock) where potential movement planes area identified prior to or during excavation.

If required, the tilt meters will be fixed into the EDM structure using 30mm deep, 6mm knock-in anchors, drilled with a rotary hammer drill only – no core drilling is permitted.

If reinforcement is encountered, the holes will be prepared with an epoxy primer and patched with structural repair mortar (to be specified by Arup, if required).

Equipment

The nature of the crack gauges may depend on the types and locations of cracking detected during dilapidation survey. Portable or fixed in place mechanical gauges may be appropriate in accessible areas, but gauges that incorporate locally or remotely read displacement transducers or wireless data transmission may be required for less accessible locations. Simple tell tales may be appropriate for minor cracks. Gauges should be established at these locations if the tell tales indicate further movement.

Timing and frequency

Crack gauges to be installed during Stage 2 commencement and monitored whenever inclinometer readings are taken (1.5m depth increments in excavation, or weekly whichever is more frequent. Additional readings should be conducted if ground movement or vibration Alarm Limits occur.

Each reading constitutes a ‘Hold Point’ for each depth increment (1.5m) of excavation. If trigger levels have been reached or exceeded, action shall be taken in accordance with the monitoring plan.

6.7. Survey Monitoring of EDM Wall 5

Purpose

Survey monitoring of the exposed EDM Wall 5 shall be carried out as excavation progresses and afterwards as indicated herein. The purpose is to monitor for and measure vertical and lateral wall movements during and following excavation work.

Requirements

Survey marks to be installed generally at top and bottom of the exposed EDM Wall 5 at 5m lateral intervals. Set out of the survey markers shall be carried out in consultation with Coffey.

Survey markers shall be installed after Stage 2 anchor stabilisation of EDM Wall 5 L-shaped panels and before commencement of SMP bulk excavation below the level of the wall base.

Survey will be carried out to an accuracy of ±1mm.

Frequency

Conduct first survey after Stage 2 anchor stabilisation then at the following minimum intervals:

- Every 1.5m depth of excavation in rock, or
- Weekly, whichever is more frequent.

Continue survey weekly after bulk excavation until permanent SMP building support is installed, or until three consecutive surveys indicate no movement.

Assessment

Check surveyed movements against deformation trigger criteria in section 8.3.1 of this GEMP. This verification constitutes a 'Hold Point' for each excavation increment.

6.8. Vibration monitoring

Purpose

The purpose of the vibration monitoring is to assess the vibration levels as excavation progresses to mitigate risk of vibration induced damage at the following assets:

A. EDM Wall 5
B. Art Gallery of NSW structure and the artefacts displayed therein
C. Wharf Terrace apartments
D. Electrical substation
E. Royal Botanic Gardens Trust Building

Damage Tolerances

The vibration tolerances selected for each of the above will be based on Australian Standards. Proposed vibration tolerances will be provided by White Noise (Vibration/Acoustic Consultants). These tolerances will need to be discussed with, and in some cases reviewed by, stakeholders in conjunction with the risk management policy of the Principal.

Vibration limits could also depend on:

- Whether the vibration exposure is short-term (i.e. does not occur long enough to cause structural fatigue or does not produce resonance in the structure) or long-term.
- The frequency of the vibrations being produced. Vibration particle velocity at lower frequency can induce higher strain than the same velocity at higher frequency.
- The current condition of the asset, which may not be known until the dilapidation surveys are completed.

Requirements

Vibrographs are to be installed at locations A, B, C and D and may be required at other locations depending on stakeholder advice.

Vibrographs are to be installed on the exposed ground surface or fixed structure so that they can be accessible throughout the construction period. Installation of vibrographs shall be carried out by Coffey or in consultation with Coffey.

An office base station is to be set up to receive and analyse the vibration data from the vibrographs installed at the site and allow assessment of the data and compilation of vibration monitoring reports.

Vibrographs should be installed a minimum one week prior to Stage 1 works and should be maintained on site for a minimum one month following the completion of the Stage 3 works.

Vibration monitors to record peak particle velocity upper limit in any orthogonal direction (PPVi). Trigger levels in Section 9 are set during the working hours with continuous monitoring system recording the maximum PPVi encountered every 5 minutes.

The vibrograph systems are to monitor the ground vibrations continuously during the works until the end of the excavation and construction works and send warnings if trigger levels in Section 0 are reached.

