9.2 Preliminary Fire Safety Strategy

The fire safety strategy is to provide a design that gives a satisfactory level of occupant life safety and protection to other properties and can facilitate FRNSW intervention, whilst meeting other project objectives. Consideration is also made of protection of the building contents, as many of these will be irreplaceable.

9.3 Design Approach

The building is generally to be built in accordance with the DtS Provisions of the BCA appropriate to the use of the building as a museum and gallery space, except as described in this report.

The Chau Chak Wing Museum plans to accommodate significant artwork both owned by the University and brought in on loan from international sources. With this in mind the building will be fully sprinkler protected throughout.

The fire rating of the structure is anticipated to be largely DtS compliant, with the exception of the basement storage areas.

The main design aspiration for the building is to be largely open plan with all floors connected. In a DtS design only 3 floors can be interconnected via open stairs and voids where one of those floors is ground floor. Chau Chak Wing Museum is proposed to have 4 levels interconnected where two of those levels have direct egress to outside. To facilitate this, the maximum compartment size will be no greater than 3,500m² across the 5 floors and egress will be over sized to allow for a quick egress time from the building when compared to a DtS compliant 3 storey connected space.

9.4 Occupant Numbers

Indicative occupant numbers provided by JPW (Architects) on 7/9/16 used as the basis for this concept design are as follows:

Table 11 Indicative occupant number for each storey

Level	Primary Use	Occupant Number
Lower Level 02	Storage and loading dock	40
Lower Level 01	Gallery	180
Lower Ground	Gallery / Study	228
Ground floor	Entry, Gallery and Auditorium	283
Upper Level 1	Gallery / Staff rooms	199
Terrace	Plant	24
	Total	954

The occupant numbers will be confirmed with the client and Project Certifier once the design development stage commences. [1]

9.5 Egress

9.5.1 General

The building is to have a simultaneous evacuation regime, where evacuation occurs from all connected floors simultaneously during an emergency. This is due to the high degree of interconnection between floors and the open nature of the stairs. Floors completely isolated can have a different evacuation regime.

There are three fire isolated stairs serving the building:

- The project north fire isolated stair, which connects all levels
- The project south fire isolated shaft is separated at Ground and Lower Ground which creates two separate fire isolated stairs:
- Project south fire isolated stair 1 - connecting Lower Level 2, Lower Level 1 and Lower ground Level
- Project south fire isolated stair 2 - connecting Ground, Upper Level and Plant Levels. See Figure 26 below.

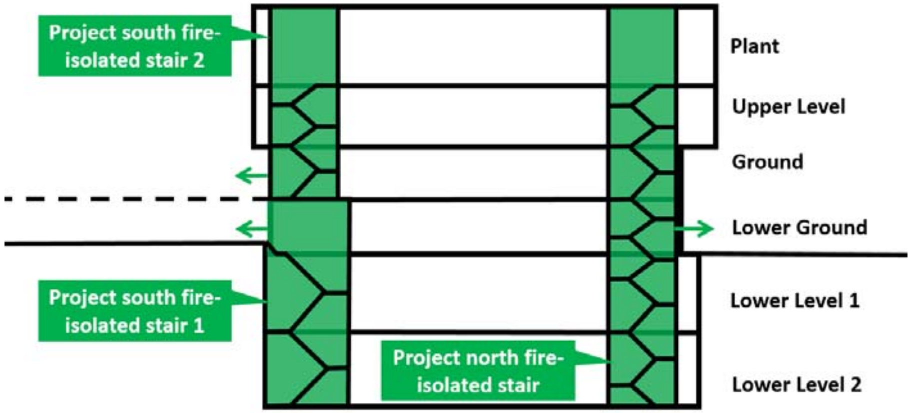


Figure 26 Schematic section illustrating fire isolated stair arrangement

The proposed configuration provides two fire isolated exists from all floors. There is also an open stair which is the main point of entry into, and circulation through, the building.

The fire-isolated stairs discharge directly to road or open space via a final exit door:

- Project north fire isolated stair – discharges at Lower Ground level
- Project south fire isolated stair 1 – discharges at Lower Ground Level (for occupants evacuating from the levels below). See Figure 27 below.

[1] For ease of understanding, the two separate stairs within the project south fire isolated shaft will be referred to as project south fire isolated stair 1 and project south fire isolated stair 2.

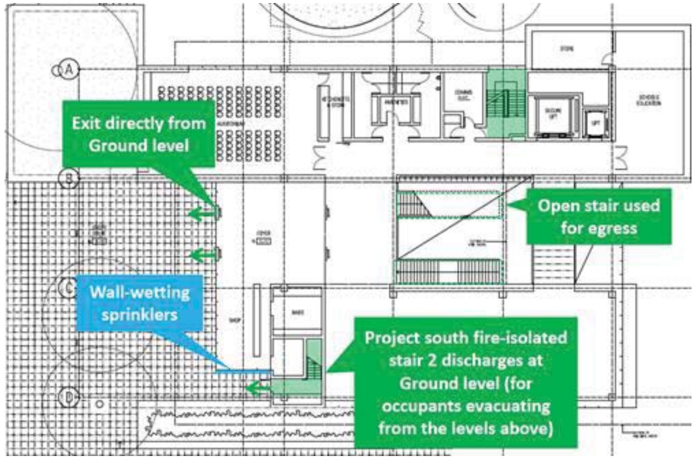


Figure 27 Exits at Lower Ground level

Occupants discharging from the southern fire-isolated stair 2 evacuate within 6m of the glazing. Wall wetting sprinkler protection shall be provided to the glazing adjacent to the path of travel from the exit, as illustrated in Figure 27 above. The wall wetting sprinklers shall meet the requirements of Clause C3.4 of the BCA.

- Project south fire isolated stair 2 – discharges at Ground Level (for occupants evacuating from the levels above)
- Egress is also available direct to outside at Ground Level. See Figure 28 below.

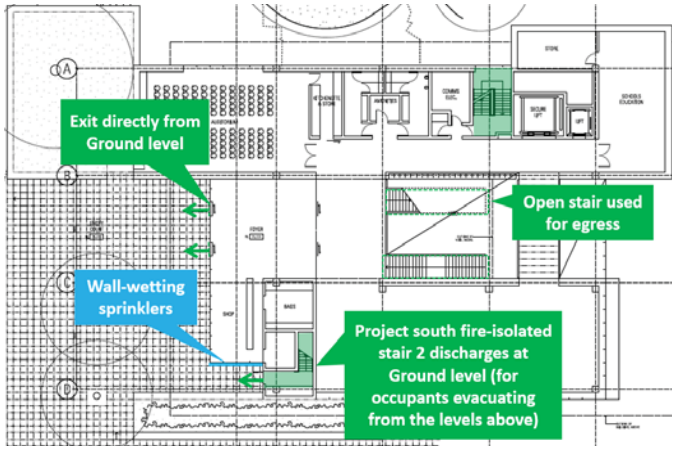


Figure 28 Exits at Lower Ground level

Occupants discharging from the southern fire-isolated stair 2 evacuate within 6m of the glazing. Wall wetting sprinkler protection shall be provided to the glazing adjacent to the path of travel from the exit, as illustrated in Figure 28 above. The wall wetting sprinklers shall meet the requirements of Clause C3.4 of the BCA.

Egress is also available direct to outside at Lower Level 01. See Figure 29 below.

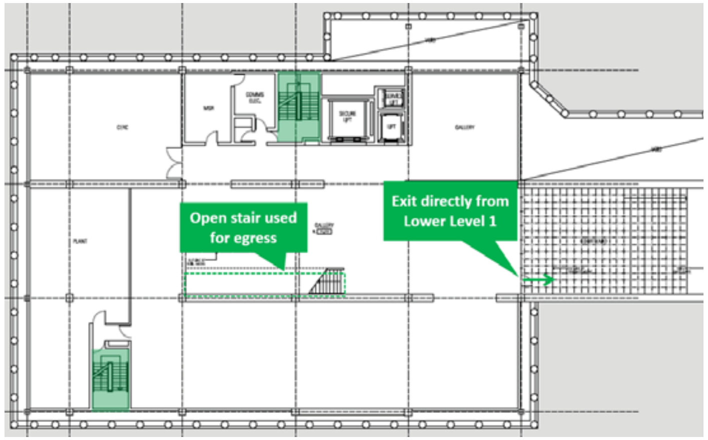


Figure 29 Exits at Lower Level 01

Final occupant numbers and aggregate exit width will need to be reviewed as the design progresses, to help ensure that there is good flexibility for events, exhibitions and functions. The stair details will also need to be confirmed (treads and risers, handrails etc.).

9.5.2 Plant Level

Egress for the plant area of the development will comply with the DtS Provisions in terms of occupant width and number of exits. The terrace has an area of 705m². Based on the floor space factors within the BCA for a plant area this could equate to 24 people at any one time.

9.6 Structural Fire Resistance

A Class 9b type A construction would require 2 hours FRL. The BCA consultant, (Group DLA, have confirmed the requirements of the storage areas requires a fire rating of 240/240/240 in line with the DtS provisions. There is potential that based on the geometry of the relevant fire compartment (area and available ventilation), the available fuel load, and the provision of sprinklers, that the FRL can be reduced to 12/0120/120 to be consistent with the remainder of the building. It is, however, noted that the available ventilation to this level is limited which may limit the ability to reduce FRL's. This will be looked at in detail at the next stage.

Provisionally Arup suggest designing for a 4hour rated basement for costing purposes.

Note that Dangerous Goods stores may require higher FRLs depending on specific requirements for the nature of these spaces (i.e. what dangerous goods are being stored in what quantities). This requirement would need to be assessed by a Dangerous Goods consultant. In addition, the proposed substation will require additional protection as per the supply authority guidelines.

9.7 Compartmentation

As part of the proposed fire safety strategy, the building will be limited to the following compartment sizes for each of the typical uses, as listed in Table 12 BCA maximum size of fire compartments

Table 12 BCA maximum size of fire compartments

Class of use (Type A Construction)	Area limitation (m2)	Volume limitation (m3)
Class 5 (office)	8,000	48,000
Class 7b (loading bay) Class 9b (Assembly)	5,000	30,000

Furthermore and notwithstanding the limits set out above the compartmentation will be limited in the Class 9b areas to not more than 3,500m² to negate the requirement for smoke control under the DtS provisions. To achieve this, it is proposed to provide vertical fire curtains surrounding the open stair on Lower Level 1 which activate upon fire trip. See Figure Figure 30 below.

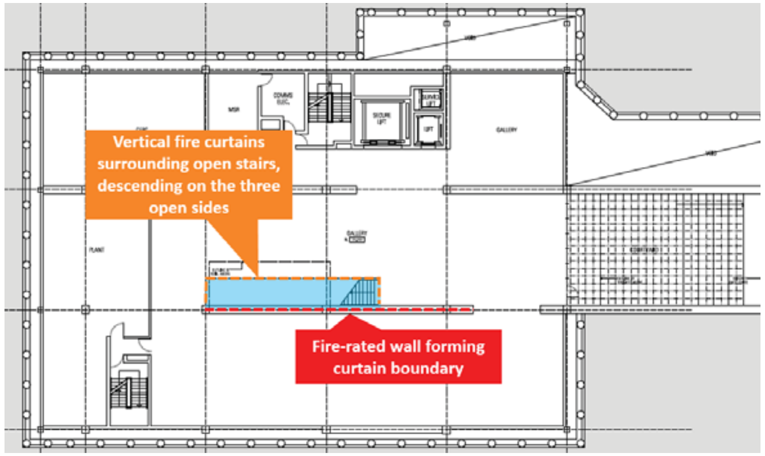


Figure 30 Lower Level 1 plan illustrating vertical fire curtains surrounding the open stair

A concertina style curtain is recommended, that would descend on the 3 open sides and be laterally guided by a connection to the adjacent fire-rated wall - isolating the connecting open stair through to Lower Level 1. See Figure 31 below.

Figure 31 Concertina fire curtain: picture taken from "Greene" fire curtains

This measure effectively fire-isolates Lower Level 1. The remaining interconnection of Lower Ground Level, Ground Level, and Upper Level is the largest fire compartment within the building resulting in a floor area of 3,289m2. Refer to Table 13 below which lists the floor area on each individual level.

Table 13 Floor areas with respect to floor area

Level	Primary Use	Floor area
Lower Ground	Gallery / Study	979m2
Ground floor	Entry, Gallery and Auditorium	897m2
Upper Level 1	Gallery / Staff rooms	1413m2
	Total	3289m2

Figure 32 shows a cross section of the fire compartment in fire mode.

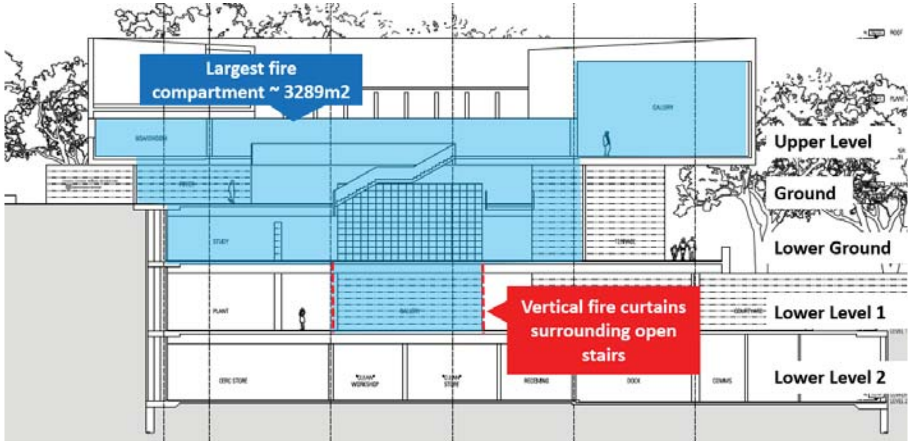


Figure 32 Section illustrating the interconnection of storeys when in fire mode

9.7.1 Interconnection of Floors and Atrium Provisions

A key design aim is to allow the floors to be interconnected and allow the flow of people uninterrupted through the space. The proposed configuration (excluding the vertical fire curtains) essentially connects 4 storeys.

As an 'atrium' is defined by the BCA as a space within a building that connects 2 or more storeys, the provisions of Part G3 are technically applicable. The proposed design does not adopt these Atrium provisions, instead being developed to meet the performance requirements.

It is considered that based on the number of floors connected by the atrium wells (as discussed below), the evacuation arrangements, and the active fire safety systems contained within the building, ta performance based solution that omits the need for fire resisting bounding construction around the atrium wells and mechanical exhaust to the atrium wells can be developed.

Comparison to DtS

The BCA DtS Provisions of Clause D1.12 would limit the number of floors connected to 3 storeys where one of those storeys is ground floor. In fire mode the design is considered equivalent to a 3 storey connection based on the fact that fire curtains will descend on Lower Level 1 and separate off the 3 storeys above - Lower Ground Level, Ground Level and the Upper Level. The heat and smoke is therefore contained to a maximum of 3 open levels which is equivalent to the DtS provisions of the BCA, and aligns with the underlying intent of the clause – to limit the spread of fire and smoke through unprotected openings for stairways, ramps escalators and moving walkways.

Fire curtain performance

The fire curtain provided on Lower Level 1 does not achieve the 90min insulation rating required by the BCA. However, the proposed fire-curtain is provided with an FRL of -/90/- and testing data shows that these curtains perform well in terms of minimising the risk of fire spread via heat transfer through the curtain. It is also highly unlikely that ignited materials will be located close to the fire curtains due to the nature of the space.

Brigade intervention

In terms of brigade intervention, the ability to fight a fire in this environment is considered equivalent to a BCA 3 storey connection.

There is added inherent design benefits within the Dr Chau Chak Museum which include the fact that access direct to ground floor is available on three levels which would assist with both occupant egress and fire-fighting intervention.

9.8 Fire Services

9.8.1 Detection

Early detection of fire is important for this building not only for life safety but also notifying the building management of potential fires. Therefore, smoke detection should be provided in accordance with AS1670.1 to help justify the interconnected floors and notify FRNSW at the earliest opportunity. Detectors may be omitted in areas where a smoke detector is prone to nuisance alarms.

9.8.2 Hose reels

Hose reels are required throughout the building. At this conceptual design stage, it is assumed compliant fire hose reels will be installed in the building.

Arup could look at removal of hose reels from the space as the design progresses as the preferred first aid fire-fighting measure would be portable extinguishers.

9.8.3 Automatic Suppression System

Automatic sprinklers will be provided in accordance with BCA Clause E1.5 and AS2118.1-1999. A grade 3 water supply only is required for this height and size of building.

9.8.4 Alarm

Sound Systems and Intercommunication Systems for Emergency purposes (SSISEP) is to be installed to AS1670.4-2015 and detection of smoke, activation of sprinklers or activation of a manual call point must immediately alert the building occupants.

The evacuation of the interconnected floors will be simultaneous.

9.8.5 Air Handling Systems

As per BCA Clause E2.2, central air-handling systems serving more than one fire compartment must shut down on fire trip. Mechanical systems should comply with the BCA and AS 1668:1-2015.

Normal mode return air systems are to shut down, as per AS1668.1-2015, as no smoke exhaust is required.

9.8.6 Hydrants

A hydrant system is to be provided in accordance with AS2419.1-2005. At this conceptual design stage, it is assumed to be fully compliant.

The hydrant booster will be located on Ground floor adjacent to the roadway; provisionally an attack hydrant will be located at the booster to provide external hydrant coverage on the ground floor level.

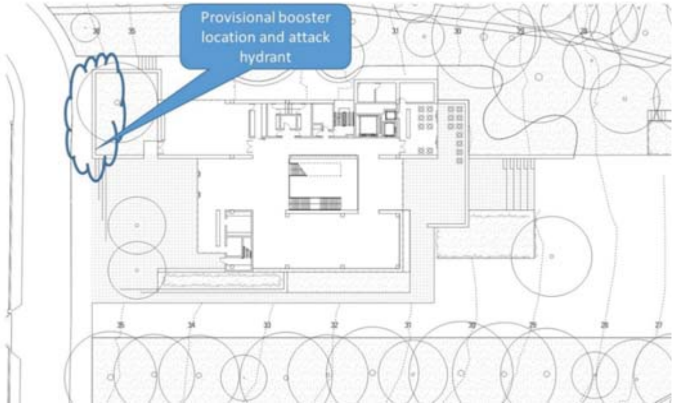


Figure 33 Hydrant booster location

9.8.7 Emergency Lighting and Exit Signage

Emergency lighting and exit signage will be as per the DtS requirements of the BCA. Exit signage shall be provided directing people to the open stair.

10 Traffic

10.1 Assessment of Travel Impacts

CCWM would result in the co-location and consolidation of the Macleay Museum, Nicholson Museum and University Art Gallery as well as collections from a number of currently fragmented locations into a new single museum.

Future visitors would likely adopt similar characteristics as the current University Museum visitors. A similar future visitor profile proportion can be expected, shown in Figure 34. A majority of the existing university museum tickets sold relate to school students which generally generate less traffic given that students would arrive by school buses or public transport.

A proportion of the remaining 47% of the visitors would likely drive, with a majority taking public transport.

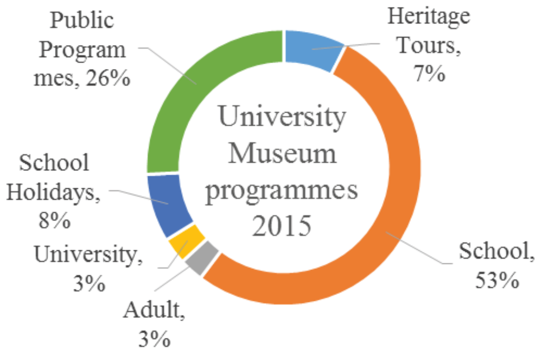


Figure 34 Number of tickets sold relating to each university museum programme 2015

10.2 Patronage Increase

As a conservative estimate and the purpose of this report only, the number of visitors to the CCWM is assumed to increase by 30% of the total number of visitors. Peak monthly data from the year 2015 is used in the assessment.

10.3 Travel Analysis

Assuming that school related visitors arrive by public transport on train or bus modes, the CCWM would likely generate an additional 40 vehicles per day. This is based on conservative journey to work assumptions, with a summary of the calculations shown in Table 14.

Table 14 Patronage and vehicle increase as a result of the completion of the CCWM

Daily patronage data	Existing university museums visitors	CCWM with a 30% increase in visitors	Number of visitors generated by the CCWM
Weekday visitors	1,178	1,531	353
Non-school related visitors (47%)	554	720	166
Daily car users (42% JTW)	132	173	40

This traffic generation is minimal given the typical arrival profile of visitors, discussed in section 10.1. Based on the profile, the weekday peak hour period at 11am would generate some 9 vehicles. Arrivals would occur outside of AM and PM road network peak hours. Given the small increase in traffic generated by the CCWM, the surrounding road network and intersections are unlikely to be affected adversely.

10.4 Proposed Development Vehicle Access

10.4.1 Vehicle access arrangements

The vehicle movements for drop-off /pick-up by bus and car and for access to the loading dock are shown in Figure 35. All vehicles enter via University Avenue from Parramatta Road where traffic signal control facilitates entry and exit. Buses and cars dropping off or picking up passengers will traverse University Avenue to arrive at the entry plaza on University Place. Trucks and vans will turn right into a ramp to access the loading dock.

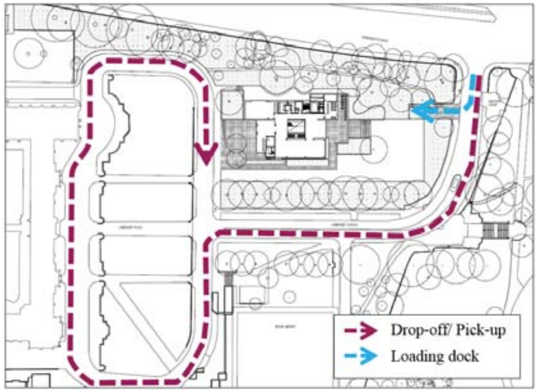


Figure 35 Vehicle access arrangements

The loading dock entry has been positioned to take advantage of the grades allowing a potentially slightly graded access roadway to a basement level. It is located 25 m from the Parramatta Road entry which provides room for three vehicles to queue on exit before blocking the ramp access. It is recommended that a keep clear marking be located on University Avenue to enable vehicles to enter the loading dock ramp as shown in Figure 36. Signage will also be installed to notify drivers not to store across the driveway.

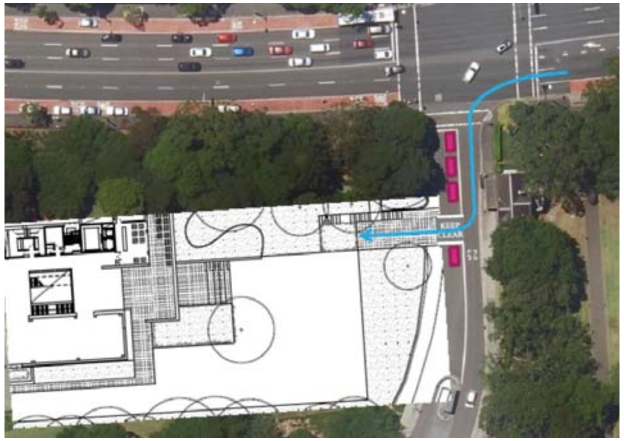


Figure 36 Vehicle access to loading dock ramp

10.4.2 Truck Turning Paths

The Chau Chak Wing Museum would have loading access in the basement. A typical delivery vehicle (medium rigid vehicle) is shown manoeuvring into the proposed loading bay in Figure 37.

The loading bay has also been designed for larger vehicles for large museum exhibitions. These deliveries are expected to occur infrequently.

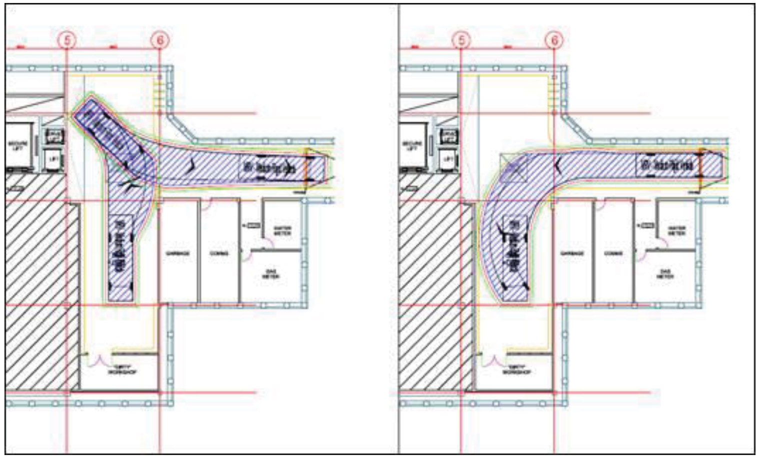


Figure 37 Loading bay in the basement showing garbage/delivery vehicle entry and exit

10.4.3 Ramp Review

The vertical clearance on the ramp has been checked for the MRV entering and exiting the loading dock and the HRV reversing down the ramp for occasional deliveries. These are shown in Figure 38 and Figure 39.

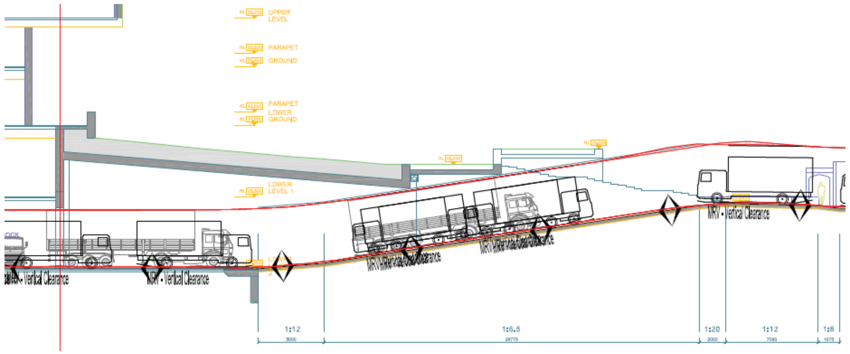


Figure 38 MRV entering and exiting loading dock

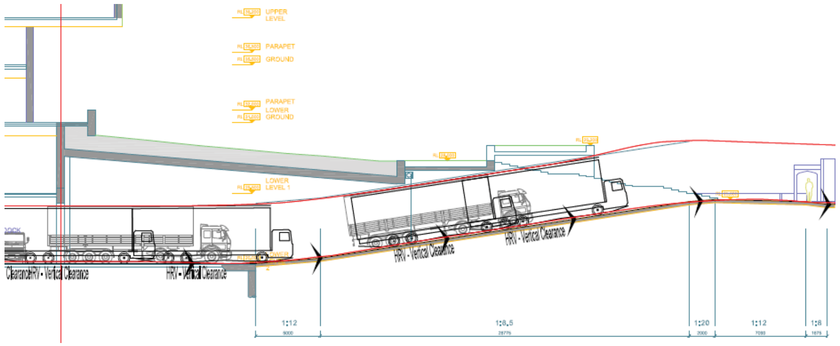


Figure 39 HRV reversing down the ramp

11 Acoustics

This Scheme Design Report sets out the proposed acoustic standards that will apply to the Chau Chak Wing Museum. This documentation is expected to be updated in the Detailed Design Report (60%) as design progresses.

The Project acoustic criteria have been developed based on relevant Australian Standards and the University of Sydney Campus Infrastructure & Services Building and Architecture Standard (18 Sept 2015, 'CIS Standard') and other guideline documents, Arup international best practice and experience on past gallery projects.

A list of questions about acoustic expectations was submitted to the Client Project Team (University of Sydney). Feedbacks have been received and considered in this concept design report. A benchmarking of acoustic criteria among galleries globally is given in Appendix C

It also helps Client team and Design team to understand/decide the expectations of acoustic requirements and experiences.

The report of necessity includes some technical acoustic terms and these are explained in Appendix B.

11.1 Level of Detail

The documentation has been developed to Scheme Design equivalent to midway through design development. To convey particular aspects of the design intent, some areas of the works have been detailed to a greater extent than others.

The documentation will be completed in Detailed Design Report (60% of design development) for preparation for the Contractor and Subcontractors to undertake an Early Contractor Involvement (ECI) and Design and Construct (D&C) process.

The Contractor and Subcontractor are responsible for finalising the design and co-ordination in accordance with the performance requirements established in the Detailed Design Report (60% of design development). This includes completing design development, detailed design, construction drawings, co-ordinated working drawings and installation drawings. It also includes undertaking and demonstrating completion of all necessary analysis and calculations to inform design finalisation.

11.2 Site and project descriptions

11.2.1 The site and surrounds

The development site is located to the northeast of the University's grounds adjacent to the Parramatta Rd entrance, within the area currently used as the Fisher Tennis Courts site.

Parramatta Rd runs in an approximate east to west alignment and borders the site to the north. University Place that runs in a north south direction is located to the west, beyond which is the University's main Quadrangle Building. University Avenue borders the site to the south, with Victoria Park located beyond the University grounds to the east.

The main portion of the site consists of three tennis courts, to the north of which is a small weatherboard tennis pavilion building. An area of lawn is located to the east of the site.

The northern boundary between the University campus and Parramatta Rd features a retaining wall above which is a linear garden bed containing significant trees. Ground conditions of the area consist of a sloped garden bed.

The development site is bound on all sides by trees of varying significance.

Figure 40 Aerial View of Site

11.3 Site analysis

11.3.1 Assessment locations

The nearest potentially affected receiver locations to the subject site are residential receivers on the opposite side of Parramatta Road, as identified in Locations within the University have not been deemed sensitive receptors based on the proposed use of the building and its proximity to other buildings on site. Furthermore, these locations are not deemed relevant to the SEARs assessment requirements.

Table 15 External assessment location(s)

ID	Location	Description
A1	13 Arundel Street	Residential location, being in closest to the proposed terrace at the eastern end of the building. Predicted noise levels will be representative for neighbouring residential premises.

11.3.2 Existing noise environment

Criteria for the assessment of operational and construction noise are usually derived from the existing noise environment of an area, excluding noise from the subject development.

Appendix B of the NSW EPA Industrial Noise Policy (INP) outlines two methods for determining the background noise level of an area, being 'B1 – Long-term background noise method' and 'B2 – Short-term background noise method'. This assessment has used long-term monitoring.

Short-term attended noise measurements have also been carried out on site for the assessment of noise ingress to the proposed building.

11.3.2.1 Noise measurement locations

Noise measurements are ideally carried out at the nearest or most potentially affected locations surrounding a development. An alternative, representative location should be established in the case of access restrictions or a safe and secure location cannot be identified. Furthermore, representative locations may be established in the case of multiple receivers as it is usually impractical to carry out measurements at all locations surrounding a site.

The long-term and short-term measurement locations are described in Table 16 and shown in Figure 41.

Table 16 Noise measurement locations

ID	Location	Description
L1	13 Arundel Street	Residential location. Logger located at the front boundary of the property, 1.2 m above the ground in the free field.
S1	Development site - south	Free-field measurements carried out 1.2 m above the local ground level at various locations around the perimeter of the development site. Utilised for noise ingress assessment, not for background noise assessment of residential receivers.
S2	Development site - southwest	
S3	Development site – northwest	
S4	Development site - north	
S5	Development site – northeast	
S6	Development site – southeast	

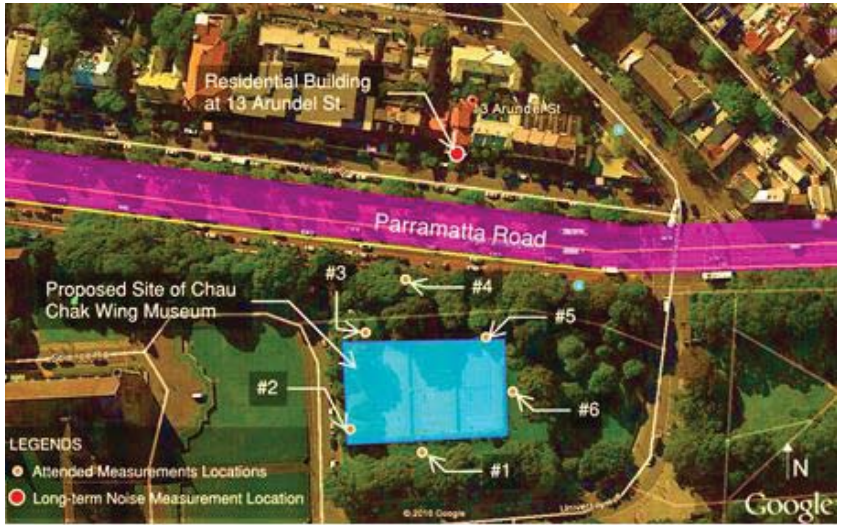


Figure 41 Project site location and measurements locations

11.3.2.2 Long-term noise measurement results

Long-term noise monitoring was carried out from Wednesday, 22 February 2017 to 09 March 2017.

Table 17 presents the overall single Rating Background Levels (RBL) and representative ambient Leq noise levels for each assessment period, determined in accordance with the INP.

Table 17 Long-term noise monitoring results, dB(A)

Location	Time period	Rating background noise levels, dBLA90	Ambient dBL_{Aeq} noise levels
13 Arundel St.	Day	55	63
	Evening	54	62
	Shoulder (22:00-00:00)	50	59
	Night	45	59

Day: 07:00-18:00 Monday to Saturday and 08:00-18:00 Sundays & Public Holidays
Evening: 18:00-22:00 Monday to Sunday & Public Holidays
Night: 22:00-07:00 Monday to Saturday and 22:00-08:00 Sundays & Public Holidays
The shoulder period has been established for 22:00-00:00. The shoulder period rating background level is taken to be the mid-point between the rating background levels between the two assessment periods that are on either side of the shoulder period.
As required by the INP, the external ambient noise levels presented are free-field noise levels. [i.e.. no façade reflection]

11.3.2.3 Attended noise measurement

Attended noise measurements have been conducted at the subject site during the traffic peak time (1600-1800) of Parramatta Road on 5 October 2016. Broadband and octave band L_{Aeq}, L_{A10} and L_{A90} measurements were made. The locations of the attended noise measurements are shown in Figure 40.

The measured noise levels are summarised in Table 18 below.

Table 18 Attended measurement summary.

Location^	dB $L_{Aeq, 15mins}$	dB $L_{A90, 15mins}$	Notes
S1	54	50	Traffic noise from Parramatta Road is dominate source. Light traffic form the University Ave. Some crowd noise from university.
S2	54	50	Traffic noise from Parramatta Road is dominate source. Some crowd noise from university.
S3	59	54	Traffic noise from Parramatta Road is dominate source. Parramatta Road is sunken from the level of measurement location.
S4	69	61	Measured at the boundary of the Parramatta Road.
S5	62	57	Traffic noise from Parramatta Road is dominate source. Angle of view to the Parramatta Road is wider at the location. Parramatta Road is sunken from the level of measurement location.
S6	58	54	Traffic noise from Parramatta Road is dominate source.

Notes:

^ Refer to Figure 10 for location

Measurements were undertaken using B&K 2270 Type 1 sound level meter. Equipment calibration was checked with a B&K Type 4231 calibrator before and after measurements and did not exhibit any significant drift.

11.4 Project Acoustic Criteria

11.4.1 External noise emission

11.4.1.1 Development conditions

The Contractor is to note that Operational noise and vibration must satisfy the Project Approval conditions which are yet to be determined.

11.4.1.2 Project specific levels

As the development is yet to be approved, the external environmental criteria is based on those established in the DA Acoustic report [Arup AC02 (v2,1) Acoustic SEARs Report Issue 2.pdf, 2017-03-30], which have been established in accordance with the NSW Industrial Noise Policy. This criteria is considered subject to review following receipt of project approval.

In addition, Project noise criteria have been set for public and tenant external areas within the project, consistent with the objectives of the CIS Standard. These are to be maintained, and are beyond the minimum requirements of the DA Approval.

The external noise project limits are defined in Table 19

Table 19 INP noise criteria modifying factor corrections for duration

Receiver	Time period	Existing noise levels1			Project goals, dB L_{Aeq}[5]		
		RBL	Industry2 dBL_{Aeq}	Traffic3 dBL_{Aeq}	Intrusive	Base Amenity	Modified Amenity
13 Arundel St. (Residential)	Day	55	N/A [4]	63	60	60	53
	Evening	54	N/A [4]	63	59	50	53
	10pm to midnight	49	N/A [4]	60	54	45	50
	Night	45	N/A [4]	60	50	45	50
External accessible areas of Project – min 1 m from inlets/outlets	All times						55

Notes:

1 – Free-field noise levels

2 – Does not include noise from the subject site

3 – For assessment against Section 2.2.3 of INP

4 – No other industrial noise sources identified

5 –L_{Aeq} assessment periods as per NSW INP

11.4.2 Internal noise levels and room acoustics

11.4.2.1 Normal operations

- Table 20 outlines the Project noise limits for steady-state or quasi steady-state sounds such as noise from normally operating Building Services Works and noise intrusion from the building envelope. The internal noise criteria applies to the cumulative sound level, and therefore individual noise sources or ingress paths need to be designed to lower individual limits, which has been indicatively allocated in Table 20. The overall noise objectives have been defined in dBL_{Aeq}, consistent with AS 2107:2016 and Arup's experience on similar projects.

- Noise ingress from mechanical plant and equipment associated with the development must also be mitigated, in conjunction with the façade design, to meet the Project internal noise limits.
- As background noise levels contribute to providing sound masking for the benefit of speech privacy in the office areas, where the cumulative noise levels from building services and façade noise ingress is more than 5 dB below the Total internal design levels, a noise masking system should be considered.
- Mid-frequency (500 Hz – 1 kHz) reverberation time criteria are also recommended in Table 20 Some notional reverberation times are proposed for most room types but for the galleries, these will be used for general guidance rather than strict criteria, given that there is a range of room acoustic conditions which can work for galleries of different sizes.

Table 20 Recommended Maximum Internal Noise Levels and Reverberation Time Targets

Space	**Recommended Maximum Noise Levels, dB L_{Aeq},1hr**			**Recommended Reverberation Time Targets, s**
	Total Internal Noise Level	**Building Services Noise Level**	**Building Envelope Break-in Noise Level**	
Front of House				
Gallery with windows/façade	40	37	37	Notionally 1.0 – 2.5 *
Gallery without windows/façade	40	40	NA	Notionally 1.0 – 2.5 *
Auditorium	35	32	32	~0.8 (Depending on Volume of the auditorium, based on AS2107 Curve 3)
Study rooms	40	40	NA	0.4-0.6
School education	40	37	37	<0.8
Café	45	42	42	As low as practical for noise control
Kitchen	55	55	NA	-
Amenities/Shower	45	45	NA	-
Foyer/Shop	45	42	42	As low as practical for noise control
Lobby/circulation	45	42	42	As low as practical for noise control
Office	40	37	37	0.4-0.6
Staff Office (open plan)	40	37	37	0.4 1
Meeting rooms	40 OR 35 if with VC	37 OR 32 if with VC	37 OR 32 if with VC	<0.6 OR <0.4 if with VC
Boardroom	40 OR 35 if with VC	37 OR 32 if with VC	37 OR 32 if with VC	<0.6 OR <0.4 if with VC
Reference resource room	40	37	37	0.4-0.6
Conservation	40	37	37	0.5-0.8
Back of House				
Collection Store	50	50	NA	-
CERC/ "Dirty" Workshop	50	50	NA	As low as practical for noise control
Store	50	50	NA	-
Dock	55	55	NA	-
Garbage	55	55	NA	-
Water Meter/Gas Meter	55	55	NA	-
MSR	TBC	TBC	NA	TBC
Comms Elec./ Plantrooms/Pump Room	85 dB $L_{Aeq,8h}$ or 140 dB $L_{C,peak}$ According to Work Health and Safety Regulation 20112	85 dB LAeq,8h or 140 dB $L_{C,peak}$ According to Work Health and Safety Regulation 20112	NA	As required for noise control

Notes:

* Reverberation time criteria for the gallery spaces are only for guidance. Detailed discussions are included in Section 11.5.3.2.

1 - Given the mixed criteria provided for this type of space within the AS 2107:2016 and our experience with these types of spaces we believe it is appropriate to target an internal reverberation time of <0.8 seconds.

2 – Where noise levels cannot be achieved due to equipment selection, exposure time should be reduced or hearing protection worn when entering plant and equipment rooms.

11.4.2.2 Impact Noise Isolation

The CIS Standard does not outline any recommendations for floor impact isolation ratings. Where active uses are located above quiet, noise-sensitive spaces, impact noise from foot fall may be of concern. For the Project the only area identified of potential concern would be between Gallery spaces, and would depend on the nature of use at the time.

At this stage of the project an impact isolation rating has not been specified, however, where practicable, impact isolation treatment should be provided for floor finishes or ceilings below, where floor finishes are not provided.

11.4.3 Emergency operations

- Noise from building services during emergency situations is to comply with Australian Standard AS/NZS 1668.1:1998 – The use of ventilation and air conditioning in buildings, Part 1: Fire and smoke control in multi-compartment buildings, being 80 dBL_{Aeq} in stair wells and 65dBL_{Aeq} in occupied spaces.

- During operation of back-up generators and emergency equipment, noise levels in open plan office areas shall not exceed 55 dBL_{Aeq}(15 minute).

11.4.4 Rain noise

- Roofs are to be designed so that the levels of rain noise at 15 mm/hr rainfall rate (defined as 'intense' rain in ISO 10140-5:2010/Amd 1:2014 [2]) are at least 5 dB below the internal noise for normal operations. Assessment is to apply to rain noise only not including other noise contributions such as building services.
- Any external façade features, such as solar shading devices are to be designed so that the levels of rain noise at 15 mm/hr rainfall rate (defined as 'intense' rain in ISO 10140-5:2010/Amd 1:2014 3) do not exceed the internal noise limits for normal operations. Assessment is to apply to rain noise only not including other noise contributions such as building services.

11.4.5 Wind noise

- External elements on the building such as façade details, louvres, shading devices etc. shall not result in creaking, audible tones, whistling etc.
- Noise from wind of < 8m/s shall not result in the internal noise criteria being exceeded.

11.4.6 Internal Sound Insulation

Minimum sound insulation ratings for partitions/doors (horizontally and vertically) are proposed based on Table 1 in 'CIS Building and Architecture Standard of The University of Sydney' and Arup's previous experience on similar projects. Sound insulation ratings have been determined and adjusted according to different adjacencies to provide appropriate sound separation and acoustic privacy.

Plant room partitions to occupiable spaces are proposed to be minimum Rw 55 provisionally. The final sound insulation ratings required for these partition should be determined according to noise levels of plant room, so that the building services noise level criteria specified in Table 20.

The proposed sound insulation requirements are presented in the form of marked up drawings based on the Scheme Design Architectural drawings (dated on 17 03 2017) in Appendix D.

It is understood that there are many of the proposed spaces are interconnecting and therefore sound insulation will be controlled by sound transfer through the various openings rather than through walls. There is some potential for this to be improved by localised addition of sound absorptive finishes on key surfaces and this will be considered carefully during the design process.

[2] Acoustics – Laboratory measurement of sound insulation of building elements – Part 5: Requirements for test facilities and equipment AMENDMENT 1: Rainfall sound

11.4.7 Vibration

11.4.7.1 Human Comfort

- Vibration from building services is to comply with the NSW DEC 'Assessing Vibration; a technical guideline' (DEC, 2006). The criteria outlined in the guideline is based on the British Standard BS 6472-1992 'Evaluation of human exposure to vibration in buildings (1-80Hz)'.
- Project limits are outlined in Table 21.

Table 21 Vibration acceleration levels for human comfort, m/s2

Location	Assessment period1	Preferred values	
		z-axis	x- and y-axes
Continuous vibration (weighted RMS acceleration, m/s2, 1-80Hz)			
Gallery, offices, educational uses and other areas within building excluding plant rooms	Any time	0.020	0.014
Impulsive vibration (weighted RMS acceleration, m/s2, 1-80Hz)			
Gallery, offices, educational uses and other areas within building excluding plant rooms	Any time	0.64	0.46
1 - Daytime is 7:00am to 10:00pm and night-time is 10:00pm to 7:00am			

11.4.7.2 Protection of Sensitive Artefacts

There is a need to provide an environment where sensitive artefacts can be left for long periods. Vibration needs to be controlled for the direct protection of the artefacts but also to ensure that there is no movement of artefacts on shelving etc. which could subsequently cause damage.