Activation

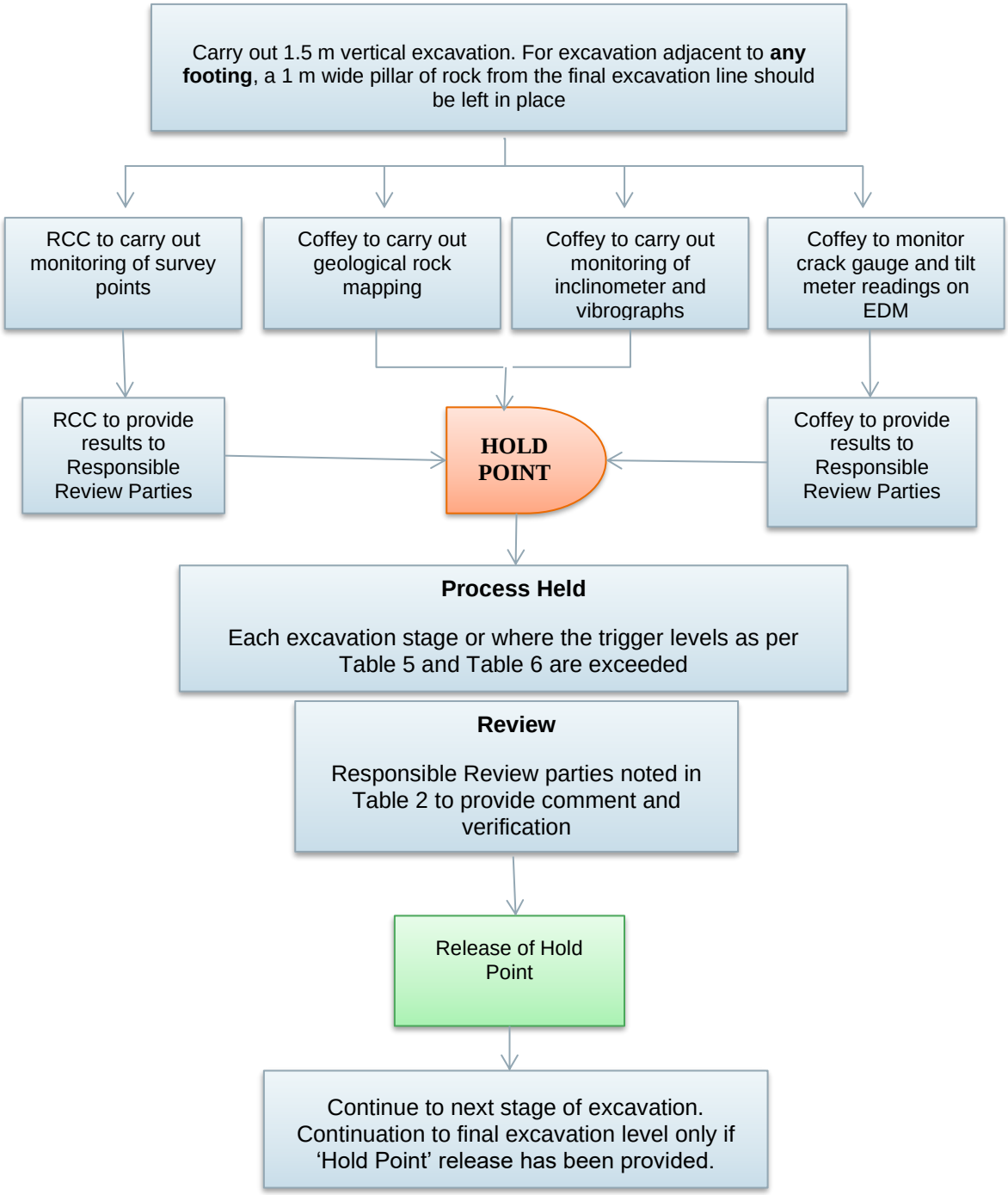
Whenever sensors detect vibrations greater than the threshold PPVi, a blinking warning light on the monitor would alert nearby workers to stop works immediately. In addition, the monitor would SMS the site manager on duty and Coffey.

The site manager would then inspect the monitor and contact Coffey to discuss the activity that set off the sensor. If it was deemed that it was inadvertently set off (e.g. dropping tools near the sensor), an accidental event would be recorded. However, if the set off was due to sustained construction works, that triggered the breach levels, the works would be halted and engineers from Coffey would attend site to investigate causes.

Excluded activities

Vibrations that could impact the Art Gallery artefacts, patrons and staff are discussed in Arup Environmental Impact statement – Acoustics Report Revision H dated 28 February 2018. The vibrations that could impact people and artworks are much lower than those that can cause building damage. Refer to the Construction Noise and Vibration Management Plan for further information.

7. Hold Points



8. Monitoring criteria for movements

8.1. Wall and ground movement criteria

The trigger movements are listed in Section 8.3. The trigger movements will be the lesser of the predicted or tolerable movements, where:

- **Predicted movement** = the movement predicted by either geotechnical analysis or experience in the local geology.
- **Tolerable movement** = 80% of the maximum movement that the structure adjacent to the excavation can tolerate without distress. (This will be agreed by structural engineers from Arup and Aecom).

8.2. Trigger levels and responses

Recommended responses to various trigger for structural or ground movements measured by survey or inclinometer are set out in Table 3.

Table 3 - Summary of movement monitoring trigger levels & responses

Trigger Level	Response
Alert: Cumulative monitored movement is greater than **50%** but less than **75%** of trigger movement.	Continue excavation Alert stakeholders when cumulative monitored movements reach 50%. More frequent monitoring may be required if Alert Level is reached earlier than expected.
Action: Monitored incremental movements between two consecutive readings at the same survey points are greater than 2.5mm. or Monitored total movement is greater than **75%** of trigger movements but less than **90%**.	**Stop excavation**. Notify stakeholders immediately. Coffey will review results and consult stakeholders. More frequent monitoring may be required.
Alarm: Monitored total movement is greater than 90% of trigger movements, or **or** Monitored incremental movements between two consecutive readings at the same survey points are greater than 5mm. **or** Sign of distress or collapse irrespective of measured movement.	**Stop Excavation**. Notify stakeholders immediately. Implement contingency measures to reduce risks if necessary. Implement any subsequent measures issued by stakeholders.

Note: The appropriate response for Action and Alarm Levels may depend on whether the Trigger Movement is based on Predicted Movements or Tolerable Movements.

8.3. Suggested Trigger Movements for elements at risk

8.3.1. EDM Wall 5

Trigger movements for EDM Wall 5 will depend on tolerable movements for the structure. Once excavation in rock commences below the level of the EDM Wall 5, the following structural tolerances will apply:

- Maximum lateral movement at top of wall = 10 mm
- Maximum lateral movement at bottom of wall = Refer to Table 4
- Maximum vertical movement = Refer to Table 4
- Maximum tilt = 0.00275 radians

8.3.2. Shoring Walls

Trigger levels for shoring walls are based on shoring design assessment (refer Coffey report SYDGE210394AW).

During Excavation to Toe of Shoring pile wall

- Maximum lateral movement for pile walls less than 3m high = 5mm
- Maximum lateral movement at pile walls greater than 3m high = 10mm
- Maximum vertical movement = 10mm

During excavation in rock below the toe of the shoring wall

The tolerable movements should not exceed the above values plus the tolerable movements in the rock e.g. if there is 20mm movement expected in the rock face below the wall, then the tolerable total movement for the 3m high shoring wall should not exceed 25mm, and should not increase between excavation episodes by more than 3mm

8.3.3. Unsupported Rock Faces

Trigger levels for the excavation faces are currently based on predicted ground movements of 1mm per metre depth of rock excavation. This may need to be revised depending on the tolerable movements for EDM infrastructure.

Table 4: Trigger movements for unsupported rock faces

Excavation state	Trigger movement LATERAL (mm) [1]	Trigger movement VERTICAL (mm) [2]
A. Where excavation face is less than 7.5m lateral distance from EDM Wall 5	10	5
B. Where excavation face is less than 12m lateral distance from EDM Wall 5	12	5
C. Where excavation face is greater than 12m lateral distance from EDM Wall 5 and rock excavation depth is less than 12m	15	5
D. Where excavation face is greater than 12m lateral distance from EDM Wall 5 and rock excavation depth is more than 12m	20	8

In Table 4, these trigger movements apply at any point during the excavation at any time. For example, if the proposed final excavation face is greater is than 12m from EDM Wall 5 and more than 15m deep, but the current excavation is less than 12m deep then the trigger values for Excavation State C will apply until the excavation exceeds 12m depth.

9. Monitoring criteria for vibrations

9.1. Trigger level definitions and responses

A summary of the Coffey recommended vibration trigger limits are provided in Table 5.

Table 5 - Summary of Vibration Monitoring Trigger Levels

Trigger Level		Response
Alert:	Vibration levels are above the Minor Breach and below the Major Breach limits with less than 3 minor breach exceedances within any 1-hour period	Temporarily cease the vibration generating activity and assess the reason for vibration exceedances. Modify the related construction practice to prevent future exceedances. Keep records of subsequent breaches to demonstrate that vibrations for modified activity do not reach Alert Level.
Action:	Vibration levels are above the Minor Breach limits with more than 3 minor breach exceedances within a one-hour period or; Vibration levels are above the Major Breach limits with 3 or less major breach exceedances within a one-hour period.	**Stop vibration generating activity**. Notify Coffey and acoustic consultant immediately. **Hold Point**. Results to be reviewed. Construction activity that causes the vibration should stop and methodology adjusted. Implement Alert level actions for 1 hour to monitor adjusted methodology. Outcomes to be reviewed by Coffey and acoustic consultant prior to release of Hold Point. Excavation/vibration generating activity to not continue until the practice is justified and reviewed by stakeholders.
Alarm:	Vibration levels exceed Major Breach limits four or more times within an hour	**Stop vibration generating activities**. Notify Coffey and acoustic consultant immediately. **Hold Point.** RCC to notify Client who will notify affected stakeholders. RCC and stakeholders will assess likely causes, alternative options and possible contingency measures. Vibration monitoring report to be completed. Visual assessment of affected property will be conducted to assess whether damage is evident. Hold Point not to be released until an action plan is agreed. The subsequent 3 hours vibration generating work activity will be scrutinised by stakeholders to confirm that the action plan has achieved the desired outcome.

9.2. Trigger Vibration Levels

Table 6 presents the selected tolerable vibration levels for the various receptors based on input from various standards including:

- British Standard BS 7385 Part 2: 1993 Evaluation & Measurement for Vibration in Buildings Part 2
- German standard DIN 4150 – Part 3 – Structural Vibration in Buildings – Effects on Structures
- Assessing Vibration: A Technical Guideline 2006.
- British Museum, Conservation Research Group. Report No 1999/6 Assessment of Vibration Damage Levels.