There have been a number of studies that have looked at the levels of vibration that are required to damage buildings. There is less information available on the potential for damage to artefacts within the buildings, as these will vary in their sensitivity markedly.

The British Museum undertook a detailed study [3] looking at potential damage to very sensitive artefacts. That study recommended a vibration levels are presented in Table 22 below:

Table 22 British Museum Vibration limits for Exhibition/storage areas

Acceleration limit	Octave band centre frequency / Hz						
	6.3	10	16	25	40	63	100
dB (dB re 10-6 m/s2)	69	73	77	81	85	89	93
Equivalent m/s2 r.m.s	0.003	0.004	0.007	0.011	0.018	0.028	0.045

To achieve this vibration level for protecting artefacts, a heavier and thicker structure/slab might be needed.

However, the paper also indicates that this criteria is ideal and that relating vibration directly to the impact on heterogeneous collections material is difficult and so this level are therefore designed to allow a margin of safety. We note that this maximum acceptable vibration level may be too stringent for this project. It is also understood from the Client Project Team that 'nothing overly sensitive to normal levels of vibration'. As such, this maximum acceptable vibration level is given here for reference and facilitation purpose. This will be further discussed with Design Team and developed as design progresses.

The highest levels of vibration are likely to be during transportation and installation of the artefacts and, with proper packaging and care, it is possible for very fragile items to be moved.

Lower levels of vibration can impact on items housed on shelving because of the tendency of shelving to amplify vibration where there are long spans. The levels of vibration that will cause items to move on shelving is not well understood – being a complex interaction between the shelf construction and the friction between the shelf and the artefact. This issue is best considered as and when shelving is being procured.

The vibration limits proposed earlier in Table 21 for human comfort are also considered sufficient for protection of artefacts. The possible movement of artefacts on shelving is considered to be a low risk but will be kept under review. There are no major external sources of vibration that are of concern.

11.5 Architectural

11.5.1 Criteria

- The Contractor shall determine the sound insulation rating of internal partitions and floors etc., to ensure noise from Building Services Works do not exceed the project acoustic criteria.
- Minimum sound insulation requirements for internal partitions are presented in the Appendix D.

[3] British Museum, Conservation Research Group. Report No 1999/6 Assessment of Vibration Damage Levels. D. Thickett

11.5.2 Internal sound insulation

11.5.2.1 General

Internal sound insulation is a key acoustic design component to provide acoustic privacy and to control noise transfer between spaces.

Acoustic privacy is less a concern for gallery spaces as no sensitive conversation is anticipated. However, it is important in the office areas where there is a need to protect personal and sensitive conversations, such as meeting rooms and offices.

There are two factors to decide the acoustic privacy which are the background noise level in the receiver room and the sound insulation performance of the partition. To achieve the same level of the acoustic privacy, the lower background noise level, the better partition sound insulation is required.

The control of noise transfer is important to spaces where are expected to be quiet/uninterrupted and/or to generate high levels of sound, such as gallery spaces, auditorium, office spaces, reference resources rooms and study room.

The amount of noise transferred between the source and receiving space depends on:

- The level of sounds created in the source room;
- The sound insulation provided by walls, roof and floor and ductwork, and;
- Sound flanking paths that allow sound to go around the intervening partition.

The acceptable level of intrusive noise will be dependent on the target sound levels in the affected rooms and this will be factored into the recommendations regarding partitioning and acoustic details.

The sound insulation rating of internal partitions and floors must also be determined to ensure noise from Building Services Works do not exceed the project acoustic criteria. The required ratings will be dependent on final equipment selection.

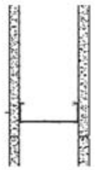
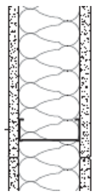
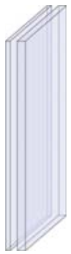
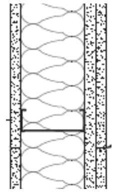
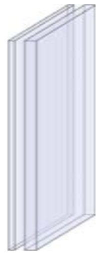
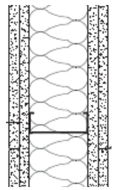
Recommended minimum sound insulation requirements for internal partitions are presented in Appendix D.

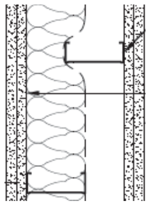
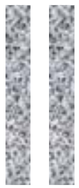
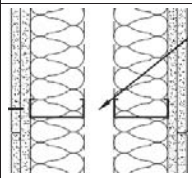
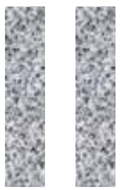
11.5.2.2 Partition Constructions

Internal partitions and doors should be designed to provide a composite sound insulation in accordance with design targets.

Indicative constructions to achieve the proposed ratings are provided in Table 23.

Table 23 Sound insulation performance of different wall build-ups

Sound Insulation Performance	Wall Build-up		
R_w 35	DRYWALL		1 x 13 mm standard plasterboard (min 8.3 kg/m2) 64 mm steel stud at min 600 centres 1 x 13 mm standard plasterboard (min 8.3 kg/m2)
	GLASS		12 mm float glass OR 10.38 mm laminated glass
R_w 40	DRYWALL		1 x 13 mm standard plasterboard (min 8.3 kg/m2) 64 mm steel stud at min 600 centres 50 mm fibreglass (min 14kg/m3) in cavity 1 x 13 mm standard plasterboard (min 8.3 kg/m2)
	GLASS		10 mm	12 mm air gap	8.8 mm laminated glass
R_w 45	DRYWALL		1 x 13 mm standard plasterboard (min 8.3 kg/m2) 64 mm steel stud at min 600 centres 50 mm fibreglass (min 14kg/m3) in cavity 2 x 13 mm standard plasterboard (min 8.3 kg/m2)
	GLASS		10 mm	16 mm air gap	12.4 mm acoustic laminated glass (dependant on final specification and framing)
R_w 50	DRYWALL		2 x 13 mm fire-rated plasterboard (min 10.5 kg/m2) 64 mm steel stud at min 600 centres 50 mm fibreglass (min 14kg/m3) in cavity 2 x 13 mm fire-rated plasterboard (min 10.5 kg/m2)
	MASONRY		190 mm hollow block (270 kg/m2) full height OR 140 mm solid blocks (260 kg/m2) full height

Sound Insulation Performance	Wall Build-up		
R_w 55	DRYWALL		2 x 13 mm fire-rated plasterboard (min 10.5 kg/m2) 2 x 64 mm studs offset in 92 mm track 50 mm fibreglass (min 14kg/m3) in cavity 2 x 13 mm fire-rated plasterboard (min 10.5 kg/m2)
	MASONRY		140 mm hollow block (140 kg/m2) full height 50 mm air gap, 140 mm Hollow Block (140 kg/m2) full height OR 90 mm solid block (150 kg/m2) full height 50 mm air gap 90 mm solid block (150 kg/m2) full height
R_w 60	DRYWALL		2 x 16 mm fire-rated plasterboard (min 13 kg/m2) 2 x 64 mm separate studs at min 600 centres 100 mm fibreglass (min 14kg/m3) in cavity 2 x 16 mm fire-rated plasterboard (min 13 kg/m2)
	MASONRY		140 mm Solid Block (260 kg/m2) full height 50 mm air gap, 140 mm Solid Block (260 kg/m2) full height

11.5.2.3 Doors and Seals

Doors will limit the overall sound insulation of a partition since they are generally of much lighter construction than the partition, and they are difficult to effectively seal. While high performance doors can be provided, it should be understood that they are likely to be heavy, more difficult to operate and relatively expensive.

Depending on the arrangement of the door, and the relationship of the room to other adjacent spaces, a door with a sound insulation performance of 10 less than the partition itself will be appropriate provide the door does not present itself as more than 25% of the total wall area. This will allow for an overall reduction in composite R_w of no greater than 5 points.

The table below indicates typical sound insulation performances of typical door constructions for reference.

Additionally, the door should provide effective compression of the door seals. Sealing mechanisms should allow for the accommodation of building tolerances and of floor level variations.

Improper engagement of acoustic door seals can be a common problem resulting in compromising the acoustic performance of the partition.

Table 24 Typical door constructions and sound insulation performances

Partition Sound Insulation Rating	Typical Corresponding Door Sound Insulation Rating	Typical Door Construction and Sealing Arrangement
R_w 35	R_w 25	32 - 35 mm solid core door with simple frame seals (e.g. Raven RP94 Si or equivalent), threshold close cut to carpet
R_w 40	R_w 30	35 mm solid core door with frame seals (e.g. Raven RP94 Si or equivalent) and threshold (e.g. Raven RP99 Si or equivalent) seals.
R_w 45	R_w 35	45 mm solid core door, with high-performance rebated frame (e.g. Raven RP10 Si or equivalent)and threshold (e.g. Raven RP38 or equivalent) seals, possibly proprietary door set
R_w 50	R_w 40	Proprietary acoustic door set
R_w 55	R_w 45	Unlikely to be met with a single door. Consider air-lock arrangement
R_w 60	-	Doors are not recommend for these partitions

11.5.2.4 Noise Transfer between Gallery and Circulation spaces

The galleries in the Chau Chak Museum are generally interconnecting and open to the circulation spaces, therefore limiting the opportunities to reduce sound transfer between spaces.

Dependant on the functional uses of the spaces on a given day, there is potential for larger crowds/events in one space will transfer between spaces and effect other quieter zones. This could cause disturbance and distraction to the visitors, and in particular impact noise intrusion to the auditorium.

There is some potential for this to be improved by localised addition of sound absorptive finishes on key surfaces. The following acoustic strategies are recommended to be considered:

- Control the reverberance and reduce the noise build-up in the circulation space;
- Sound absorptive ceiling panels could be incorporated on the entrance to the gallery spaces to absorb/reduce sound reflected by the ceiling.

11.5.3 Room acoustics

11.5.3.1 General

The choice of architectural finishes is important in determining the acoustic quality of an environment. Architectural finishes may be categorised as acoustically “hard” or “soft” depending on the behaviour of a sound wave incident on the surface. “Hard” finishes, such as glass, stone or tile, reflect most of the energy of a sound wave; acoustically “soft” finishes, such as carpet, mineral fibre ceiling tiles or foam, absorb most of the energy of the sound wave.

Spaces with only “hard” finishes are typically reverberant and may be perceived as “echoey” or “live”. Reverberant rooms increase sound in two ways. Noise from a given noise source in a reverberant room will be louder than in an acoustically dead room due to the additional energy from reflective surfaces. Where noise sources are human, the potential exists in a reverberant room for the acoustic environment to modify behaviour. For example, in a room where reverberant sound makes communication difficult, people may raise their voices. This effect is cumulative as others do the same to make themselves heard, and is sometimes known as ‘the cocktail party effect’.

Providing sound absorptive finishes helps to break this vicious circle and reduce the overall level of occupational noise. This control of occupational noise is important for comfort reasons and reducing noise spill between connected spaces but also for meeting rooms, board rooms etc. where effective verbal communication is important.

The room acoustic of a space can be quantified using the Reverberation Time (RT). It quantifies the time taken for sound to decay, measured in seconds.

Table 25 Provisional acoustic treatments for general spaces below presents the recommended provisional acoustic treatments to the general spaces. This will be discussed and coordinated with Architect.

Acoustic treatments for gallery spaces are discussed in Section 0

Table 25 Provisional acoustic treatments for general spaces

Space	Provisional Acoustic Treatments
Auditorium	Sound absorptive soffit treatment and Absorbing / diffusing wall treatment With carpet if acceptable
Study rooms	Carpet and sound absorbing ceiling Absorbing/diffusing wall to reduce echoes
School education	Sound absorbing ceiling (with carpet if acceptable) Absorbing/diffusing wall to reduce echoes
Café	Sound absorbing ceiling
Amenities/Shower	Sound absorbing ceiling (optional)
Foyer	Sound absorbing ceiling (if acceptable)
Shop	Sound absorbing ceiling or wall panels behind the counter
Lobby/circulation	Sound absorbing ceiling is recommended to control the noise build-up and transfer between spaces (with carpet if acceptable)
Office	Carpet and sound absorbing ceiling
Staff Office (open plan)	Carpet and sound absorbing ceiling
Meeting rooms	Carpet and sound absorbing ceiling Some wall treatments on adjacent walls.
Boardroom	Carpet and sound absorbing ceiling Some wall treatments on adjacent walls.
Reference resource room	Carpet and sound absorbing ceiling
Conservation	Sound absorbing ceiling
Collection Store	NA
CERC/ “Dirty” Workshop	Sound absorbing ceiling
Store	NA
Dock	NA
Garbage	NA
Water Meter/Gas Meter	NA
MSR	NA
Comms Elec./ Plantrooms/Pump Room	May be required for noise control. Make provision for 50 mm treatment to walls. TBC on plant noise levels.
Terrace	NA
Entry Court	NA

11.5.3.2 Gallery

The guidance on reverberation time criteria for gallery spaces has been presented in Table 20

Based on our experience of similar museum projects, the design decisions towards the sound absorbing finishes in gallery spaces are distinctive. This section presents a detailed discussion to gallery room acoustics to facilitate the decision making process.

Galleries are typically designed to be large open spaces, called 'white cube'. They could become very reverberant if there is no acoustic treatment. The excessive reverberance in the galleries is usually associated with the following acoustic issues:

- Noise build-up
- Noise could be built-up very quickly in a reverberant environment. This is especially a concern when there is a function or a group gathering in the gallery (particularly children). In addition, noise transfer from the circulation space outside the gallery space would also contribute to the noise build-up.
- However, this may not be a concern during normal/typical operations where small groups of visitors are generally quiet. Busier areas such as the café and entry, may more regularly have a congregation of people.
- Reduction of speech intelligibility
- The excessive reverberance tends to reduce speech intelligibility. This is typically an issue for guided tours, functions or a group of people where raised voice/loudspeaker may be used.
- Flutter echoes
- Most art galleries have acoustically hard parallel walls and are therefore prone to flutter echoes (repeated echoes resulting from reflections between walls). In practice, this is rarely problematic and it is therefore not proposed to provide any wall-mounted acoustic treatments in the galleries to mitigate this phenomenon.

It is also worth highlighting that if functions/events are expected to be held in the gallery spaces, a controlled reverberation time is desired to provide appropriate acoustic environment and comfort to the guests.

Meanwhile, it is not appropriate to design the gallery spaces to be acoustically 'dead'.

In summary, acoustic treatments are not strictly required in the gallery space, since it is typically not an issue at most of time during normal operations where people are quiet. However, we recommend incorporating sound absorptive finishes to improve the acoustic quality of the space and to provide flexibility.

The ceiling is the typical surface to incorporate sound absorptive finishes in gallery spaces. Various options of ceiling material and facing could be used for sound absorbing purposes, such as sound absorptive plasterboard and perforated ceiling panels. Examples of acoustic absorption materials are given in the Table 26 below.

For gallery spaces with concrete floor and ceilings, sound absorptive walls should be considered to reduce the reverberation time and noise build-up.

Table 26 Examples of sound absorptive ceilings

Acoustic Finishes	Product	Images of Sample Installations
Fibreglass covered by fabric or perforated metal/timber panel. Typically, a minimum 20% opening is recommended for perforation pattern.		
Sound absorptive plasterboard		

11.5.3.3 Atrium

An atrium is proposed, linking each floor. The central atrium provides limited opportunities to mitigate noise travelling through the building.

Acoustic treatments could be provided to control the excessive reverberance in the Atrium, in order to control the noise build-up and reduce noise transfer between floors.

- The potential acoustic treatments are indicated in Figure 41 Potential acoustic treatments for atrium
- and as follows:
- Sound absorptive ceiling finishes near the Atrium Space on each floor;
- Sound absorptive finishes in the area of noise generation such as circulation and foyer;
- Sound absorptive baffle under the skylight.

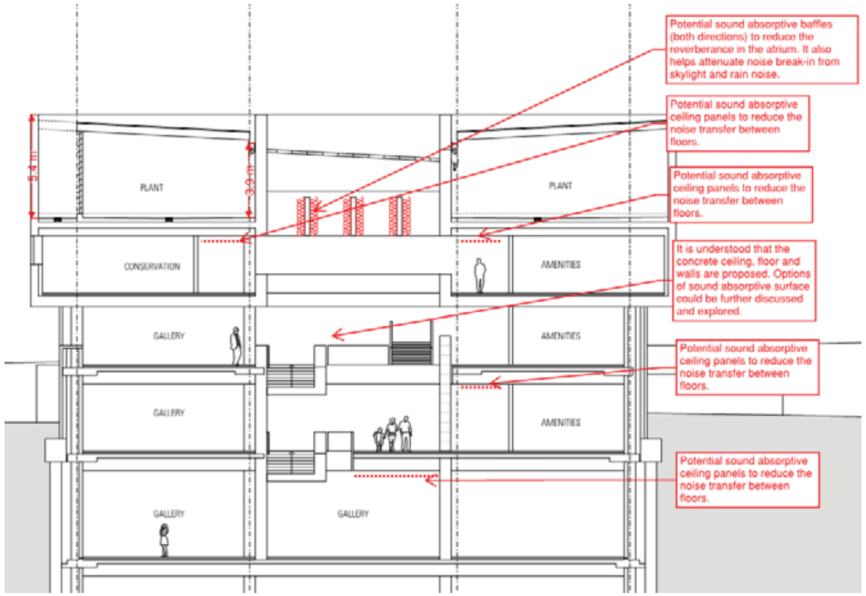


Figure 42 Potential acoustic treatments for atrium

11.6 Envelope

11.6.1 Provisions

11.6.1.1 Façade Break-in Noise Control

It is recommended that the façade be designed such that the intrusive noise (measured in dB L_{Aeq}) is in accordance with Table 20.

Noise from extreme events such as thunderstorms, fireworks, public events etc. will be excluded from the design.

The preliminary recommendations of the façade sound insulation targets are given in Table 27. Example glass build-ups are also given as a reference. Please note the proposed build-ups are those required for acoustic purposes only. It may be necessary to have different glass build-ups for other purposes, such as thermal, light, security and fire engineering.

Table 27 Preliminary Recommended Façade Sound Insulation Target

Direction	Preliminary Recommended Façade Sound Insulation Target
North (Staff Office)	R_w 37 (e.g. 6mm/12mm gap/10mm)
North (Auditorium)	R_w 40 (e.g. 6mm/12mm gap/10mm Lam)
East	R_w 33 (e.g. 6mm/12mm gap/6.38mm Lam)
South	R_w 33 (e.g. 6mm/12mm gap/6.38mm Lam)
West	R_w 32 (e.g. 6mm/12mm gap/6mm Lam)

11.6.1.2 Sky-light

Noise break-in via the sky-light and rain noise may be an acoustic concern.

The junction between sky-light and walls is typically a noise flanking path. It is recommended to have the wall higher than the junction (as currently documented) to avoid complicated and weak details, as shown in figure below:

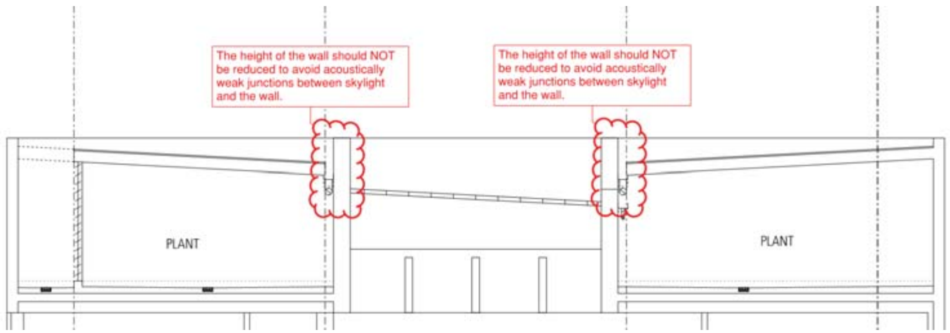


Figure 43 Skylight-wall junction

The assessment will be further developed as design progresses.

11.6.1.3 Concrete Roof

It is assumed all roofs are made of concrete, which has been factored into the assessment of building services noise emission. Rain noise is also not expected to be of concern with a concrete roof.

11.6.1.4 Flanking

Vertical and horizontal flanking via the façade and façade junction will need to be addressed to ensure overall system performance and Project criteria are achieved.

11.7 Building Services Noise and Vibration Control

11.7.1 Criteria

- Internal noise from mechanical noise sources is to be limited to the criteria outlined in Table 20. Allowance shall be made for the cumulative effect of all services noise sources normally operating. The criteria shall apply at all normal listening locations a minimum of 1.2 m above floor levels and no closer than 1 m from any sound-reflecting surface, with services operating normally and all together.
- External noise emission from mechanical services shall achieve the criteria in Section 11.4.1. Allowance shall be made for other services noise.
- Vibration from hydraulic services equipment or pipe work shall not contribute to an exceedance of the criteria outlined in Section 11.4.7.

11.7.2 Recommended provisions

11.7.2.1 Cooling towers

- Solid balustrades to the perimeter of the roof in proximity to the cooling towers.

11.7.2.2 Chillers

- Allow for floating slab/floor to reduce noise/vibration transfer to boardroom.

11.7.2.3 Air Handling Units (AHUs)

- AHUs shall be supported on steel springs and/or neoprene/rubber pads.
- Access doors to AHUs shall be sealed with neoprene gaskets to provide an airtight seal.
- All connections between AHUs and ductwork shall be properly aligned and executed using flexible material (rubberised canvas, lead impregnated PVC or an approved equivalent).
- All pipe and conduit penetrations of AHU casings shall be acoustically sealed.
- All pipes connected to AHUs shall have flexible union pipe connectors if the fan is not isolated from the unit.
- The Contractor shall ensure that all AHU casing/enclosures are adequate to ensure that noise due to break out does not exceed the internal noise limits specified. Consideration may need to be given to double skin casings and internal insulation.