The trigger levels in Table 6 have been developed by Arup and White Noise Acoustics.

Table 6 - Vibration Trigger Levels

Asset	Frequency	Short-term vibrations Minor Breach if PPV exceeds	Short-term vibrations Major Breach if PPV exceeds [2]	Long-term vibrations Major Breach if PPV exceeds [3]
EDM assets and substation Note **1**	less than 10 Hz 10 Hz to 50 Hz 50 Hz to 100 Hz	10 mm/s 15 mm/s 20 mm/s	15 mm/s 20 mm/s 25 mm/s	10 mm/s 10 mm/s 10 mm/s
Residential Note **2**	less than 10 Hz 10 Hz to 50 Hz 50 Hz to 100 Hz	3 mm/s 6 mm/s 10 mm/s	5 mm/s 10 mm/s 15 mm/s	5 mm/s 5 mm/s 5 mm/s
Heritage structures Note **3**	less than 10 Hz 10 Hz to 50 Hz 50 Hz to 100 Hz	2.5 mm/s 3 mm/s 8 mm/s	3mm/s 5 mm/s 10 mm/s	2.5 mm/s 2.5 mm/s 2.5 mm/s
Museum Artefacts	All	1.5 mm/s	2 mm/s	1.5 mm/s

Notes:

1. Based on Table 1 of DIN 4150-3: 1999-02 – Using 50% or less of guideline lower bound values for industrial/commercial structures. This may be conservative
2. Based on Table 1 of DIN 4150-3: 1999-02 – Using guideline lower bound values as major breach criteria.
3. Based on Table 1 of DIN 4150-3: 1999-02 – Using approximately lower and upper bound guideline values for minor and major breach criteria respectively.

Table 7 (extracted from Reference 2) presents vibration limits for human comfort that may prevail at some of the asset locations.

Table 7: Vibration limit levels for human comfort (m/s^2 from 1 to 80 Hz)

Location	Z axis vibration	X and Y axis vibration	Z axis vibration	X and Y axis vibration
	Preferred values		Maximum Values	
Continuous vibration				
Residential Daytime	0.010	0.0071	0.020	0.014
Residential Nighttime	0.007	0.005	0.014	0.010
Office Anytime	0.020	0.014	0.040	0.028
Gallery Areas Anytime	To be determined based on items in collection at the time			
Impulsive Vibration				
Residential Daytime	0.3	0.21	0.60	0.42
Residential Nighttime	0.1	0.071	0.2	0.14
Office Anytime	0.64	0.46	1.28	0.92
Gallery Areas Anytime	To be determined based on items in collection at the time			

Table 14: Vibration Limit Values (m/s^2 from 1 to 80Hz)

10. Closure

This GEMP is based on our current understanding of the proposed development and ground conditions. If the currently proposed development changes the GEMP should be reviewed and revised as required.

Appendix A - Instrumentation and Monitoring Locations

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BOTANICAL GARDENS
CAHILL EXPRESSWAY
ART GALLERY ROAD
LINCOLN CRESCENT
THE DOMAIN
ART GALLERY OF NSW
COWPER WHARF ROAD
Proposed inclinometer locations

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Appendix B - RMS Technical Direction: Excavation adjacent to RMS Infrastructure

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Technical Direction

Geotechnology

Transport Roads & Maritime Services

GTD 2012/001 27 APRIL 2012

Excavation adjacent to RMS infrastructure

Background

The number and size of ground excavations in close proximity to Roads and Maritime Services (hereafter referred to as "RMS") infrastructure have increased steadily in recent years. It is imperative that the design and construction of the supporting structures to these excavations are adequate to provide security to the road infrastructure and its operations.

Purpose

The purpose of this document is to provide a technical direction for all proposed excavations by private and commercial developments with their influence zones, and/or any temporary structures extending onto the road reserve and RMS easements. It sets out the requirements for RMS concurrence upon referral of a Development Application involving excavation adjacent to classified roads affecting the road infrastructure.

This technical direction is an integral policy document for the management of excavation related geotechnical risks within the Work Authorised Development (WAD) Approval framework.

The document lists the contents of submission required for RMS review and it also details technical requirements for the design and construction of retaining walls for these excavations.

Scope

This document applies to retaining structures (typically embedded cantilever and propped/anchored retaining structures) constructed to support the sides of excavations which are within close proximity to the roadway. It also outlines the requirements for installing ground anchors and instrumentation as part of these excavations. Proponents must contact the RMS Project Manager for areas that are not covered by this Technical Direction.

It should be noted that the RMS review relates to the impact on its road assets and does not relieve the wall designers and property developers of their obligations with respect to any other statutory requirements as part of the development.