11.7.2.4 Fan Coil Units

- It is recommended that Fan Coil Units (FCUs) are not located in spaces with room criteria of 35 dB(A) and below.
- FCUs must be selected by the Contractor to achieve the Project noise criteria for the space served
- Prior to ordering the FCUs, the Contractor shall be required to demonstrate that the Project noise criteria will not be exceeded by the proposed FCUs. This will require the Contractor to provide noise predictions and acoustic test data detailing the noise levels associated with the FCUs. This test data will have been obtained from an accredited test laboratory and shall include intake, discharge and casing radiated sound power levels.
- To control noise from Fan Coil Units (FCUs), consideration should be given to the supply air, return air and casing break-out to occupied spaces to ensure that background noise targets are met. Depending on the noise sensitivity of the occupied space, the following acoustic mitigation measures may be necessary:
- Supply and return air attenuators with a length of 900 mm to 1200 mm
- Acoustically lined ductwork on supply and return paths.
- Acoustic lagging (loaded vinyl wrap) on FCU casings to control noise breakout.
- Return air openings in ceiling should not be located close to FCUs.

11.7.2.5 Diffusers, registers and grilles

Terminals should be selected in accordance with the dB(A) for the spaces being served. Terminals should be selected so that the manufacturer ratings, minus 10 dB, align with the room criteria they serve.

11.7.2.6 Pumps

- All pumps shall be selected with the highest efficiency consistent with the specified duty and pump and impeller diameter shall not exceed 0.9 of the maximum impeller diameter capability of the pump housing to reduce the possibility of tonal effects.
- Pump impellers, shafts and drive couplings shall be statically and dynamically balanced to the best commercial standards. Maximum vibration amplitude shall not exceed 2.5 mm/s RMS vibration velocity when measured on the machine structure with the pumps/motors mounted on the inertia blocks as specified.
- Unless otherwise indicated by the engineer, the pump and motor assembly shall be mounted on a concrete filled inertia block and completely isolated as specified. Pump inertia blocks shall be sized to support the weight of elbows, bellows and other fittings without creating undue stress on the pump assembly. The weight of water in the pump and

connected pipe work shall be taken into account in selecting the final size of the required inertia blocks.

- Where inertia bases are recommended, the pump and motor assembly shall be bolted directly onto the concrete inertia block.
- The inertia base shall be sufficiently large to provide support for all parts of the pumps, including any components that over-hang the equipment base, such as suction and discharge elbows on centrifugal pumps.
- The construction and installation of all inertia bases shall be in full compliance with the details provided in this specification.
- Electrical connections to the equipment motors shall be made with a long floppy length of flexible cable and all piping shall be resiliently supported.
- T-shaped inertia bases shall be used as support for pump elbows where applicable.
- Unless otherwise specified, vibration isolators shall be unenclosed steel spring type in series with 8 mm neoprene 'noise stop' pads.
- Inlet and discharge pipe work to the pumps shall incorporate flexible pipe connections of the twin sphere type. Tie rods shall not bridge across the flexible connectors and if fitted shall be loosened. Care shall be taken to ensure the alignment between the pipe work and the pump system is in accordance with the flexible pipe connection manufacturer's recommendation.

11.7.2.7 Plant rooms

- Low noise or attenuated plant shall be selected, with particular reference to the casing radiated noise.
- AHU casings with insulated double skin construction.
- Possible lagging of ductwork in the plant room after the primary attenuator to mitigate noise break-in to the system.
- Minimum 150 mm thickness concrete (345 kg/m^2) floor slabs to control transmission of sound vertically from the plant rooms to above and below. Note minimum 200 mm thick concrete base slab below floating slab for generator rooms.
- Where the plant rooms are not glazed (i.e. façade), acoustic attenuators and or minimum 140mm thickness solid block work (320 kg/m2) plant room walls shall be allowed for.
- Acoustic door sets with minimum R_w 35 rating. Preference for lobbied doors where plant rooms open directly onto tenanted areas.
- Atmosphere side attenuators to be used on ventilation systems and fans. Intakes to be ducted, via attenuators or acoustically lined ductwork to the external louvres. Acoustic louvres may be needed for air exhaust of plant rooms.

11.7.2.8 Lagging

11.7.2.8.1 Pipe lagging and cladding – acoustic type

- All areas with a building services noise criterion of 35 dB (A) or below shall include pipe lagging consisting of 25 mm medium density (45 kg/m3) mineral wool or open cell foam covered by continuous sound barrier material of surface weight not less than 4.5 kg/m2 wherever pipework runs across the ceiling. Pipework running vertically through rooms with a building services noise criterion of 35 dB(A) or below shall include the pipe lagging in addition to a minimum of one layer of contiguous plasterboard forming the riser.
- All areas with a building services noise criterion of 30 dB(A) or below shall not have any pipework running through the room or attached to walls outside the room unless it is resiliently supported. If pipework cannot by avoided in these areas the pipework shall be lagged with 25 mm medium density (45 kg/m3) mineral wool or open cell foam covered by continuous sound barrier material of surface weight not less than 4.5 kg/m2 and boxed within a construction comprising a minimum of one layer 16 mm fire rated plasterboard.

11.7.2.8.2 Acoustic lagging to ductwork flexible coupling

- Where acoustic lagging or cladding is necessary and is located on both sides of a flexible ductwork coupling, the coupling shall also be clad.

11.7.2.9 Penetration details

To maintain the sound insulation integrity across sound insulating and vibration isolating constructions, services penetrations shall require attention to detailing.

Generally, contractual responsibilities for services penetrations and penetration sealing are as follows:

- The Mechanical Subcontractor shall be responsible for providing detailed dimensional information to the Contractor, including sizes and locations of all holes required.
- Penetrations shall be formed by the relevant Sub-contractor (e.g. masonry, concrete, drywall packages).
- The Contractor and Mechanical Subcontractor shall provide all the necessary sleeves for services penetrations and locate them loose on the services at the penetration point.
- The Contractor and Mechanical Subcontractor shall provide acoustically rated fireboxes (e.g. HPM 430) for power outlets located in acoustically critical walls ($\geqslant$Rw 50; see Table 28).
- The responsibility for acoustically sealing all the services penetrations (e.g. in drywall, ceiling, precast concrete, and block constructions) shall be part of each of these trade packages.
- Acoustically sealing all services penetrations shall be coordinated by the Contractor.
- Cooperation with this work shall be part of this Tender.

Table 28 Partition penetration details

Partition rating	Penetration type	Description
≤ R_w 45	Standard	An oversize mild steel sleeve, minimum thickness of 1.2 mm, shall be built into the partition leaving 15 mm to 20 mm clearance all around the duct/pipe and any insulation. The gap shall be packed with mineral wool (density 45 kg/m3), compressed during packing to about 80 kg/m^3. The packing shall be sealed on both sides with a resilient non-hardening sealant such as Selleys ProSeries FireBlock.
≥ R_w 50	Critical	As for the Standard detail plus, in addition, a close fitting cover plate comprising 13 mm gypsum plasterboard, or building board of similar surface mass, bedded in mastic and fitted around the duct/pipe on one side. The joint between cover plate and duct/pipe shall be sealed with mastic. Where external thermal insulation with a vapour barrier is applied to the duct/pipe, the thermal insulation shall be stopped on either side of the partition but the vapour barrier shall be continuous and pass through the penetration.

11.7.2.10 Vibration isolation

- Noise and vibration isolation systems shall be selected to suit the environment in which the equipment is to be located. Components of the system located in the open air shall be weatherproof, non-rusting and be resistant to or protected from rodent and insect attack by choice of materials and design of components.
- Should any rotating equipment cause excessive noise and vibration, the Contractor shall be responsible for re-balancing, realignment or other remedial work required to reduce noise and vibration levels. 'Excessive' is defined as exceeding the approved manufacturer's specifications for the unit in question and/or the requirement of this specification, whichever is the more stringent.
- Any additional equipment or any modification of the existing equipment shall be reviewed and approved prior to installation. It is the Contractor's responsibility to select the isolation equipment appropriate for the equipment requiring isolation. The Contractor shall submit all necessary technical data/information, including the manufacturer's specification for vibration levels.

The following plant items require vibration isolation that achieves 95-98% isolation efficiency. Suitable isolators for each item are listed in Table 30

- Air Handling Units
- Chillers
- Condensing Units
- Cooling Towers
- Pumps (requires vibration isolation with inertia base).
- Fans
- Fan Coil Units
- Vibration isolators shall be sized and selected with the proper loading to meet the specified deflection requirements.
- Shop drawings or equipment approval requests shall be submitted indicating the following information:
- equipment identification and fundamental forcing frequency
- isolator type
- static deflection under the design load
- isolation stiffness (horizontal and vertical)
- isolation efficiency
- The following table describes various isolator types.

Table 29 Isolator and mounting types

Type	Detail
Type I - Spring vibration isolators	Spring type vibration isolators shall be unhoused, freestanding and laterally stable, preferably be constructed from suitably treated and finished steel or steel alloys. They shall be manufactured with rubber, neoprene or glass fibre noise stop pads, minimum static deflection 2 mm, to prevent transmission of high frequencies. The material of the pad shall be selected to suit the location. Holes shall be provided for fixing both to the supported machine and to the supporting structure. The criteria of spring stability under compression shall be that the ratio lateral stiffness/vertical stiffness is at least 1.2 times the ratio static deflection/working height. Spring type isolators with (a) static deflection more than 50 mm or (b) fitted to reciprocating machinery or (c) fitted to rotating machines with long rundown times, shall have ancillary dampers or adjustable snubber type restraints which prevent excessive movement as the machine speed passes through the resonant frequency of the mounting system.
Type II - Rubber, neoprene, glass fibre in shear vibration isolators	The active element of the isolator shall be bonded to mild steel or steel alloy plates, sleeves, pressings or forgings. Both element and bonding agent shall be resistant to lubricating oil and water. Holes shall be provided for fixing both to the supporting machine and to the supporting structure. The holes shall be located and formed in such a way that making the fixing does not stress the active element. The dynamic stiffness and damping coefficients of the active material, at the operating speed of the supported equipment, shall be used in calculation of isolation efficiencies. Alternatively certified isolation efficiency charts may be used. Mountings whose stiffness varies with direction of deflection, shall be mounted with orientation marks for use during maintenance and installation.
Type III - “Pad” or “mat” mountings	The material used for pad or mat type mountings may be cellular, ribbed, or studded. Pads and mats shall normally be bonded both to supported and to supporting surfaces. Material and bonding agents shall be resistant to lubricating oil and water. Pads or mats of vibration isolation material, used to obtain acoustic isolation in installations which do not require vibration isolators, shall be selected and loaded to avoid resonance. The resonant frequency of the assembly shall not lie between 2/3 and 4/3 of the disturbing frequencies of the supported equipment. Pads or mats of vibration isolation material used in cast-in-situ concrete sandwich construction machine bases, shall be separated from the concrete, to ensure exclusion of grout and fine aggregate from internal voids, with materials recommended by the manufacturer.
Type IV - Pipe and duct hangers	Hangers used for vibration control shall consist of a mild steel welded cage containing a helical spring, or neoprene/rubber/glass fibre isolator, (or both) and be suitable for suspension from drop rods. Where both types of isolating elements are used together, the spring shall be at the pipe or duct end of the hanger. The spring or active materials shall be used in compression. Steel springs shall be stable at all loadings up to full compression and full compression shall not occur before 150% of the rated maximum loading. No permanent deformation shall be caused by full compression. The load shall be transmitted to the spring through a neoprene washer bushed into the moving end to prevent metal to metal contact. Neoprene/rubber/glass fibre isolators shall be protected from overloading by metal to metal restraints or lateral containment. The hanger cage shall be capable of carrying five times the maximum rated normal service load without permanent distortion. The drop rod arrangements shall allow the rod to swing through a 30 degree angle about the vertical before metal to metal contact. Neoprene, rubber or glass fibre pipe clamp inserts shall be fitted between the pipe and clamp such that the two are completely separated. The maximum compression of the insert shall be at least 150% of the compression under normal load.
Inertia bases	Where specified or where otherwise required to achieve the specified static deflection or control out-of-balance forces, inertia bases shall be constructed from reinforced concrete and shall be designed for the loading due to the supported machine, the vibration isolation equipment and its own weight. The surface shall be steel float finished or equivalent and levelled to the machine manufacturer's requirements. The total weight (static and dynamic) of each item of plant, plus the weight of the inertia base must be provided to the Structural Engineer within 4 weeks of appointment of the Contractor. Machinery shall be fixed to the base with grouted in holding down bolts located in reverse tapered cast sockets. Inertia base depth shall be at least 1/12 the longest dimension of the inertia base but not less than 150 mm. The base footprint shall be large enough to provide stability for supporting equipment. Where the inertia base will be supported on spring or rubber in shear mountings, the base shall be formed with a prefabricated mild steel continuous edge frame, to which the necessary cross members and reinforcing shall be fixed. The mountings shall be fixed to brackets that are welded to the sides of the edge frame.

The following table provides general guidance on isolator specification.

Table 30 Indicative plant mounting and isolation

Plant type	Base type	Mount type	Min. static deflection
Pump (ground bearing slab)	Steel frame	Neoprene in shear vi ration isolator	8 mm
Pump (suspended slab)	Concrete inertia base	Open spring	25 mm
Condenser units	Wall mounted on steel frame	Neoprene in shear vibration isolator	8 mm
AHU	Rails	Internal springs and external neoprene	25 mm / 3 mm
Fan coil units	None	Neoprene in shear vibration isolator in hanger	8 mm
Fans	To suit fan	Spring hangers / spring mounts	25 mm
Cooling towers	To suit tower	Restrained spring mounts	45 mm
Pipework	None	Refer to sections 11.7.2.10.8 and 11.7.2.10.10.	Refer to sections 11.7.2.10.8 and 11.7.2.10.10.

11.7.2.10.1 Levelling and Height Adjustment of Vibration Isolators

- Vibration isolators shall be provided with means of adjustment of deflections to allow for unevenness in bases, unless they are located between prefabricated accurately parallel frames. The amount of adjustment for floor mounted isolators shall not be less than twice the permitted tolerance in the levelling of the floor. Levelling bolts or studs shall be provided with lock nuts.
- Alternatively, the means of adjustment of deflections’ may be located between the supported machine and the isolators, or between the isolators and the basic supporting structure.

11.7.2.10.2 Lateral Stiffness of Isolators

- The lateral stiffness of vibration isolators shall be selected to suit the lateral isolation efficiency required without causing instability. For rotating machines with horizontal shafts, the horizontal stiffness perpendicular to the shaft shall not be less than the vertical, if floor mounted, and vice versa if side mounted.

11.7.2.10.3 Asymmetrical Loading of Anti-Vibration Mounts in a Vibration Isolation System

- The vibration isolation system shall have levelling screws and locking nuts to allow the deflection of each mounting to be adjusted to the design value at the operating condition of the supported equipment.
- The vibration isolation system shall allow the deflection of each mounting to be adjusted to the design value at the operating condition of the supported equipment.
- The maximum difference between resonant frequencies of any two mountings of a set when the supported equipment is operating shall not be more than 15%. Inertia bases shall be incorporated where necessary to ensure even loading of the mounts.

11.7.2.10.4 Static and Dynamic Forces Due to Fluid Pressure at Flexible Connections to Fans and Pumps

- Vibration isolation systems for fans and pumps shall allow for forces and movement due to pressure differences at flexible connections. Mountings shall be laid out and sized for their loadings at all operating speeds. Inertia bases and counterweights may be used to reduce the percentage variations in mounting loads at varying speeds to the amount specified.
- Isolated sway braces, buffers and similar devices may be used to prevent movement in directions perpendicular to the vibration.

11.7.2.10.5 Prevention of Overloading of Vibration Isolation or Equipment Connections

- Vibration isolation systems whose mountings can be overloaded by excessive deflections, not caused by the running machine or normal service, shall be provided with bottoming or similar restraints that may be part of the mountings, machinery or bases. Allowance shall be made for additional travel to solid equal to 50% of the rated deflection.
- These restraints may be omitted only from vibration isolation systems that cannot be overloaded by pipe or ductwork during erection and which will not be used to assist access.
- Vibration isolation systems fitted beneath boilers, chillers, condensing units or other equipment in which the weight of the liquid contents acts through the mountings and forms a significant part of the load, shall be provided with restraints which limit the movement of the equipment on draining down to distances which do not strain service connections or adjacent runs.

11.7.2.10.6 Variable and Multi-speed Machinery

- Vibration isolation systems for variable or multi-speed machinery shall achieve the standard of isolation required by the specification at all the normal operating speeds. The resonant frequency of the isolation system shall be lower than any operating speed approved by the manufacturer.
- The resonant frequency of vibration isolation systems for machinery and electric motors with stepped speed starting arrangements (star delta, tapped resistor and transformer etc.) shall not correspond to any of the speeds at the step changes and shall allow for long run-up and run-down times.

11.7.2.10.7 Expansion Joints in Pipework

- The tie rod systems on expansion joints used for vibration isolation shall be designed to achieve the isolation required across the joint. The tie rod fixings shall use rubber or neoprene bushed washers to prevent metal-to-metal contact throughout the normal range of movement of the joint.

11.7.2.10.8 Pipes, Ducts and Service Supports

- Pipes, ducts, and their contents, or other services connected, shall be supported to avoid load on equipment items.
- Pipework and ductwork shall not be rigidly fixed to ceilings or walls of noise sensitive spaces.
- The first five service supports for ductwork on either side of the vibration source shall be provided with vibration isolators with the same vibration isolation efficiency as for the equipment.
- Where services are jointed to isolated equipment by flexible connectors and the internal pressure in the connectors is 100 kPa or less, the first three service supports next to the equipment shall include vibration isolators giving 80% efficiency at the fundamental forcing frequency of the equipment, or the efficiency required for services supports in the plant space if it is higher. The supports shall be designed to prevent movement of the connected pipe or duct from static or dynamic forces due to the fluid weight or velocity.
- Where piped services are jointed to isolated equipment without flexible connectors, or the internal pressure in the flexible connectors is greater than 100 kPa, the services shall be isolated in accordance with the Pipe Support Isolation Table below, which determines the type and extent of isolation on either side of the vibration source for different pipe sizes and noise criteria.
- The degree of isolation is determined based on to the building services noise criterion of the spaces the system passes through and serves.
- The support vibration isolators shall provide the same static deflection as the equipment supports for the length of service relating to the first type of pipe support isolation specification.
- It shall be ensured that electrical connections to equipment mounted on vibration isolation bases shall be made through flexible conduit that changes direction by at least 90° in a minimum length of 25 conduit diameters. Mineral insulated cables shall be looped through at least 360° at 75 mm radius or double the permissible minimum radius whichever is larger.

11.7.2.10.9 Reinforced Flexible Pipe Connectors

- Flexible pipe connectors made from corrugated metal, rubber, neoprene or other flexible liner with braided metal or other similar internal or external reinforcing, and intended for use without tie rods, shall have the following minimum live lengths when used for anti-vibration purposes.

Table 31 Minimum live lengths for vibration isolating ducts for given bore diameters.

Pipe nominal bore (mm)	Live length (mm)
0 – 28	230
32 – 80	340
90 – 133	455
150 – 200	570
250 – 300	690

- The minimum internal bore shall not be less than the actual pipe internal diameter.
- The axis of the connectors shall be perpendicular to the direction of vibration. Alternatively, where the design allows, the connectors shall be formed into 90° bends.

11.7.2.10.10 Distributed Pipework Isolation

- All pipework shall be attached to vibration isolated equipment with flexible connectors. Pipework supports shall also be vibration isolated. The support vibration isolators shall provide the same static deflection as the equipment supports for the length of service relating to the first type of pipe support isolation specification.
- Pipes, ducts, and their contents, or other services connected, shall be supported to avoid load on equipment items.
- Electrical connections to equipment mounted on vibration isolation bases shall be made through flexible conduit that changes direction by at least 90° in a minimum length of 25 conduit diameters. Mineral insulated cables shall be looped through at least 360° at 75 mm radius or double the permissible minimum radius whichever is larger.
- Drain pipes should not be left without isolation, as vibration will short circuit the vibration isolated equipment and pipes.
- Vibration isolation should be provided to all distributed piped services as determined by the previous specification clause and the table given below. In addition to the table, the following should be provided:
- Where any pipework is within ceilings of offices, the pipework shall be provided with minimum hanger incorporating low deflection resilient insert.
- Where any pipework is within false walls or plaster board shafts/chases, the pipework shall not be fixed to the false wall but should be fixed to the concrete wall behind.
- The Contractor shall provide insolation to all distributed piped services as determined by the previous specification clause and Table 32.

Table 32 Vibration isolation requirements for distributed pipework

Pipe diameter (mm)	Isolation requirement		
	Building services noise criterion of area served or passed through		
	< NR 35	NR 35-45	> NR 45
<15	RI for distance of 10 m	-	-
15-25	RI for distance of 15 m	RI for distance of 7 m	-
25-50	PH for distance of 30 m	RI for distance of 10 m	-
50-100	SH for distance of 20 m, + PH for distance of 10 m	SH for distance of 10 m, + PH for distance of 10 m	PH for distance of 10 m
100-150	SH for distance of 30 m, + PH for distance of 10 m	SH for distance of 15 m, + PH for distance of 10 m	PH for distance of 15 m
150-200	SH for distance of 50 m, + PH for distance of 10 m	SH for distance of 25 m, + PH for distance of 10 m	PH for distance of 25 m
200-300	SH for distance of 75 m, + PH for distance of 10 m	SH for distance of 35 m, + PH for distance of 15 m	PH for distance of 35 m

- NOTE: distances given are from the vibration source.

KEY:

- RI - resilient insert within pipe clamp
- SH - spring hanger incorporating noise stop pad (static deflection 15 mm)
- PH - hanger incorporating low deflection resilient pad

11.7.2.10.11 Sewer and Sanitary Pipework

- Sewer and sanitary pipework shall not be fixed to ceilings or walls of noise sensitive spaces. Where this cannot be avoided the pipework shall not be rigidly fixed to ceilings or walls of noise sensitive spaces. At a minimum the fixing shall be a resilient insert within the pipe clamp.

11.7.2.10.12 Storm Water Down Pipes

- Storm water down pipes shall not be fixed to ceilings or walls of noise critical spaces. Where this cannot be avoided the pipework shall not be rigidly fixed to ceilings or walls of noise critical spaces. At a minimum the fixing shall be a resilient insert within the pipe clamp.

11.7.2.10.13 Vibration Standards for Fans, Pumps and Chiller Impellers

- Rotating impellers of fans, pumps, chillers, etc. shall be balanced to standards not inferior to the balance quality grades of ISO 1940 Part 1 or to the corresponding residual eccentricities. The criteria shall apply to finished impeller and shaft assemblies at delivery.
- Where the balancing quality grades are not indicated they shall be to the following minimum standards:
- Where the product (impeller mass in kg x operating speed in Hz) is less than 250; grade G6.3.