For:	Engineers, Works Supervisors, Surveillance Officers and Councils		
Enquiries:	Supervising Geotechnical Engineer (Standards)	Phone:	8837-0248
Amendment / Addition to:		Ref File: GEO 4364	xxxxxxxx

Referral from Consent Authority

Where the consent authority refers a development application to RMS for comment and an excavation is proposed as described above then the consent authority is to be advised that the developer needs to comply with this Technical Direction.

Submission to RMS

The following documents are to be submitted for RMS concurrence at least six weeks prior to commencement of construction:

Dilapidation Survey: RMS may require a dilapidation survey for sensitive assets where there is a potential risk of damage caused by the proposed development. The dilapidation survey must cover RMS assets within the influence zone of the excavation. Where applicable these may include the road pavement, associated subsurface drainage structures, bridges, traffic signal structures and other road assets.

Design documentation: The design documentation must be presented in a format that is readily understood by engineers. The structural engineering report must detail an accurate geometry of the retention scheme, load and design assumptions, load cases, structural section properties / material parameters including analysis output (such as moment and shear envelopes and deflections). Cross sections at critical sections of the proposed excavation showing the geotechnical model used for design must be clearly indicated. The geotechnical report on which the design is based must be provided with the design documentation. The design report must include both temporary and permanent structures where applicable.

Drawings: The Drawings must show the layout of the proposed structure(s) relative to RMS assets including but not limited to roads, tunnels, bridges, embankments, walls, noise walls and traffic signals. Longitudinal and cross sections showing the proposed structures and RMS assets must be drawn at critical locations. The construction sequence must be shown on the Drawings.

Specifications : Copies of the specifications are to be included where necessary to interpret the design and Drawings.

Instrumentation and Monitoring:

The instrumentation layout proposed for the monitoring of movement as a result of the excavation must be included in the Drawings together with the frequency of monitoring, trigger levels and action to be taken when trigger levels are exceeded.

Construction

Following RMS concurrence, construction is to be carried out in accordance with the Drawings, and specifications accepted by the RMS. Any modifications to the design, following acceptance, must be referred to RMS for concurrence.

Work-As-Executed (WAE) Drawings: Upon completion of construction the WAE Drawings of the retaining structures supporting the RMS infrastructure, including stabilisation measures in the case of excavation in rock must be submitted to RMS for record purposes.

For:	Engineers, Works Supervisors, Surveillance Officers and Councils		
Enquiries:	Supervising Geotechnical Engineer (Standards)	Phone:	8837-0248
Amendment / Addition to:		Ref File: GEO 4364	xxxxxxxx

Technical Requirements

Design Standards

Retaining structures must be designed in accordance with the relevant RMS documents and the current edition of the following Standards as appropriate, unless otherwise specified in this document. Where conflicting information occurs, the RMS document is to take precedence.

AS 1726 Geotechnical Site Investigations

AS 1170 Structural design actions – General principles

AS 5100 Bridge design – Scope and general principles

AS 3600 Concrete structures

AS 2159 Piling – Design and installation

The design of the proposed structures must be in accordance with AS 5100 unless otherwise specified in this document. The design life of permanent retaining wall structures is 100 years and the design of these walls and associated elements is to be include both short term and long term effects. In particular, the unplanned excavation as detailed in Section 13.3.1 of AS 5100.3 for stability design must be considered.

Geotechnical Investigations

As a minimum, geotechnical investigations are to be undertaken in accordance with AS 1726 to develop surface/subsurface geological models and groundwater conditions and to determine the properties of the soil and rock units. The geotechnical field investigations and laboratory testing must be comprehensively carried out to determine the site conditions and geotechnical material parameters for the detailed design and construction of the retaining structure. These investigations must be carried out to a minimum of 3 metres below the final excavation level. Investigation by test pits is generally not considered acceptable. Non core and rock core drilling using triple tube sampling is the preferred technique. Where proposed excavations are predominantly in rock, the geotechnical investigations must define adverse defect mechanisms (joints, fault zones, volcanic intrusions, weak zones etc) which may have an adverse impact on the development and adjacent RMS Infrastructure. Where excavations are in excess of 10 metres depth in rock, an assessment of the rock stress state and its effects on the excavation is required.

Utilities

The nature of any utilities located within the zone affected by the proposed excavation must be established. The effect of the excavation on these utilities must be analysed and reported. The requirements of utility owners and the sensitivity of these utilities to ground movements must be taken into account in the design and construction.

Where the utility owner requirements are not established, the design must consider either the effect of ruptured utilities or the underpinning of such utilities.

Types of Acceptable Ground Support

Whilst most types of ground support structures can be considered, the following types are not generally considered acceptable as permanent retention structures:

- Use of steel sheet pile walls below the groundwater table.
- Wall toes founded above the final excavation levels on unsupported rock ledges with rock quality inferior to Class III sandstone (Pells Classification System) or where the rock has adverse defects.

Design Loads and Combinations

Design loads and load combinations must be in accordance with AS 5100, but with a minimum uniformly distributed live traffic load (UDL) of 20 kPa for the serviceability limit state. This minimum UDL must be applied on the road which represents the most adverse loading condition for the retaining structure. The Accompanying Lane Factors given in AS 5100 may be applied to the UDL for multiple lanes.

The design must take into account construction loads, loads from neighbouring structures and other surcharge loads as required by the relevant design standards. A minimum UDL of 10 kPa must be applied for the serviceability limit state for loads other than traffic loads.

Particular loads or load cases may need to be considered for design of the retaining structures impacting on RMS infrastructure, and the developer must inform themselves of any special requirements before commencing design.

Groundwater Levels

Design groundwater levels must take into account both short term, long term and accidental groundwater levels in the vicinity of the retaining structure. Possible damming effects leading to elevated water pressures should be considered.

Where drainage measures are proposed to relieve water pressures behind the structure these must be readily accessible for inspection and maintenance. This requirement may apply either during the construction phase or the in-service phase of the structure.

Design groundwater levels and drainage details must be shown on the Drawings.

Ground Anchors

Where proposed ground anchors are located in whole or in part within the road reserve and RMS easements, the following requirements applies :

- Only temporary ground anchors will be permitted;
- Ground anchors are to be designed and tested in accordance with AS 5100;

- Temporary ground anchors must have a minimum design life of 2 years. Where ground anchors are required for more than 18 months they must be designed as permanent anchors;
- No anchor forming part of the works must be stressed to greater than 75% of the tendon UTS under either working load or test load;
- No part of any ground anchor must be less than 2 metres below the surface within the State road reserve and RMS easement.
- Once the anchors are no longer required to carry load, all structural connection between the anchors and the proposed development must be removed.

'Nails and Bolts' used as structural support elements are treated the same as ground anchors.

Ground Deformation and Wall Deflection

The prediction of vertical and horizontal deflections of the proposed retaining structure for each stage of construction and in the long term must be provided in the design documentation. These deflections must be presented in graphical form at critical sections for the full height of the retaining structure.

Retaining wall structural deflections must not result in any damage to RMS assets. Ground deformation estimates must consider the full zone of influence of the proposed excavation and include the following:

- Demolition of existing retaining or support structures.
- Construction of the retention elements.
- Excavation and deflection of the retention elements.
- Groundwater drawdown.
- Consolidation of soils.
- Other site specific work or processes affecting ground deformation

Permissible deflections will be determined by RMS on a case by case basis, taking into account the sensitivity of RMS assets to movements, the proximity of the structure to such assets and the ground movements that will occur within RMS property or the road reserve. However, total serviceability deflection of the wall in any one direction acceptable for non-sensitive RMS assets is to be limited to 0.5% of the excavated height or 30 mm, whichever is the lesser. Generally, the permissible movements on infrastructure assets should be clarified with RMS prior to the design.

Instrumentation and Monitoring

RMS requires geotechnical instrumentation and monitoring where infrastructure assets may be affected by the proposed excavation. These include bridge structures, associated foundations, existing wall structures etc adjacent to the proposed excavation. Instrumentation and monitoring may be required for the following retaining wall types:

- Cantilever retaining walls with a retained height exceeding 3 metres
- Propped or anchored walls with a retained height exceeding 6 metres

Where required, instrumentation will generally include a minimum of two inclinometers installed to at least 3 metres below the toe level of the walls. Where the groundwater level is above the final excavation level a number of piezometers must also be installed. Other monitoring systems such as a Total Station Survey system (using remote data capture or other technology) may also be required depending on the nature of the development and RMS assets affected by the development.

Where monitoring is required, it is to be carried out at the following stages:

- Before commencement of construction of retaining structures where appropriate to determine baseline readings. Two independent sets of measurements must be taken confirming measurement consistency.
- After construction of the retaining structures, but before commencement of excavation.
- After excavation to the first row of supports or anchors, but prior to installation of these supports or anchors.
- After excavation to any subsequent rows of supports or anchors, but prior to installation of these supports or anchors.
- After excavation to the base of the excavation.
- After de-stressing and removal of any row of supports or anchors.
- One month after completion of the permanent retaining structure or after three consecutive measurements not less than a week apart showing no further movements, whichever is the later.

Instrumentation and monitoring must be carried out by a competent person experienced in the equipment used. The results of each monitoring stage must be reported to the design engineer. Before work proceeds to the next stage the design engineer must verify that based on the monitoring results and the inspections carried out the structure is performing in accordance with the design intent and that where trigger levels have been exceeded, action has been taken in accordance with the monitoring plan. Verification by the design engineer must constitute a 'Hold Point' for each stage of construction.

RMS must be informed immediately when the trigger levels are exceeded.

The monitoring detailed above does not override any monitoring scheduled by the design engineer or required for any other reason. However, the monitoring detailed above may be included in monitoring programs prescribed by others provided all the requirements described in this document are incorporated into the monitoring program or plan.

Thresholds

It is recommended that the following trigger threshold criteria be adopted and shown on the Drawings:

- **Alert**: If lateral displacements are less than 80% of agreed value, excavation could be continued.
- **Action**: If lateral displacements are greater than 80% but less than 100% of the agreed value, RMS should be notified and the monitoring data be reviewed. The frequency of monitoring should be increased.