- Where the product (impeller mass in kg x operating speed in Hz) is greater than 250; grade G2.5.
- Impellers operating below 10 Hz shall be balanced as if they operated at 10 Hz.
- Impellers on equipment located in occupied areas, on fan convectors, packaged ventilation extract units and warm air heaters with motor power inputs more than 100 W or canned rotor pumps or similar; grade G2.5.
- Impellers of multi-speed or variable speed machines shall be balanced to the quality grade determined by their highest operating speed.
- Vibration caused by fluid dynamic effects of any kind shall not be greater than the equivalent permission vibration due to an impeller rotating at the frequency of the vibration.

12 Security Services

12.1 Security principles

The security management report for Chau Chak Wing Museum (CCWM) has been developed through several underlying security principles which are discussed below. These underlying principles provide a holistic approach to mitigating security risk for the museum. These security principles will be applied to the treatment measures outlined in the following sections of the security management report.

12.1.1 Defence in depth

To effectively design a security system, security measures should be layered to provide a succession of concentric barriers around an asset as seen in Figure 44 below. This design principle underlies the security advice provided to the CCWM. Ideally, each layer in a security strategy will require an adversary to conduct a separate and distinct act from the last, increasing the complexity of defeating the overall strategy. Such an approach increases uncertainty for would-be adversaries, increases their preparation and skill requirements, and increases the probability that any attempted act will be unsuccessful.

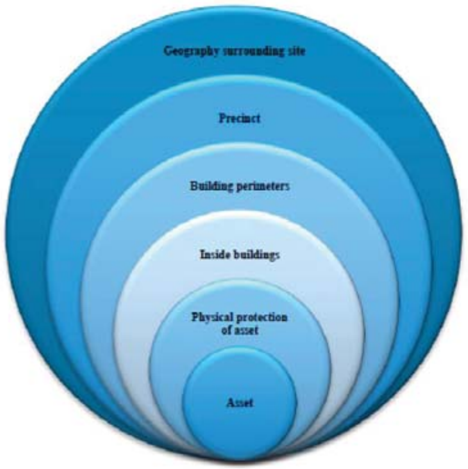


Figure 44 Defence in Depth

Effective defence in depth design will increase the time it takes for an adversary to reach an asset, while increasing the probability that they will be detected at the earliest possible point of misconduct. This detection will allow a suitable response to intervene before the adversary has achieved their goal; whether vandalism, theft, assault or other actions of security concern.

12.1.2 Deter, detect, delay, respond

Deter, detect, delay, and respond (D^3R) are the core components of a security protection strategy. They are embedded in the security advice provided to the CCWM. Ideally, each layer of protection within a defence in depth approach to security would have some form of deterrence, detection, delay, and response capability, however this is not always possible to achieve.

12.1.2.1 Deterrence

The purpose of the deterrence is to incorporate a variety of security measures that can be used to reduce the likelihood of opportunistic crime from occurring. Deterrence is achieved by increasing the perceived risk of detection or effort required to commit a crime.

Security methods such as signage, adequate lighting levels, CCTV coverage, and Crime Prevention through Environmental Design (CPTED) can deter opportunistic crime from occurring.

12.1.2.2 Detection

In order to minimise the loss or damage of assets, it is important to be able to detect unauthorised access into a protected area.

The security protection system should accurately detect an offender at the earliest possible point in order to provide the appropriate response. The earlier the positive detection of an adversary, the less likely offenders will be able to reach the desired asset or achieve their goal before being apprehended.

The detection function of the D^3R security principle can be achieved by installing and using passive infrared (PIR) volumetric detectors in nominated rooms/locations, installing recessed magnetic reed switches, and installing and monitored CCTV. Ensuring the site has appropriate illumination and has clear sight lines and natural surveillance can also significantly improve the ability to provide the detection function.

12.1.2.3 Delay

When unauthorised access to a restricted space has occurred, it is important to delay the progress of the intruder to prevent and minimise the loss or damage of assets. This delay can be achieved through a series of barriers such as fences, locks, safes, doors, windows and walls. Ideally the length of delay should be greater than the time for a response force to arrive, in order to apprehend the offenders before they reach the asset or leave the facility after completing their objective.

Achieving effective delay in a publicly accessible space is difficult to effectively achieve.

12.1.2.4 Respond

A timely and appropriate response is required at the CCWM by in-house, contract security or local Police, depending on the nature of the event that needs responding to. Response forces should be suitable to the security event occurring.

12.1.3 Crime prevention through environmental design

CPTED is a contemporary design practice that aims to design out the opportunity for certain types of crime to occur in a particular location. Further, CPTED is the process of designing the built environment to passively deter opportunistic crime using a combination of three elements: natural access control, natural surveillance, and territoriality (Figure 45 Crime Prevention through Environmental Design (CPTED)

Figure 45 Crime Prevention through Environmental Design (CPTED)

CPTED does not rely solely on the implementation of physical barriers as part of an overarching Defence in Depth approach, but can also include psychological influences (soft solutions) such as lighting, music, ground coverings etc. The aim is to deter opportunistic crime at and around the museum. A formal CPTED review and analysis has been undertaken for CCWM (refer to the CPTED Report).

12.2 Security zoning

Security zoning is the process of delineating space within a precinct or building; identifying areas of public, staff or restricted access, and providing appropriate security controls to restrict movement between these zones to legitimate users. In cultural and arts precincts and buildings, the naturally open and inviting space requires careful control to restrict the movement of the general public to nominated areas without imposing an aggressive security presence. To effectively achieve security control in such a way, careful consideration of the space, its natural barriers, and human behaviour is required.

12.2.1 Public areas

Public areas are considered to be any area that can be freely accessed by the general public without special privilege. Such areas are considered low security and uncontrolled from a security perspective, and must be carefully monitored by museum staff.

Buildings such as the CCWM have significant areas of publically accessible space. In context, these public spaces are vital for the activation of the building, and should be as welcoming and inviting as possible. Public spaces in and around the museum include:

- Exterior spaces such as the café terrace and the courtyard;
- Lobby, reception and foyers;
- Public lifts;
- Cafe and shop;
- Gallery spaces;
- Study and education areas;
- Auditoriums;
- Public toilets; and
- Any other generally accessible areas without special access privileges.

Public spaces should be protected in architecturally sensitive ways, drawing from CPTED principles in the first instance, and minimising the use of overt physical security controls. Surveillance of public spaces alongside efficient emergency or security response is vital for effective protection.

Study areas within the museum that may be accessible after official gallery opening hours but may need to be partitioned and access controlled from the internal gallery spaces. If access is provided to the general public to use specialist facilities such as the study rooms, segregation of these users from the broader gallery spaces is vital to maintaining an appropriate security perimeter.

12.2.2 Staff areas

Staff areas are those spaces considered restricted to museum staff (including café staff), third party contract staff, and other similar people. Staff areas must be clearly segregated from public space, and restricted to authorised users only. Staff areas are considered controlled from a security perspective, and would generally require an electronic access control credential or mechanical key to gain entry. Note that café staff and third party contractors would be controlled separately to museum staff via EACS access privileges.

Staff areas at the CCWM include:

- Loading docks;
- Service lifts;
- Storage rooms;
- Maintenance and equipment storage spaces;
- Back of house areas and kitchenette storage; and
- Staff and board meeting rooms.

Entry into these back of house areas should be monitored and controlled. CCTV surveillance is not required in all areas, but may be required at entry/egress points. Such areas should be functional and easily navigable, however security controls will place some restriction of free movement to increase the difficulty of illegitimate users accessing the space.

12.2.3 Restricted areas

Restricted areas are considered higher security areas (including storage areas that hold high value goods) that are only accessible to appropriate museum staff members or pre-authorised service staff. Such areas should be controlled and monitored by CCTV, electronic access control and intruder alarm systems, alongside physical hardening of structure and doors as required.

Such areas include:

- Communications and server rooms;
- Conservation rooms;
- Plant rooms; and
- High value goods, artwork, equipment or physical assets storage.

Restricted areas should be protected on a ‘need to go’ basis, and staff should have a clear reason for accessing these spaces. At no time should the general public have access to these areas.

12.2.4 Secure lines

Secure line diagrams provide a visual overview of the proposed segregation of space through the Museum. Each floor has been separated into the public, staff, and restricted areas articulated in the previous section. Typically at the interface between these security levels, a form of barrier with increased security measures (such as a card reader) would be provided.

Secure lines are illustrated below (Figure 46 - Figure 51)

Figure 46 Secure Lines – Lower Level 2

Figure 47 Secure Lines – Lower Level 1

Figure 48 Secure Lines - Lower Ground Level

Figure 49 Secure Lines – Ground Level

Figure 50 Secure Lines – Upper Level

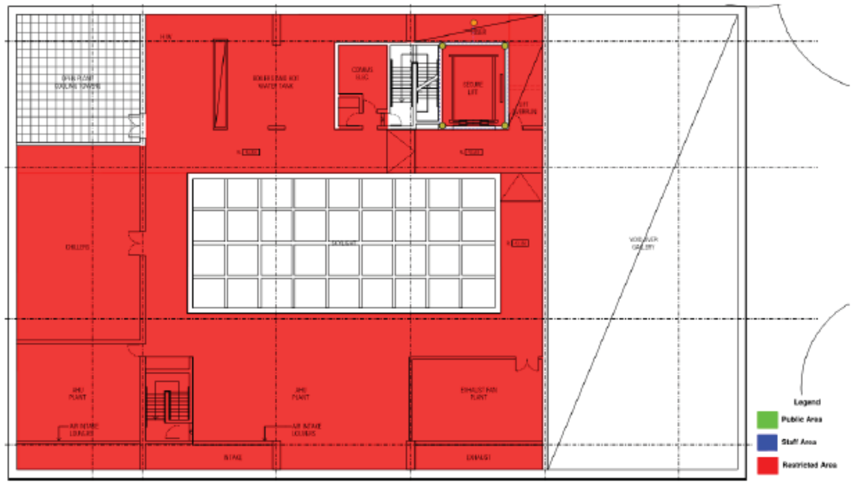


Figure 51 Secure Lines - Plant Level

12.3 Protective security strategy

The protective security strategy aims to increase the risk to potential offenders by improving passive security such as natural surveillance (making people more observable), while hardening selected areas with robust physical security controls. This combination will deter opportunistic offenders, and increase the difficulty for individuals who have targeted the museum for specific crimes (such as theft).

The protective security strategy aims to reduce the risk of a foreseeable loss, as well as protect the building, staff, and other assets such as information from harm.

The protective security strategy accounts for the University of Sydney (USYD) Campus Infrastructure and Services (CIS) Security Services Standard.

12.3.1 Signage

Security signage is an important component of a passive security strategy as it provides a deterrent to opportunistic criminals. Signage should be prominently displayed throughout the museum, particularly along heavily trafficable areas and main entrances. Signage should outline the use of CCTV, and provide emergency service and security telephone numbers.

Signage should include:

- Security and emergency telephone phone numbers;
- CCTV in operation; and
- Security officers patrol this area.

Figure 52 Example CCTV in operation sign

Further, signage should not be placed or mounted in such a way as to provide a climbing aid.

12.3.2 Security lighting

Security lighting acts as a deterrent to opportunistic crime as it increases the visibility of potential offenders to pedestrian and vehicle traffic. Lighting is vital in aiding electronic surveillance systems to capture high quality imagery.

Security lighting to the external perimeter of the CCWM should, at minimum:

- Comply with the Security Lighting standard outlined in the USYD CIS Security Services Standard (5.3). The Australian standard AS1158 P category 2 (public pathways and cycle-ways) and 7 (public activity areas);
- Produce a white light to improve the accuracy of CCTV image capture;
- Provide a Uniformity Ratio (i.e. the ratio of maximum illuminance to average illuminance) not exceeding 4:1, or a Minimum Longitudinal Uniformity not less than 0.25;
- Be located in easily maintainable locations;
- Be of vandal resistant construction;
- Minimise glare on signage and way finding;
- Automatically turn on and off to suit surrounding conditions;
- Provide deterrence against anti-social behaviours and crimes conducted at night;
- Increase the perception of safety for individuals along designated routes; and

12.3.3 12.3.3 Vegetation

It is important to keep vegetation around the Museum well maintained and to a low height where reasonably practical in order to reduce places for concealment of activities, places for potential offenders to hide, and to enhance the natural and electronic surveillance of the area:

- Tree types should be selected and maintained with the view of maximising clear sightlines (foliage lower than 500mm and higher than 2000mm);
- Trees/vegetation should be regularly and practicably maintained to ensure the security aspects of the surrounding area are not compromised as the vegetation matures. Specifically, clear sightlines should be maintained throughout the life cycle of the vegetation.
- By maintaining vegetation around sites, public perception of the space being cared for and safe will increase. By increasing this positive perception, legitimate users of the space will be more likely to engage and take ownership, reducing the opportunity for crime to occur.

12.3.4 Vandalism and graffiti

Resistance against vandalism should be considered as a design factor in the chosen construction material and methodology, particularly for outdoor, public furniture and fixings. Construction should be of a robust standard, whereby joints, screws and other fixings are hardened and concealed where possible.

Public tables and seating’s should be designed to resist scratching and shattering, and porous construction materials should be fully sealed and easily cleanable to remove graffiti.

12.3.5 Joinery and furniture

In consideration of the concern for the safety of front of house staff from physical assault or harm, measures should be taken to increase the difficulty of achieving such acts. It is recommended that the front of house reception desk be designed to a height and depth that increases the difficulty of scaling for would-be offenders, and increases the reach required to grab objects or attack staff members.

12.3.6 Mechanical locking systems

Mechanical locking systems should be used throughout the museum for storage areas, equipment rooms, or other back of house areas. The locking system should be:

- Of a high security type;
- Security Construction and Equipment Committee (SCEC) endorsed with restricted key profiles where relevant (to provide pick, bump and drill resistance); and
- Installed as part of the University’s current Bi-lock system.

Locksets installed in doors should be protected with strike shields on the unsecure side of all outward opening perimeter doors, to limit the possibility of a forced door attack. Furthermore, collection storage rooms within the museum must not be on the building master or grand master key; rather, they should be on a separate locking system within the University’s Bi-lock system.

Figure 53 Example Bi-Lock

12.3.7 Doors

It is recommended that all main entrance doors to the building should be:

- Externally fitted in a suitable location with an intercom that has an integrated emergency button, hard wired into the University's chosen system;
- Lit after hours as per Section 12.3.2;
- Monitored by a dedicated CCTV camera; and

Furthermore, all exterior doors (including fire doors) should have:

- Robust solid core construction, steel or timber (where relevant);
- Vandal resistant materials (where the external door is either sliding or glazed). This should be achieved by an anti-shatter film and a reinforced door frame.

Any doors that are designated entry/exit doors through the external perimeter, or that lead internally to high security zones should be:

- Fully access controlled to restrict access to legitimate users only (i.e. staff); and
- Solid core doors in steel rebated frames, with walls that are solid and of a non-penetrable construction. Door locking mechanisms should have electric mortise locks, door closers and a lockable drop bolt on the fixed leaf (where relevant).

12.3.8 Windows

To provide holistic perimeter protection to the CCWM, external glazing should be protected to a similar level as entranceways throughout the museum. It is recommended that external windows are tempered and/or laminated with a Polyvinyl Butyral (PVB) interlayer to improve intruder resistance.

The provision of anti-vandal or anti-shatter film should also be provided as a protection measure, particularly for full height glazing around the perimeter.

Windows should further be protected by reed switches or magnetic security switches to detect attempted intrusion.

12.3.9 Vehicle management

Vehicle access to the CCWM museum is largely restricted to the loading dock and the drop off zone to the buildings east. Importantly, there is little opportunity for vehicles to gain significant speed around the building perimeter, with several landscaping features posing barriers to any potential hostile vehicle.

In light of this, to ensure a concentric barrier around the CCWM, and using landscaping features (i.e. gradients and trees), further vehicle management measures should be considered for implementation, particularly at the entry court area on the ground level of the museum.

To provide this concentric barrier, non-rated bollards or architectural equivalents are recommended. For example, planter boxes, parking bollards, hedges, water features, or public art.

Figure 54 Example vehicle management bollards

Figure 55 Example vehicle management Planters

12.3.9.1 Roller shutters

There is a vehicular entry point into the CCWM on Lower Level 2 (LL2), leading to the loading dock area. To prevent unauthorised vehicular and pedestrian access through this entry point, a barrier is recommended to enforce a security checkpoint before vehicular entry is granted to the area. Figure 55 Proposed illustrates the proposed positioning of the roller shutter.

Such measures should include a roller shutter that is controlled by the CCWM reception desk, for vehicular control during delivery times. The shutter should:

- Be a light weight solid shutter;
- Be automated (including an automatic exit loop) and motorised; and
- Be powder coated a colour to suit architectural designs.

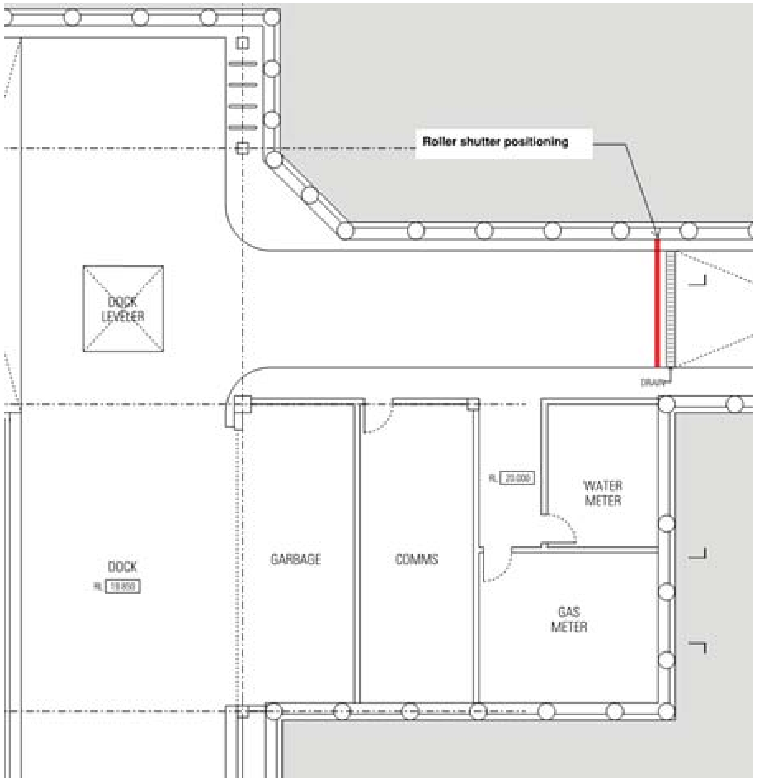


Figure 56 Proposed roller shutter positioning

Figure 57 Example light weight roller shutter

An anti-lift device should be installed on the roller shutters as an additional security protection measure. Anti-lift devices provide protection against individuals attempting to manually lift the shutter when in a closed state. Without an anti-lift device, shutters are susceptible to individuals forcing the shutter open by hand or with tools.

Interfacing with the EACS will provide security operations staff with the ability to control and manage the loading docks and precinct security system from a central location (or locations), while receiving feedback as to the status of the system.

Safety considerations

There are several occupational health and safety considerations for the installation of security roller shutters. This includes the use of appropriate signage to identify potential crush or pinch points, and warnings about tailgating and other mistreatments.

It is recommended that photoelectric (PE) beams (proximity sensors) are installed with the shutter, which, when broken by an object, keeps the shutter open. It is recommended that the PE be provided with a covering shroud to reduce environmental factors affecting the PE beam's operation.

12.3.10 Communications rooms and server rooms

Communications and server rooms within the CCWM should be protected from unauthorised access. Due to the critical nature of such areas, clear audit access trails should be recorded for post incident investigation. Server rooms may house a variety of equipment, including security servers, audio and visual equipment, and IT infrastructure.

It is recommended that communication and server rooms be protected by:

- Electronic access control (read in);
- SCEC endorsed mechanical locking systems;
- Strike shields on outward opening doors;
- Electric strike or mortise locks; and
- Physically robust doors, walls, ceiling and floors.

12.4 Electronic security strategy

The electronic security strategy for CCWM has been developed to increase the difficulty for potential offenders, while providing a sophisticated personnel management system for the museum.

Electronic security systems provide substantial information for post-incident investigation and review, as well as provide real-time information for security operators and museum staff to monitor and respond to as required.

12.4.1 Security management system

An integrated security management system (SMS) is in place for the University of Sydney, and will be utilised in the CCWM. The SMS should govern the electronic access control, intruder and duress alarm, intercom, and CCTV systems throughout the precinct.

Figure 57 indicates the proposed network arrangement of electronic security systems and devices for the CCWM.

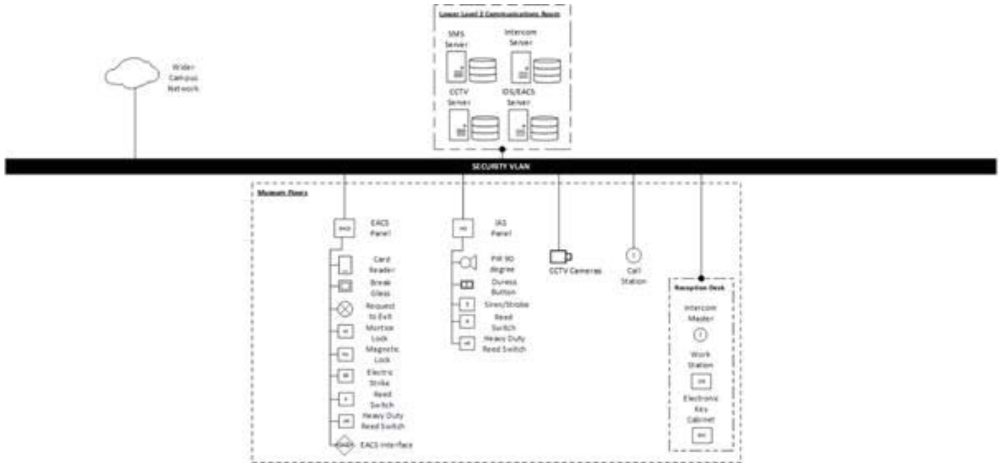


Figure 58 Concept network diagram

SMSs reduce uncertainty and complexity for staff during electronic security system operation. Staff interact with the system through one graphical user interface, operating intrusion detection, CCTV, and electronic access control functionality from one location. This arrangement makes training and operation for staff simple and straightforward, and provides more efficient operation in day to day and emergency activities.