- **Alarm**: If lateral displacements are greater than the agreed value, the RMS Project Manager must be advised immediately in which case the excavation works is to be terminated. A comprehensive Risk Management / Contingency Action Plan is to be implemented with measures taken to safeguard the road infrastructure.

Hold Points

Construction must be carried out in accordance with the Council approved plans and work method statements agreed by the RMS. Construction must not proceed to the next stage until preceding 'Hold Points' have been released.

Completion of the each stage of construction listed below constitutes a 'Hold Point'. At each 'Hold Point', certification must be provided by a Chartered Professional Engineer that the conditions listed after each stage of construction below have been met before releasing each 'Hold Point'.

1. After construction of the retaining structures, but before commencement of excavation:
   a. Certify that the structures have been constructed in accordance with the approved Drawings.

2. After excavation to and installation of the first row of supports or anchors:
   a. Certify that the geotechnical conditions are in accordance with those described in the geotechnical report. If not, specify actions required and confirm that these actions have been carried out.
   b. Certify that the anchors/supports have been constructed in accordance with the approved Drawings.
   c. Certify that the anchors have been tested and passed in accordance with RMS requirements.

3. After excavation to and installation of any subsequent rows of supports or anchors:
   a. Certify that the geotechnical conditions are in accordance with those described in the geotechnical report. If not, specify actions required and confirm that these actions have been carried out.
   b. Certify that the anchors/supports have been constructed in accordance with the approved Drawings.
   c. Certify that the anchors have been tested and passed in accordance with RMS requirements.

4. After excavation to and construction of the base of the excavation:
   a. Certify that the geotechnical conditions are in accordance with those described in the geotechnical report. If not, specify actions required and confirm that these actions have been carried out;
   b. Certify that the excavation base conditions have been constructed in accordance with the approved Drawings;

5. After de-stressing and removal of any row of supports or anchors:
   a. Certify that all temporary anchors have been de-stressed, removed or disconnected from the permanent retaining structure.

Access to Site

Access to the site by RMS Engineers must be allowed for the purpose of reviewing compliance to the requirements of this document and the Work Authorised Development documents agreed with RMS.

For:	Engineers, Works Supervisors, Surveillance Officers and Councils		
Enquiries:	Supervising Geotechnical Engineer (Standards)	Phone:	8837-0248
Amendment / Addition to:		Ref File: GEO 4364	xxxxxxxx

Appendix C – RMS, Transurban and IC review / comment tracking sheet

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Project:	Sydney Modern
Package Name	Review of: Geotechnical Monitoring