It is recommended that an operator workstation with access to the Museums access control, CCTV, and intercom systems is provided to the front reception desk.

12.4.1.1 Security network

The security network should as a minimum:

- Be connected to the University Gallagher Command Centre head end via the University’s IP Network;
- Operate within a VLAN;
- Be firewalled from the internet;
- Provide device access control measures through IEEE 802.1X or MAC address verification.

All security devices, including operator workstations, CCTV cameras, security servers, intercoms and access control equipment should communicate through this security network.

12.4.2 Closed circuit television

A complete digital IP CCTV system is used throughout the University of Sydney, and as such should be used throughout the CCWM. All CCTV equipment throughout the museum should be integrated into Gallagher Command Centre Version 7. The USYD CCTV system consists of Avigilon cameras, therefore it is recommended that this same standard be used for the CCWM.

The CCTV system should be monitored, controlled and administered from the security control room and operator workstations (i.e. the reception desk).

The CCTV System should perform a combination of the following core functions, as required:

- General display of video for ad-hoc security monitoring;
- Control room display for dedicated CCTV operations;
- Simultaneous playback of one or more IP camera video streams; and
- Recording of the IP camera video streams to the appropriate storage location.

CCTV is a useful tool for post-incident investigation and review. CCTV does not stop the incidence of crime, but does provide increased situational awareness, and an improved capacity to respond to security incidents appropriately when they occur.

12.4.2.1 Cameras and camera coverage

It is recommended that CCTV cameras be installed throughout the museum to provide coverage of critical areas. CCTV cameras should be a low profile dome type to reduce visual impact on the buildings architecture.

Figure 59 Example internal dome camera

CCTV cameras should cover the following areas:

- Museum entry/exit points;
- Cafe;
- Lifts;
- Cash handling areas; and
- High value item store entries/exits.

External cameras should at minimum be:

- Fixed to buildings, not poles;
- IP65 and IK10 rated;
- Fixed field of view (no Pan-Tilt-Zoom cameras); and
- Mounted above 4 m. If this is not possible they must have vandal proof housings (all housings should be fitted with heaters and blowers as required);

12.4.2.2 Recording and storage

CCTV footage should be kept to an evidentiary standard, with inbuilt watermark, time and date stamp, as well as clear identification of which camera footage was recorded from. This footage should be able to be exported and provided to investigators as required.

CCTV image recordings should be stored for 28 days as a minimum.

12.4.3 Electronic access control

A centralised electronic access control system (EACS) is recommended for the CCWM. A centrally monitored and controlled system allows for easier maintenance of cardholder records and access rights, alongside operator certainty of ongoing events within the museum. A centralised system increases operating flexibility and the capacity for security operators to make changes as needed to changing circumstances.

It is recommended that the following elements and functionality are provided for the EACS:

- Configurable access zones and sub-zones;
- Anti-pass back controls;
- Collective controls (groupings of users, zones, access rights etc.);
- Configurable access groups comprising users and their access rights to access zones, sub-access zones and individual portals, as well as date / time control;
- Configurable user information;
- Independent intelligent door controllers;
- Manual portal control;
- Interfaces with the CCTV system, fire system, lift system, and other motorised portals;
- Multi technology access cards and compatible readers; and

- Electric locking and control devices.

12.4.3.1 System architecture

The electronic access control system should be configured with several multi-door controllers, each communicating back to the University's central access control server (Figure 60). This architecture allows for simpler maintenance of the system, and less component parts to securely store.

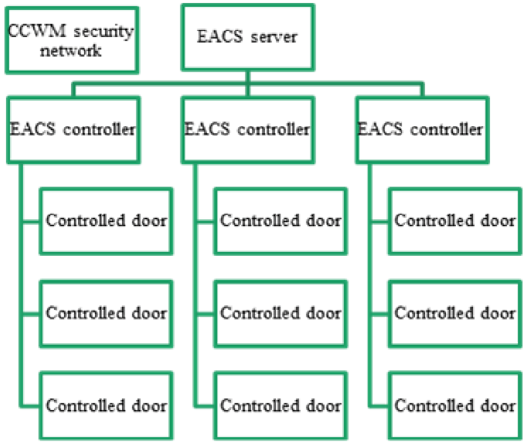


Figure 60 Example EACS system architecture

12.4.3.2 Access credentials and card readers

It is recommended that card readers be multi-technology (125KHz proximity card, 13.56MHz smart card, and Bluetooth) readers. Multi-technology readers allow for flexibility in card administration, particularly when dealing with legacy card systems.

Authorised staff should be provided with their own access card, programed to provide them with access to nominated access controlled portals. Staff will not automatically be provided with access to all access controlled portals within the CCWM, but only those that they reasonably require access to.

Card readers throughout the museum should be Gallagher T11 multi-technology black readers (Figure 61).

Figure 61 Example Gallagher T11 card reader

Furthermore, the Gallagher T20 terminal card and PIN reader (Figure 62) is recommended for assisting with the arming and disarming of security zones within the museum.

Figure 62 Example Gallagher T20 card reader

Card readers should be mounted adjacent to the associated portal, on the continuous accessible path of travel, and in clear line of sight of people approaching the portal.

It is recommended that access credentials used throughout the CCWM should be to the USYD standard, i.e. Mifare DESFire EV1 (Plus or Classic), or 125 kHz proximity cards. Alternatively, Bluetooth mobile credentials (or a mixture of these) can be used.

12.4.3.3 Electric locks

Electric locks throughout CCWM should typically be provided in the following situations:

1. Electric Mortise Locks; for timber single leaf doors, double rebated doors, or double doors with the inactive leaf not electrically controlled. Door leaves must be hinged on the edge (not centrally pivoting, enabling the lock cable to pass cleanly from the frame to the leaf).
2. Electric Strikes; for fire stair doors, or frameless glass doors, aluminium framed doors or centrally pivoting doors.
3. Electromagnetic Locks; for double doors where both leaves need to be electrically controlled.
4. Electric drop bolts are not recommended on any door type.

All electric locking solutions provided for CCWM should be fail-safe in operation, meaning the associated portal will unlock on loss of power to the lock.

12.4.3.4 Other equipment

Request to exit (REX) buttons and emergency break glass buttons should be provided to facilitate general or emergency egress through electronic access controlled portals.

REX and emergency break glass buttons should be mounted adjacent to the associated portal, on the continuous accessible path of travel and in clear line of sight of people approaching the portal.

REX and emergency break glass buttons should comply with and be mounted in accordance with AS 1428.1-2009 – Design for Access and Mobility.

Figure 63 Example break glass button and REX Button

12.4.4 Intruder alarms

Intruder alarm devices should be provided to monitor the integrity of nominated areas. Zones should be independently armed and disarmed as required. Such areas will include:

- Valuable item/collection, and equipment stores;
- Cash handling areas;
- Gallery spaces;
- Back of house areas outside of operating hours; and
- Commercial, office and study spaces outside of operating hours.

Intruder alarm devices should use the same security control panels as the electronic access control system.

The system should comply with AS 2201 – Intruder Alarm Systems.

Monitoring, control and administration of the Intruder Alarm and Duress devices should occur at the University security monitoring centre.

12.4.5 Duress

Duress alarms should be provided in nominated high risk locations such as cash handling areas, the front desk, and in accessible toilets.

Duress alarm system devices should consist of double push button style duress buttons that are either wall or under counter mounted (Figure 64).

Accessible toilets should be of single push or twist, wall mount design. Upon the activation of a duress device, a priority alarm will indicate the location of the alarm via a graphical display at the university security control room.

Figure 64 Example double push duress button

Duress alarms should be latching such that the alarm does not automatically reset until acknowledged and processed at the security control room.

The fixed duress alarm system should interface to the IP CCTV system to provide recording and automatic display of camera views of the area in which a duress alarm is initiated.

12.4.6 Electronic key control

Electronic key cabinets provide a secure storage and key management solution that can be controlled by the electronic access control system.

It is recommended that an electronic key management system be implemented at the CCWM to control and manage display case keys. This system should ensure a single orientation and positive key capture, with electronic access control to the cabinet. Furthermore, this system should be stored in a restricted location within the museum, such as the reception back of house area (bag store).

Electronic key control reduces the complexity of key management for precinct facility managers, improves the audit trail surrounding access to physical keys, and reduces opportunity for key theft and misplacement.

Further considerations for an electronic key system include:

- Tamper resistance;
- Solid and intruder resistant construction;
- Integration with SMS / EACS;
- Option for multiple authentication to sign out high security keys (e.g. two person sign out);
- Key alarms;
- Maximum key issue per user; and
- Electronic Audit Trail.

Figure 65 Example electronic key management system

12.4.7 Intercom system

An IP Intercom system should be provided to aid visitor and staff interaction between remote doors. Intercom systems provide surety in visitor recognition, and reduce the opportunity for trespass by allowing perimeter doors remain locked at all times. Intercom systems provided throughout the CCWM should interface with the security management system, CCTV system, and electronic access control system.

It is recommended that an intercom be provided to the Loading Dock entry, and Front Entry for afterhours use.

It is important that intercoms be installed and mounted in accordance with AS 1428 – Design for Access and Mobility.

The IP intercom system should operate using digital technology over an IP network, providing the following interactions when the Door Station Intercom push button is pressed:

- Clear, undistorted voice communication, free from background noise and external distortion regardless of environmental surrounding;
- Ability to automatically display the video from CCTV camera/s viewing at the Door Station Intercom on nominated Operator Workstations; and
- Ability to automatically display or highlight the portal associated with the Door Station Intercom when used so the operator can remotely unlock the portal by clicking a master intercom button.

The intercom system should have a high level interface with the access control system and the CCTV system.

12.5 Security operations

Security operations procedures included in this section outline a number of considerations for the museum operations team to consider. Examples included in this section are considered best practice.

12.5.1 Security awareness and training

Security awareness training is staff training that occurs on a regular basis through numerous avenues. For example, security awareness training could consist of an email campaign, security message posters, or formal presentations. Security awareness training is important to educate staff on their responsibilities and what to do when faced with a potential security incident. Further, security awareness training helps to build a security culture, which significantly reduces the possibility of insider risks.

12.5.2 Conservation, security and maintenance

To achieve a holistic and comprehensive security, conservation, and maintenance strategy within the museum, it is strongly recommended that these services are integrated as much as possible.

Examples of best practice in museum operation include providing basic security, maintenance, and conservation training to all staff involved in providing these services to the museum. In doing so, internal reporting, management, and response of and to incidents can be improved.

12.5.3 Security procedures

The security operations strategy should include comprehensive policy and procedures. Such procedures should include (but not be limited to):

- Suspicious package;
- Bomb threat;
- Terrorist attack;
- Active shooter;
- Duress procedure;
- Unusual activity reporting;
- Clear desk policy;
- Computer and email usage;
- Information classification;
- Internet usage;
- Password protection;
- Social media usage;
- Media policy;
- Workplace violence;
- Alcohol management and abuse;
- Employee screening;
- Cash handling;
- Radio communications;
- Theft & loss prevention;
- Security investigations;
- Deliveries / delivery management;
- Key management, including lost key and re-keying;
- Access control management, including lost card;
- Precinct emergency shutdown and evacuation;
- Security coordination with emergency services;
- Business continuity;
- Forged or fraudulent tickets, ID, or other identifying documentation;
- Trespass, graffiti, vandalism or other criminal action;
- Post incident evidence handling;
- Event and external event operations;
- VIP or special event functions, including secure escort of individuals; and
- Protests or demonstrations.

The above is not meant to be an exhaustive list, but provides some indication of required security and staff procedures.

12.6 Security management strategy

The security management strategy provides an overview of security considerations in managing the daily operations of the museum from a security perspective.

12.6.1 Loading docks

Loading docks are areas of security concern due to their interface with uncontrolled third parties such as delivery workers, and the secure access to back of house areas. This interface introduces a potential vulnerability to the overall security perimeter, and must be managed carefully.

The loading dock on Lower Level 2 (LL2) of the CCWM should be a controlled area, with deliveries and arrivals being monitored at all times. Due to the expected low level of vehicular activity in the dock per day, the following is recommended for loading dock ingress:

1. The loading dock roller shutter should be closed at all times, except for when access to the dock is granted.
2. Vehicles approaching the loading dock should request access via an intercom that is external to the dock. This intercom should be an IP Video Intercom that is linked to the museum's reception desk. The reception desk should have access to the following systems:
   - CCWM EACS;
   - 1CCWM SMS; and
   - CCWM CCTV.
3. The CCWM reception desk should have authority to authenticate incoming vehicles and deploy the shutter. This authentication can be achieved by visual inspection (of both the driver and the vehicle) via the associated CCTV camera.
4. Staff member to greet driver in the loading dock and oversee delivery/pickup.

Egress from the loading dock should be managed via an automated inductive loop. Vehicles arriving should, where possible, be pre-scheduled and expected by museum staff.

The current arrangement does not provide for absolute confirmation of individuals before access to the loading dock is granted. This is due to the lack of a dedicated security officer or dock master presence in the loading dock. Electronic security measures such as the IP video intercom and CCTV may be suitable solutions, alongside operational measures such as providing staff members to oversee delivery and pickup once a vehicle has been granted access to the basement.

12.6.2 Café

The café within the CCWM should be carefully managed due to its interface with third parties such as delivery workers and third party staff.

The café on the Lower Ground Level (LGL) of the CCWM should be a controlled area, with deliveries and staff being monitored by museum staff. The following strategy is recommended for LGL café:

1. The café's rear double door (opening on to the gallery space) should be opened at all times during gallery operating hours, and secured during non-operating hours (to eliminate access of third party staff to the rest of the building).
2. The café's front sliding door should be access controlled with card readers, to facilitate the electronically controlled access functionality. This function will become operational during non-operating hours of the galleries. The distribution of these access cards to third party café staff should only be granted upon the museums approval. Furthermore, these access cards should be limited to the café front entrance and exit, and no other areas within the building (unless approved by the museum).

In consideration of the CCWM's proposition to have a third party operate the LGL café, it is considered best practice to have a communication strategy in place for café management and museum management. This communication strategy should consider the following:

- All third party café hire vetting should be conducted by the café, but approved by the museum management. This should be communicated from the café management to the museum management; and
- Distribution of any access cards to third party café staff should only be deployed upon the museum management's approval to café management.

12.6.3 Storage areas

Storage areas within the CCWM present possible targets and should be secured appropriately. These areas can be split into general storage areas and collection storage areas, each holding their own security zoning classification. Both areas should be monitored by CCTV, and should be access controlled by an electronic access control credential.

12.6.3.1 General storage

General storage areas within the CCWM are those storage areas that are considered restricted to museum staff (including third party staff) and other similar people.

Areas within the CCWM that are classified as general (staff) storage areas include:

- Study/schools education storage;
- Café storage; and
- Reception back of house storage.

General storage areas should be a controlled areas. The following is recommended for general storage areas within the museum:

1. Areas are to be clearly segregated from public space, and restricted to authorised users only;
2. Should have a barrier to entry such as a lockable door;
3. General CCTV surveillance around entry/egress points; and
4. Such areas should be functional and easily navigable, however security controls will place some restriction of free movement to increase the difficulty of illegitimate users accessing the space.

12.6.3.2 Restricted storage areas

Restricted storage areas are considered high security areas that are only accessible to museum staff members. Areas within the CCWM that are classified as restricted storage areas include:

- Collection storage areas.

The following is recommended for restricted storage areas within the museum:

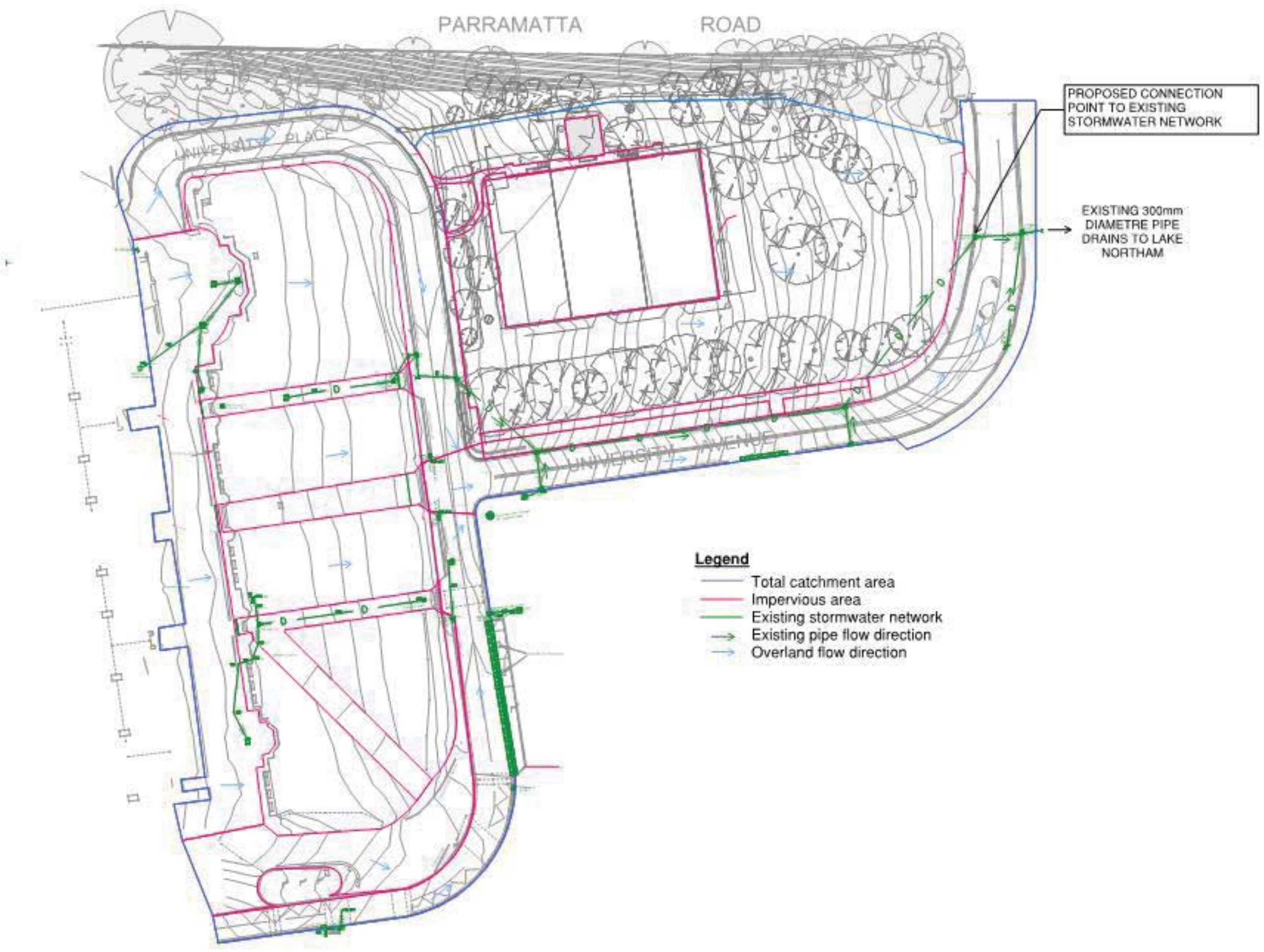
1. Such areas should be controlled and monitored by CCTV. CCTV in these areas should cover entry/exit points, as well as the internals of the area;
2. Electronic access control card readers should be implemented on all entry/exit doors of these areas. Access should only be granted on a need to go basis, and distribution of access credentials should only be authenticated by museum management; and
3. Intruder alarm systems should be implemented to all restricted storage areas.

The proposed strategy for restricted storage areas should be applied to all future determined areas that are of a similar nature and security classification.

Appendix A

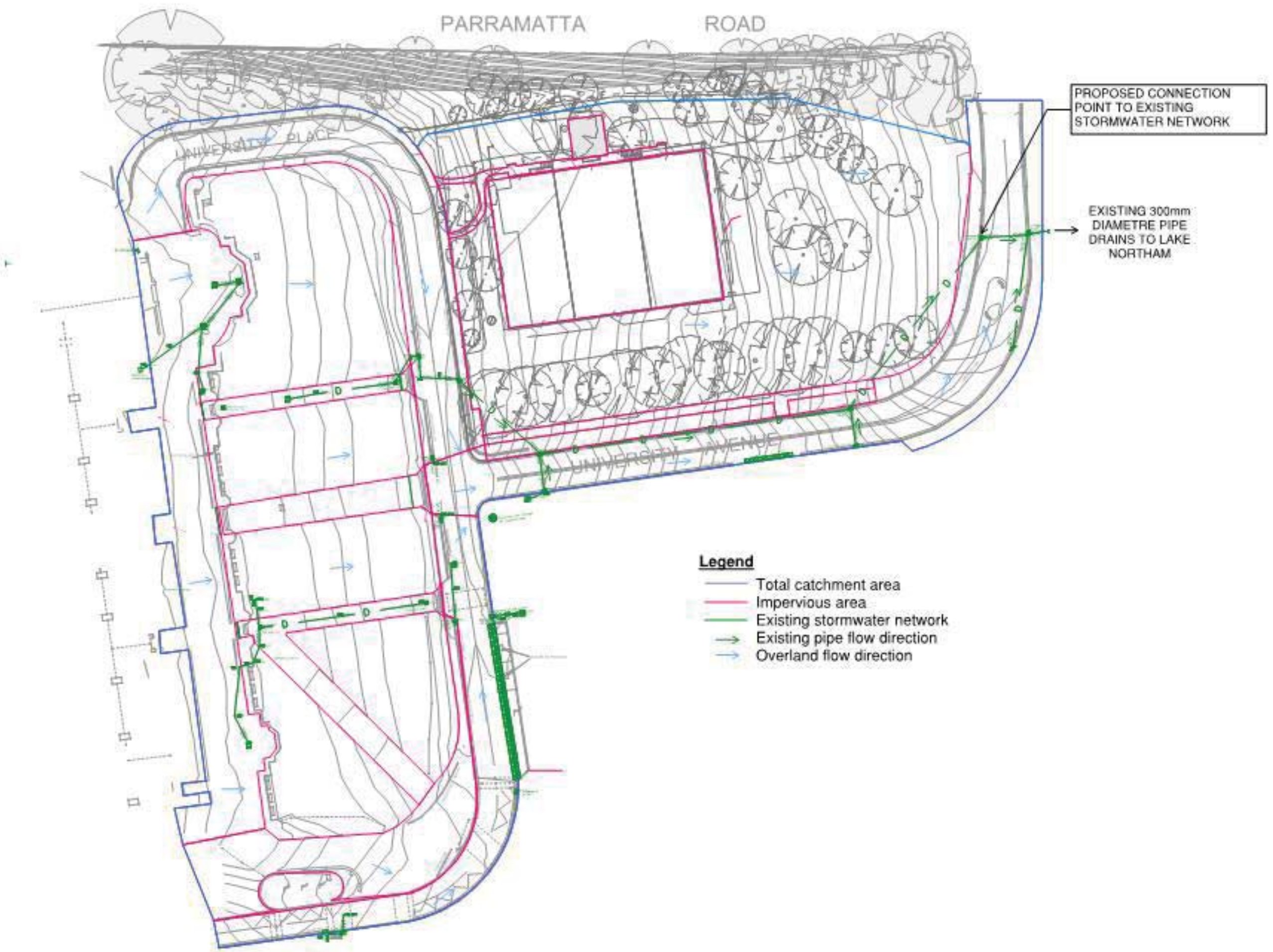
Civil Arrangements

A1 Catchment Map: Existing Stormwater Network

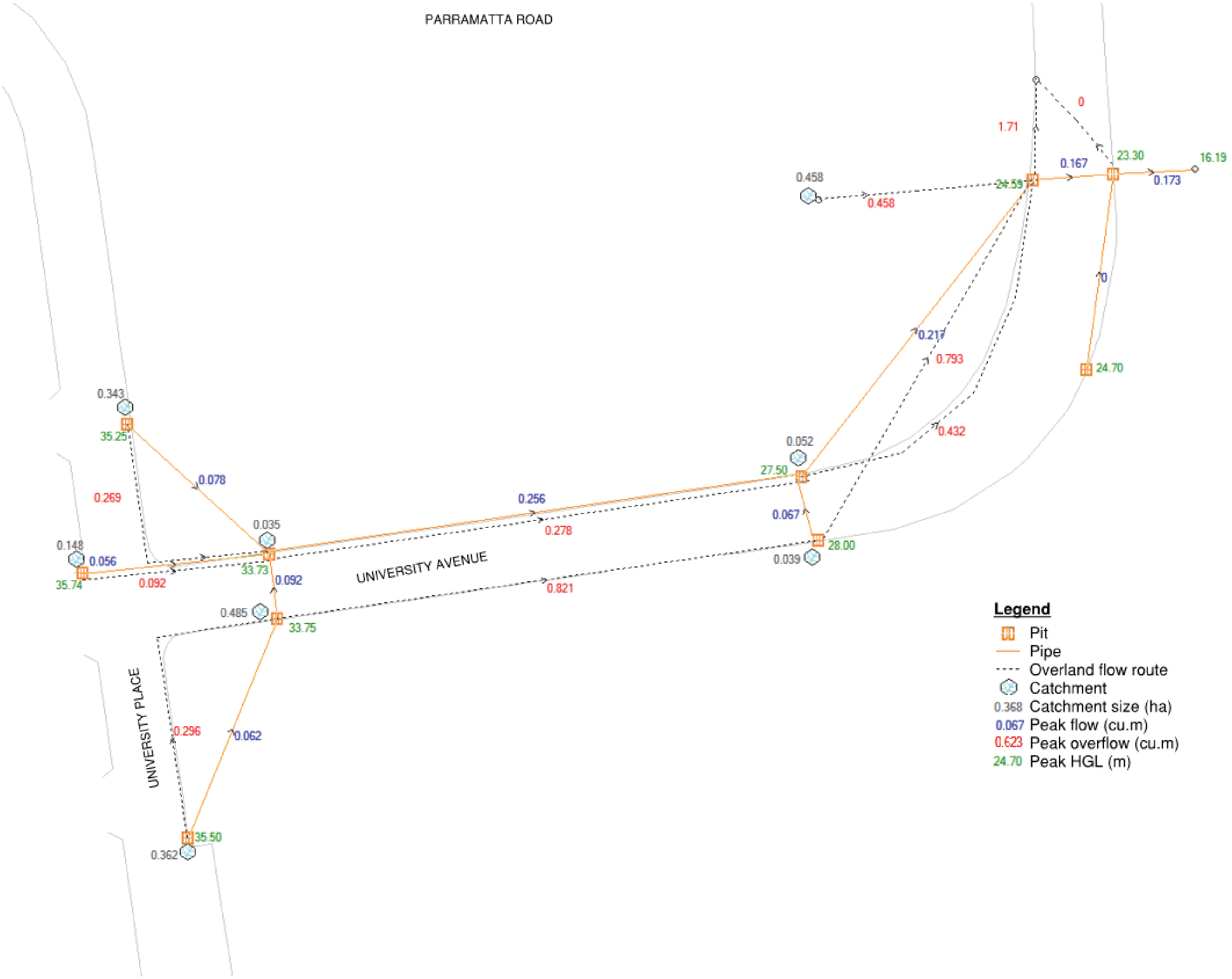


A2 Drains Results for Existing Stormwater Network

20 Year Storm Water Event

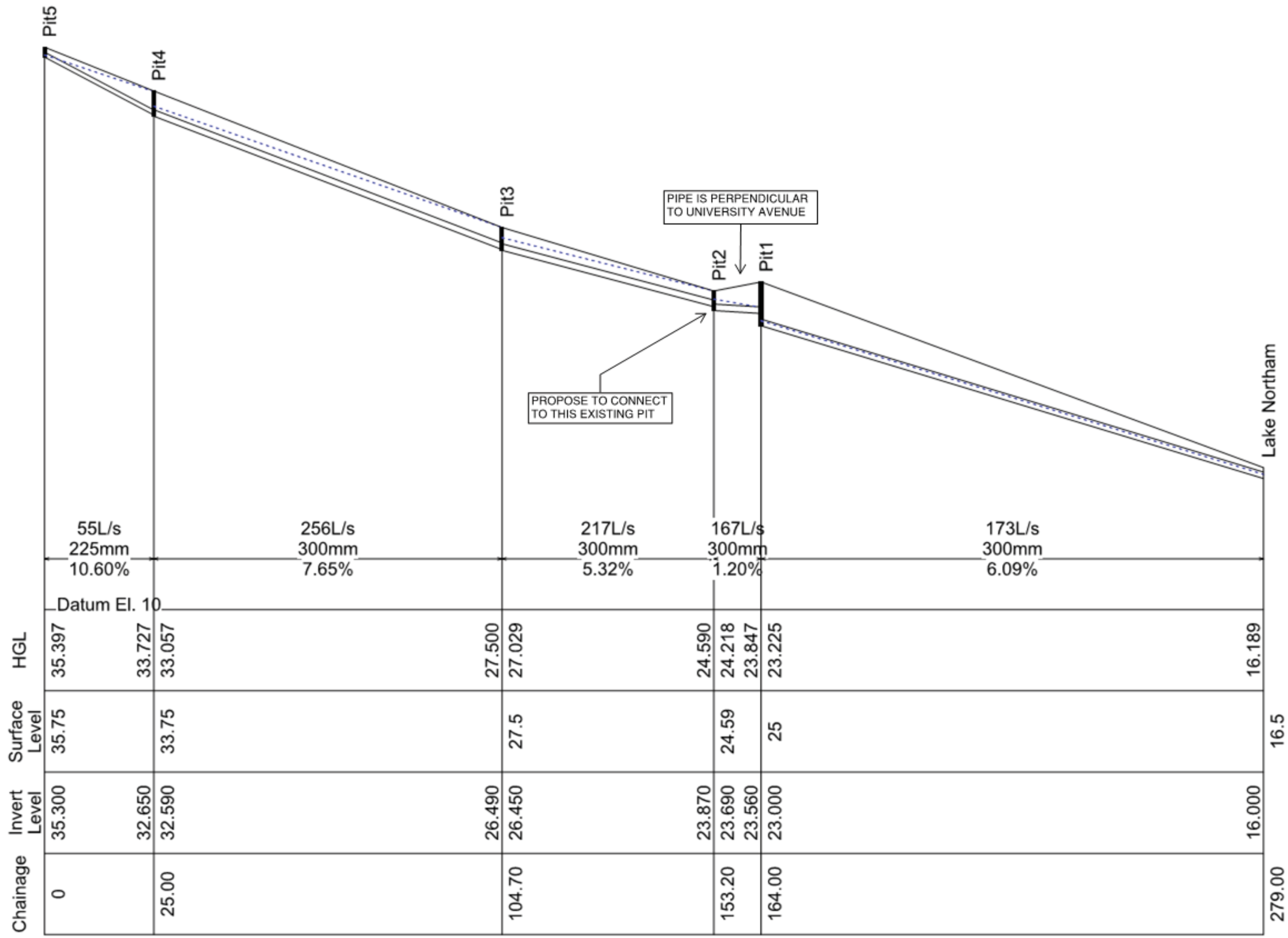


100 year storm water event

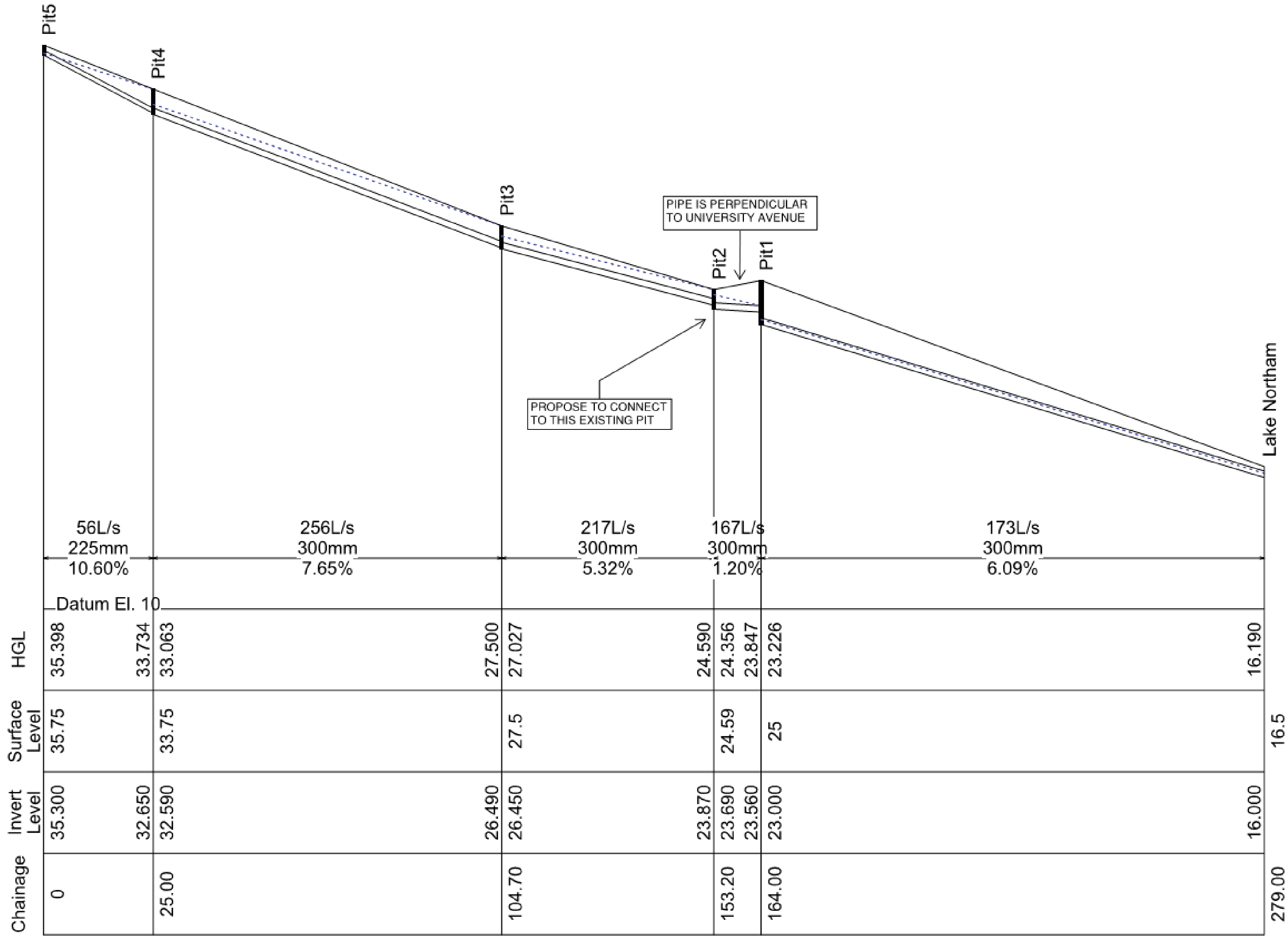


A3 Drainage long sections of existing stormwater network trunk line

29 Year Storm Water Event

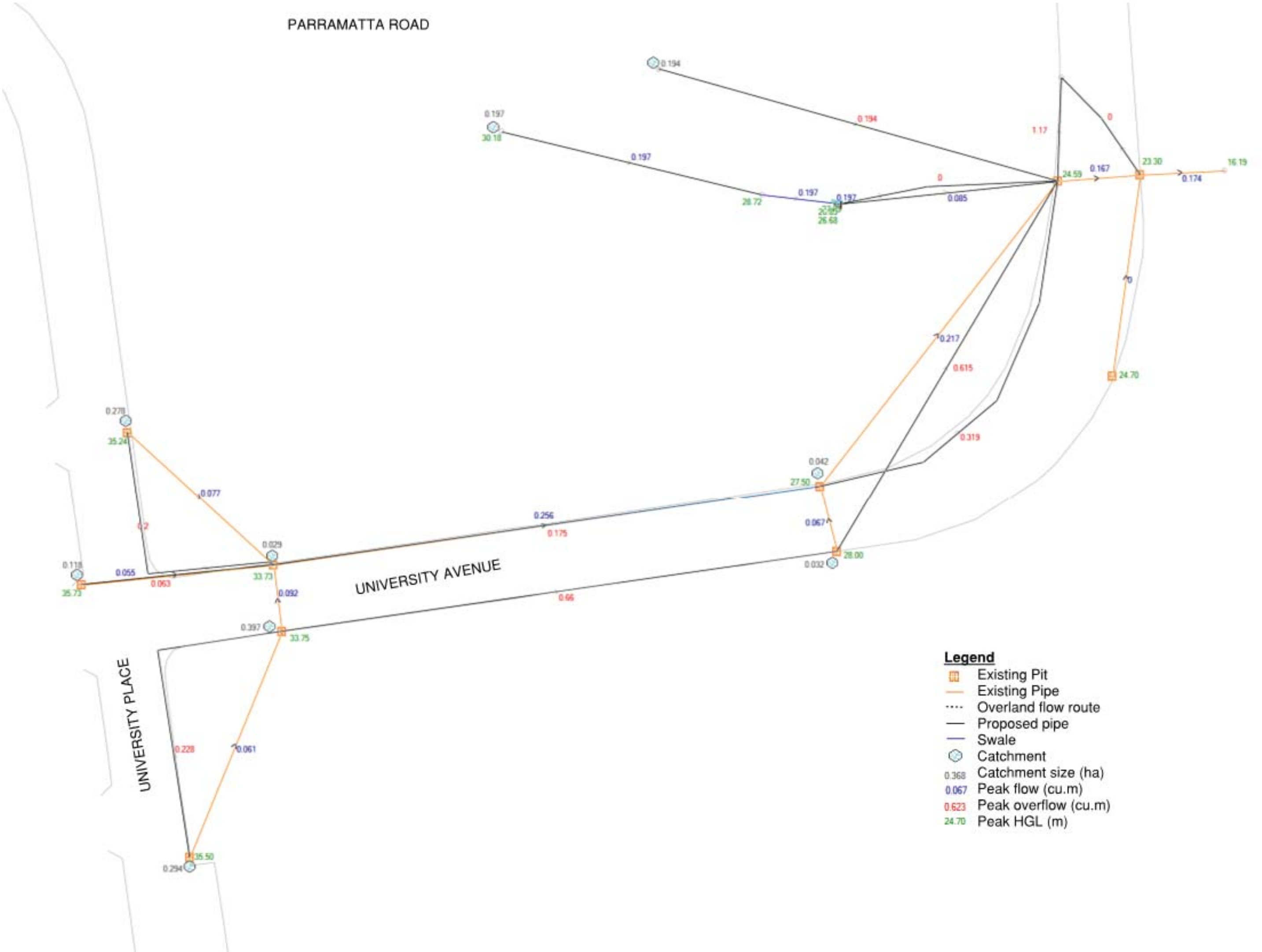


100 Year Stormwater Event

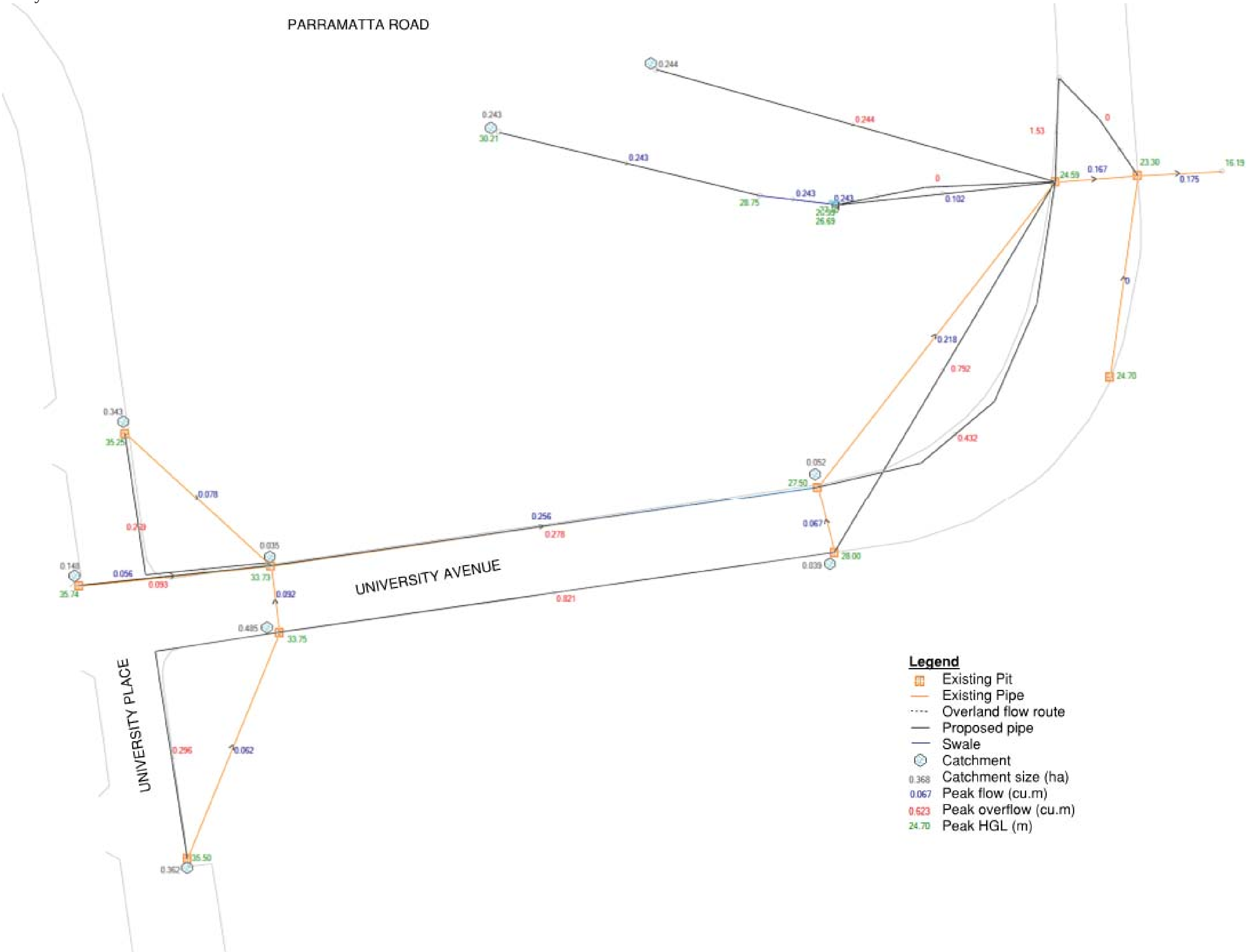


A4 Drains Results For Proposed Stormwater Network

20 year stormwater event

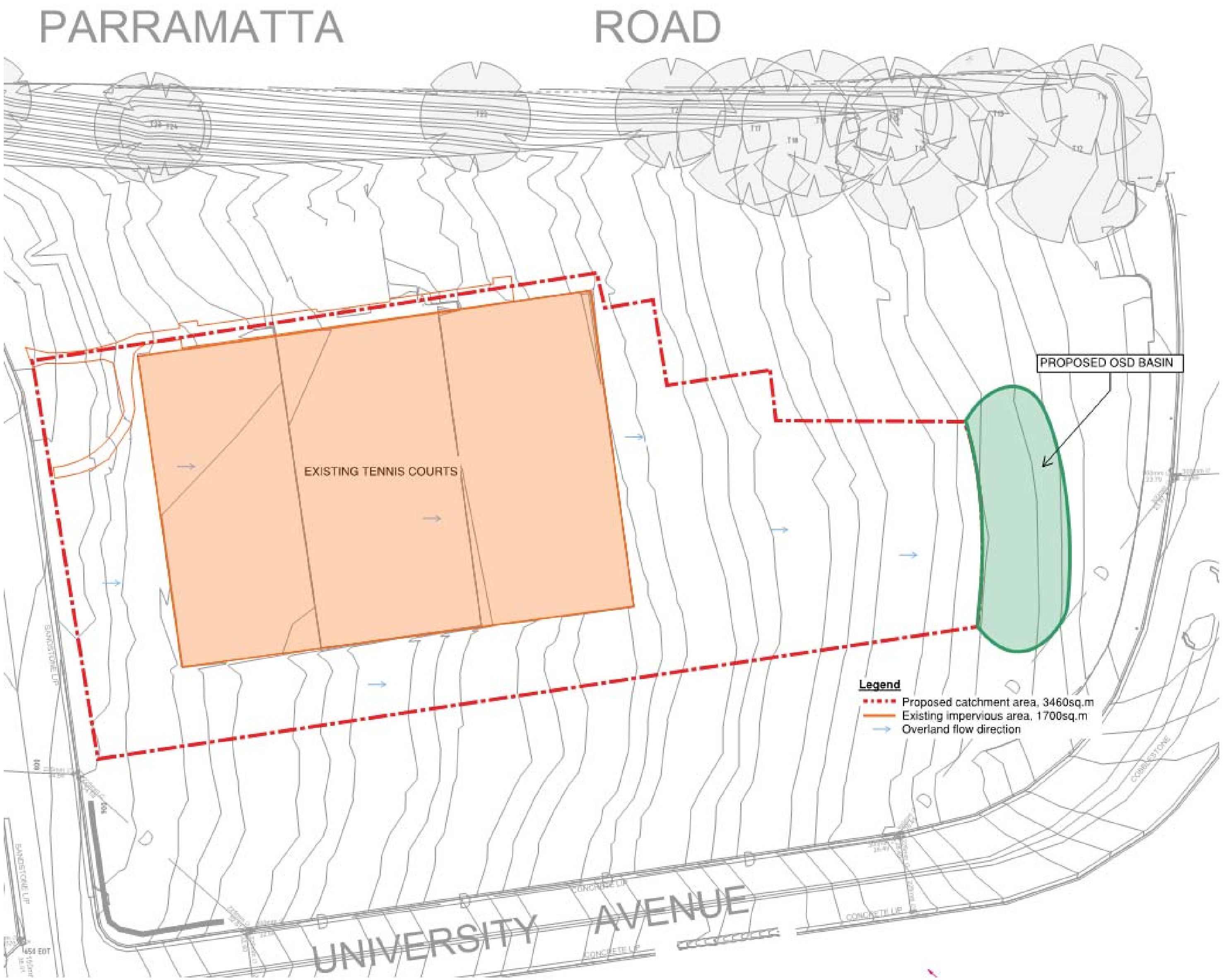


100 year stormwater event

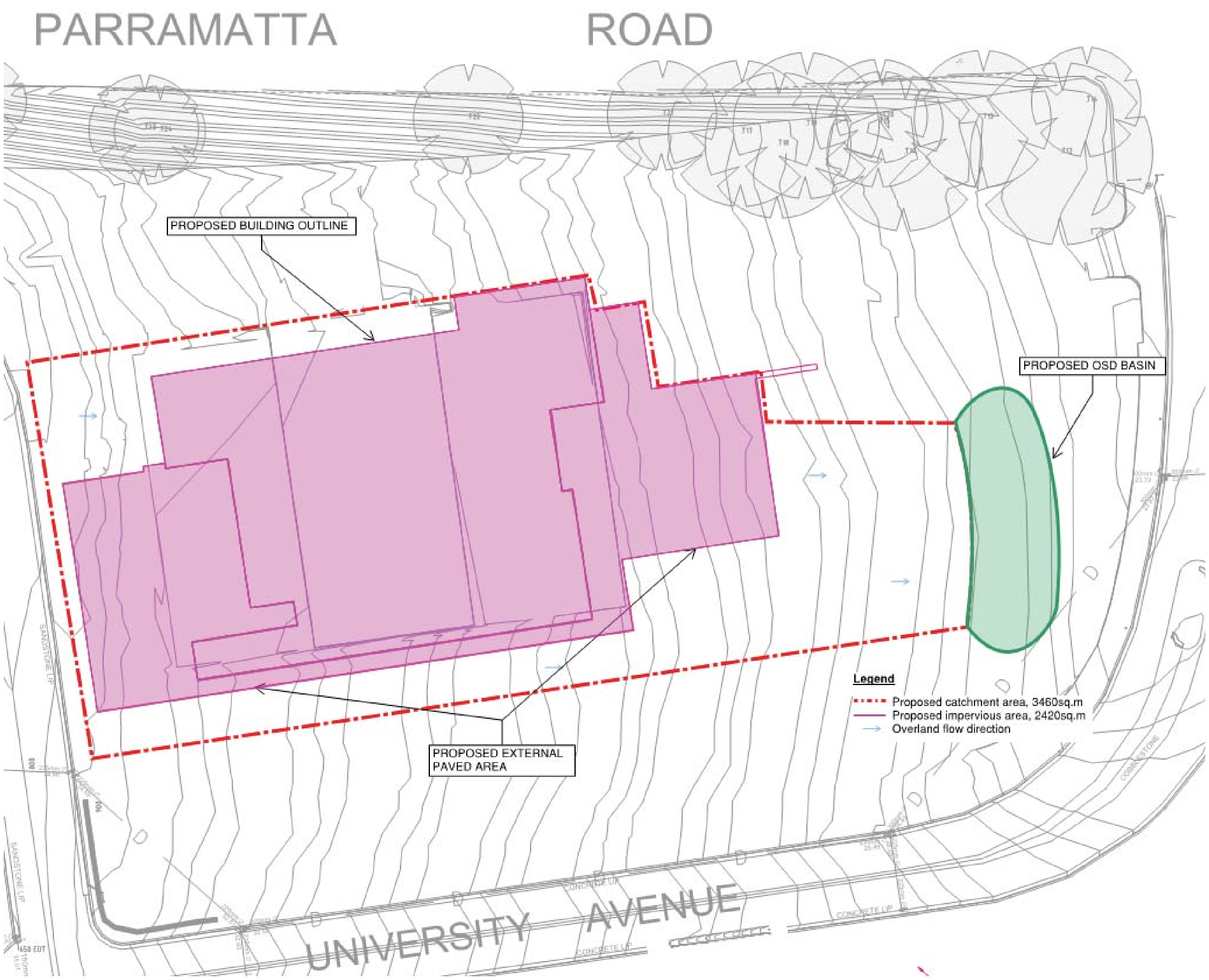


A5 Catchment Map: Proposed catchment area

Existing Catchment



Proposed Catchment



Appendix B

Acoustic Terminology

B1 Acoustic Terminology

Absorption Coefficient, α

The amount of sound absorbed by a sample is characterised by the absorption coefficient, □. A perfect absorber (e.g. a sufficiently large opening in a room) from which no sound is reflected has an absorption coefficient of 1.00. There are two common methods for measuring sound absorption coefficients of a material.

One, the impedance tube method, is useful for readily obtaining results and only requires a small sample to be tested, but is limited in that it can only measure the normal-incidence absorption coefficient – i.e. the absorption coefficient for a single angle with sound propagating perpendicular to the material.

The other method, the reverberation chamber method, requires more extensive tests and a larger (~10 m²) sample size, but obtains the random-incidence absorption coefficient- i.e. the effective absorption coefficient of the material averaged over all angles. The random-incidence absorption coefficient is required for detailed room acoustic calculations.

Note that the reverberation chamber method can legitimately measure coefficients greater than 1.0 due to "edge effects" such as diffraction or scattering from the edges of the sample. These edge effects are reduced by using a barrier around the sample or by using a larger sample.

Ambient Noise Level

The ambient noise level is the overall noise level measured at a location from multiple noise sources. When assessing noise from a particular development, the ambient noise level is defined as the remaining noise level in the absence of the specific noise source being investigated. For example, if a fan located on a city building is being investigated, the ambient noise level is the noise level from all other sources without the fan running. This would include sources such as traffic, birds, people talking and other nearby fans on other buildings.

Background Noise Level

The background noise level is the noise level that is generally present at a location at all or most times. Although the background noise may change over the course of a day, over shorter time periods (e.g. 15 minutes) the background noise is almost-constant. Examples of background noise sources include steady traffic (e.g. motorways or arterial roads), constant mechanical or electrical plant and some natural noise sources such as wind, foliage, water and insects.

Decibel

The decibel scale is a logarithmic scale which is used to measure sound and vibration levels. Human hearing is not linear and involves hearing over a large range of sound pressure levels, which would be unwieldy if presented on a linear scale. Therefore a logarithmic scale, the decibel (dB) scale, is used to describe sound levels.

An increase of approximately 10 dB corresponds to a subjective doubling of the loudness of a noise. The minimum increase or decrease in noise level that can be noticed is typically 2 to 3 dB.

dB(A)

dB(A) denotes a single-number sound pressure level that includes a frequency weighting ("A-weighting") to reflect the subjective loudness of the sound level.

The frequency of a sound affects its perceived loudness. Human hearing is less sensitive at low and very high frequencies, and so the A-weighting is used to account for this effect. An A-weighted decibel level is written as dB(A).

Some typical dB(A) levels are shown below.

Sound Pressure Level dB(A)	Example
130	Human threshold of pain
120	Jet aircraft take-off at 100 m
110	Chain saw at 1 m
100	Inside nightclub
90	Heavy trucks at 5 m
80	Kerbside of busy street
70	Loud stereo in living room
60	Office or restaurant with people present
50	Domestic fan heater at 1m
40	Living room (without TV, stereo, etc)
30	Background noise in a theatre
20	Remote rural area on still night
10	Acoustic laboratory test chamber
0	Threshold of hearing

L1

The L1 statistical level is often used to represent the maximum level of a sound level that varies with time.

Mathematically, the L1 level is the sound level exceeded for 1% of the measurement duration. As an example, 87 dB LA1,15min is a sound level of 87 dB(A) or higher for 1% of the 15 minute measurement period.

L10

The L10 statistical level is often used as the "average maximum" level of a sound level that varies with time.

Mathematically, the L10 level is the sound level exceeded for 10% of the measurement duration. L10 is often used for road traffic noise assessment. As an example, 63 dB LA10, 18hr is a sound level of 63 dB(A) or higher for 10% of the 18 hour measurement period.

L90

The L90 statistical level is often used as the "average minimum" or "background" level of a sound level that varies with time.

Mathematically, L90 is the sound level exceeded for 90% of the measurement duration. As an example, 45 dB LA90,15min is a sound level of 45 dB(A) or higher for 90% of the 15 minute measurement period.

Leq

The 'equivalent continuous sound level', Leq, is used to describe the level of a time-varying sound or vibration measurement.

Leq is often used as the "average" level for a measurement where the level is fluctuating over time. Mathematically, it is the energy-average level over a period of time (i.e. the constant sound level that contains the same sound energy as the measured level). When the dB(A) weighting is applied, the level is denoted dB LAeq. Often the measurement duration is quoted, thus LAeq,15 min represents the dB(A) weighted energy-average level of a 15 minute measurement.

Lmax

The Lmax statistical level can be used to describe the "absolute maximum" level of a sound or vibration level that varies with time.

Mathematically, Lmax is the highest value recorded during the measurement period. As an example, 94 dB LAmax is a highest value of 94 dB(A) during the measurement period.

Since Lmax is often caused by an instantaneous event, Lmax levels often vary significantly between measurements.

Flutter Echo

Flutter echo refers to an acoustic defect where sound reflects backwards-and-forwards between a set of parallel surfaces with very little energy loss. The resulting flutter echo decays very slowly and can "linger" in the room long after sound travelling in other directions has been attenuated.