Item No.	BG&E/Tranurban/RMS Comments	Date	Reviewer	Drawing No. / Reference	Page	RCC/Arup Response	BG&E/Tranurban/RMS Comments	RCC/Arup Response	Status(open/closed)	Date closed	Action
1	Section 3.3/6.5/6.6 – Please provide details on how the tilt meters and crack gauges will be attached to the EDM Wall 5.	10/02/2020	Transurban			The tilt meters are fixed to the structure using a 6mm drill and knock in anchor system. Other fixing methods can be adopted for sensitive structures. Please advise any restrictions Transurban may have on fixings.	Please advise embedment depth of the anchors. If deeper than the reinforcement cover, please advise remediation methodology if reinforcement is struck during drilling. Epoxy is not permitted	RCC confirm that the embedment depth is approximately 30mm and will be drilled using rotary-hammer drill only. If the reinforcement is struck, the holes will be prepared and patched with an epoxy mortar	Closed	24.03.2020	
2	Section 3.3/6.6 – It is noted that crack gauges will need to be installed where cracks exist or develop. Will this include the EDM side of the wall? If so, how will these be monitored and how will the development of new cracks on the EDM side be identified? Who will confirm the location that the crack gauges need to be installed?	10/02/2020	Transurban			Based on the Level 3 condition Report, Arup have confirmed there were no cracks that require monitoring on the EDM side. Regular inspections by Arup will be undertaken on the site side to identify any cracks that are currently present under the stone cladding and top soil, and based on the findings a management strategy is to be developed.	Closed subject to receipt of evidence of Arup confirmation.	Noted	Closed	27.03.2020	
3	Section 3.3/6.6 – If crack gauges will be installed on the DEM side of Wall 5, how will access be managed to allow readings to be taken in accordance with the recommendations of the monitoring report?	10/02/2020	Transurban			Based on the Level 3 Inspection, Arup have confirmed there are no crack monitoring required within the ED.	Closed subject to receipt of evidence of Arup confirmation.	Noted	Closed	27.03.2020	
4	Section 3.3 – Please confirm all instrumentation that is proposed for installation on the Land Bridge structure.	10/02/2020	Transurban			The overall GEMP is predominantly focused on the land bridge structure. The monitoring to be installed on the land bridge is as follows: - Tilt Meters, - Crack Meters (if cracks are observed, currently not required) - Vibration Monitor	Please provide evidence / confirmation from Arup that no vibration monitoring is required on the girders or other elements of the land bridge.	Noted	Closed	27.03.2020	
5	Section 3.3/3.4/6.8 – Is there a separate structural monitoring plan? Will instrumentation such as vibration monitors or crack gauges be installed on the girders or other structural elements?	10/02/2020	Transurban			RCC has received advice from Arup that based on the Level 3 bridge condition report, they don't see any particular issue arising from the survey which necessitates structural monitoring in excess of that already nominated in the monitoring plan written by Coffey (imputed and reviewed by Arup).	Closed subject to receipt of evidence of Arup confirmation.	Noted	Closed	27.03.2020	
6	Section 6.7 – Please ensure AML are provided updates on all survey results relating to the monitoring of EDM Wall 5.	10/02/2020	Transurban			Noted, please advise the best contact.	Closed. Rez Ramzan, 0426 582 822, to be the contact.		Closed	24.03.2020	
7	Section 7 – Please confirm AML are a 'Responsible Review Party' for all hold points relating to EDM asset monitoring.	10/02/2020	Transurban			We'll amend the GEMP to include AML.	OK. Please provide a copy of the updated GEMP.		Closed	24.03.2020	
8	Section 8/9 – Please ensure AML are notified of each trigger level exceedance for all monitored items relating to or have the potential to impact the EDM.	10/02/2020	Transurban			What alert level would AML like to be notified of? Action or Alarm? Once confirmed we'll update GEMP.	Action to Rez Ramzan, 0426582 822. Alarm to Rez Ramzan and the ED Motorway Control Centre, 8356 2216. Closed subject to receipt of updated GEMP.	Noted	Closed	24.03.2020	
9	Section 9.2 – Have the vibration limits for the Land Bridge been considered by a structural engineer? The report notes that the trigger levels are indicative only at this stage and require further assessment. When will this be completed and confirmed?	10/02/2020	Transurban			RCC confirm ARUP have reviewed the vibration limits, this comment is left over from previous revision	Closed subject to receipt of evidence of Arup confirmation.	Noted	Closed	27.03.2020	
10	Are there any plans to inspect the structure as it is exposed. Or will the monitoring systems be relied on to pick up issues during the excavation. There are is a risk that there are structural issues that only become apparent as buried structural elements become exposed.	19/02/2020	BG&E (Joe Daven)			Regular site inspections will be undertaken on the site side to identify any cracks that are currently present under the stone cladding and spoil, and based on the findings a management strategy may need to be developed. The monitoring systems will be mostly relied upon to identify events that may impact the structure.	Noted.		Closed	24.03.2020	
11	In Section 2.2, EDM wall 5 will be monitored from CH0 to CH75. Will CH100 to CH125 be monitored too	19/02/2020	BG&E (Joe Daven)			Between CH100 to CH125 there minimum works, RCC demolishes the existing stair, anchors the existing footing, excavates a small lift pit adjacent, and constructs finishes. These works will be monitored by the vibration monitor located on the land bridge.	Noted.		Closed	24.03.2020	
12	Cracks may form or develop on either face of EDM wall. Will both sides be monitored?	19/02/2020	BG&E (Joe Daven)			RCC has received advice from Arup that based on the Level 3 bridge condition report, they don't see any particular issue arising from the survey which necessitates structural monitoring in excess of that already nominated in the monitoring plan written by Coffey (imputed and reviewed by Arup), therefore RCC is only proposing to monitor the site side. If significant cracking or damage is found on the site side during the removal of finishes and spoil, or during excavation; RCC will consult Arup to advise if an inspection internal will be required.	Noted		closed	24.03.2020	
13	How are the tilt meters interpretted, and limits set. The tilt meter reads rotation, however this can be caused by the structure expanding and contracting over the course of a day, as the structure responds to changes in temperature. How is a local rotation differentiated from a global displacement as this can skew alerts, and obscure key events.	19/02/2020	BG&E (Joe Daven)			"The monitoring is continuously sampled and records the sensor temperature and local environment factors such as temperature, rainfall etc from a local weather station. This allows for the understanding and correlation of environmental factors. We understand structural changes due to temperature are real and will not be ignored. If desired, analysis can be provided that allows for understanding the total effects of tilt as an array. Please confirm if this is a requirement?"	Noted and understood. It is important that when setting limits for the alerts, the limit considers the range of potential movement from all causes. The interpetation of results and placement of sensors, needs to avoid triggering false alerts which may lead to the site teams ignoring alerts. If we are trying to measure 2mm of ground movement, yet there is 5mm of thermal movement, it becomes important to analyse the data prior to sending alerts to site teams.		Closed	24.03.2020	
14	Where are the surveys taken from, is there consistent point of reference that is visible throughout the excavation process to control survey error. How are these targets maintained	19/02/2020	BG&E (Joe Daven)			Due to the long odd shape of the excavation, the top of the oil tanks will be used as a central survey point to control survey, although as the excavation progresses a number of locations on the rock ledges will be utilised to supplement this location for the rock faces below the ED footing and to survey the western end of ED Wall 5. Survey targets and/or mini prisms will be used which require little maintenance, should maintenance be required these will be access by platform ladders or EWPs pending the height.	Noted		closed	24.03.2020	

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