Flutter echo can cause distortion to the sound quality, making it sound "metallic", or if the flutter is strong enough or delayed enough, it can cause a sound to sound "blurred" and even be heard as a separate sound (an "echo").

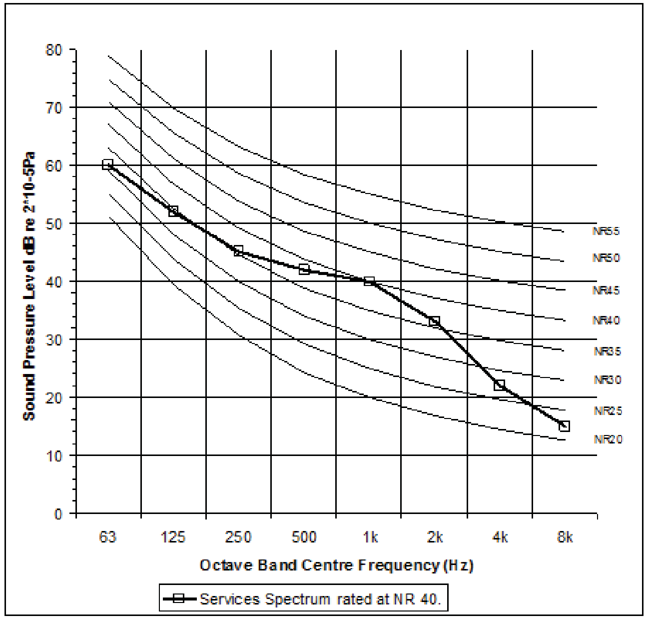
Flutter is treated by angling surfaces so they are not parallel, adding absorption to one or both surfaces, or by adding diffusion to one or both surfaces.

Frequency

Frequency is the number of cycles per second of a sound or vibration wave. In musical terms, frequency is described as "pitch". Sounds towards the lower end of the human hearing frequency range are perceived as "bass" or "low-pitched" and sounds with a higher frequency are perceived as "treble" or "high pitched".

Noise Rating (NR) Curves

Noise rating (NR) curves are a set of internationally-agreed octave band sound pressure level curves, based on the concept of equal loudness. The curves are commonly used to define building services noise limits. The NR value of a noise is obtained by plotting the octave band spectrum on the set of standard curves. The highest value curve which is reached by the spectrum is the NR value. Shown below is a plant noise spectrum that is equivalent to NR 40.



Peak Particle Velocity (PPV)

Peak Particle Velocity (PPV) is the highest velocity of a particle (such as part of a building structure) as it vibrates. Most sound level meters measure root mean squared (RMS) values; it is common to approximate the PPV based on an RMS measurement.

PPV is commonly used as a vibration criteria, and is often interpreted as a PPV based on the Lmax or Lmax, spec index.

Reverberation Time (T60)

The time, in seconds, taken for a sound within a space to decay by 60 dB after the sound source has stopped is denoted at the reverberation time. The RT is an important indicator of the subjective acoustic within an auditorium. A large RT subjectively corresponds to an acoustically 'live' or 'boomy' space, while a small RT subjectively corresponds to an acoustically 'dead' or 'flat' space.

Examples of typical design reverberation times are provided below:

Mid-frequency Reverberation Time, s	Example
< 0.1	Anechoic
0.1 – 0.4	Call centres
0.4 – 0.6	Library
0.6 – 0.8	Offices / board rooms
0.8 – 1.0	Small auditorium for speech
1.0 – 1.2	Music studios
1.2 – 1.5	Chamber music venues
1.5 – 2.0	Orchestral music venues
2.0 – 3.0	Church
3.0 – 8.0	Cathedral

Sound Level Difference (D)

Sound level difference is used to quantify the sound insulation between two spaces, and is equal to the difference in sound level between the two rooms at a particular frequency (e.g. if the sound level in the source room is 100 dB and the sound level in the adjacent room is 75 dB, the sound level difference is 25 dB). The weighted sound level difference, Dw, (as defined in AS/NZS ISO 717.1) is commonly used to provide a single-number descriptor to describe the overall performance of a partition across a wider frequency range.

The terms used to describe the airborne sound insulation rating of a building element when tested on-site are the weighted normalised level difference (Dn,w), which corrects the measured sound level difference to a reference absorption area in the receiving room, or the weighted standardized level difference (DnT,w), which corrects the measurements to a reference reverberation time in the receiving room.

These single numbers are determined by comparing the spectral sound insulation test results (as defined in ISO 140-4) with reference values, as outlined in AS/NZS ISO 717.1.

Sound Power and Sound Pressure

The sound power level (Lw) of a source is a measure of the total acoustic power radiated by a source. The sound pressure level (Lp) varies as a function of distance from a source. However, the sound power level is an intrinsic characteristic of a source (analogous to its mass), which is not affected by the environment within which the source is located.

Sound Reduction Index (R)

The sound reduction index (or transmission loss) of a building element is a measure of the loss of sound through the material, i.e. its sound attenuation properties. It is a property of the component, unlike the sound level difference, which is affected by the common area between the rooms and the acoustics of the receiving room. R is the ratio (expressed in decibels) of the sound energy transmitted through the building element to the sound energy incident on the building element for a particular frequency.

The weighted sound reduction index, Rw, is a single figure description of sound reduction index across a wider frequency range and is defined in BS EN ISO 717-1: 1997. Rw values are calculated from measurements in an acoustic laboratory. Sound insulation ratings derived from site measurements (which are invariably lower than the laboratory figures) are referred to as apparent sound reduction index (R'w) ratings.

Structureborne Noise

The transmission of noise energy as vibration of building elements. The energy may then be re-radiated as airborne noise. Structureborne noise is controlled by structural discontinuities, i.e. expansion joints and floating floors.

Vibration

Waves in a solid material are called "vibration", as opposed to similar waves in air, which are called "sound" or "noise". If vibration levels are high enough, they can be felt; usually vibration levels must be much higher to cause structural damage.

A vibrating structure (e.g. a wall) can cause airborne noise to be radiated, even if the vibration itself is too low to be felt. Structureborne vibration limits are sometimes set to control the noise level in a space.

Vibration levels can be described using measurements of displacement, velocity and acceleration. Velocity and acceleration are commonly used for structureborne noise and human comfort. Vibration is described using either metric units (such as mm, mm/s and mm/s^2) or else using a decibel scale.

Appendix C

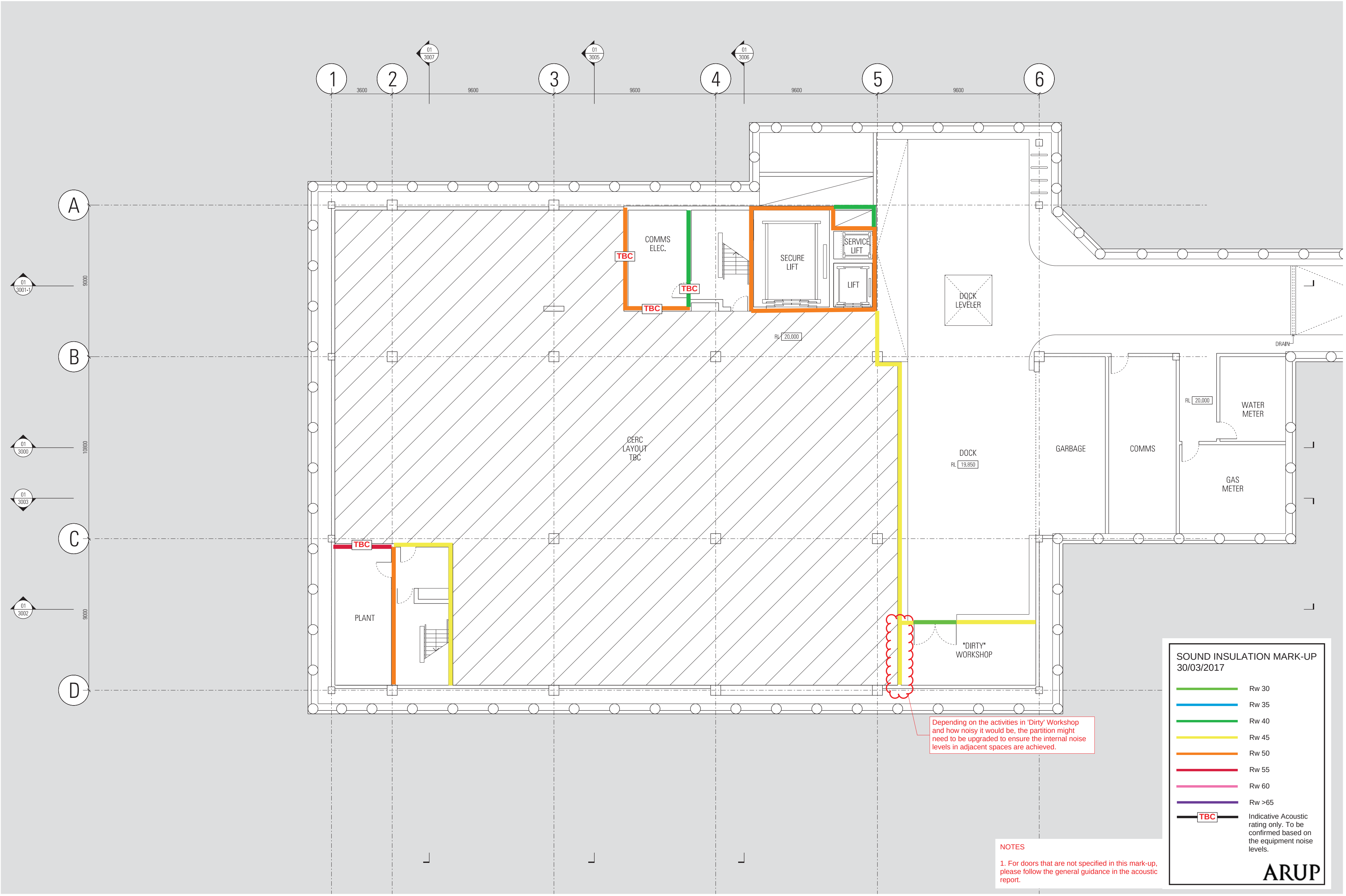
Benchmarking of Acoustic
Criteria for Galleries

Arup have collated information from a variety of international art gallery projects to help with benchmarking the proposed criteria.

Museum	**Victoria & Albert Museum, UK**	**National Portrait Gallery, UK**	**Tate Modern, UK**	**Tate Modern, UK**
				
Target Noise Criteria	NR35-NR40 (Gallery)	NR35-NR40 (Gallery)	NR35 (Gallery) NR30 (Auditorium) NR35 (Seminar Room) NR35 (Private Office) NR40 (Group Office)	NR40-NR45 (Turbine Hall)
Target Reverberation Time	1.7-3.5s (small to medium size gallery)	<1.8s (Gallery)	1.4-2.0s (Gallery) 0.7-1.0s (Auditorium) 0.5-0.8s (Seminar Room) 0.35-.065s (Private Office) 0.4-0.8s (Group Office)	>5s (Turbine Hall without absorption)
Sound Insulation	Gallery – Rw48 (Floor to Floor)	Rw 45 (Gallery to Cafe) Rw 50 (Gallery to Kitchen) Rw 58 (Lecture Theatre to Entrance Hall)	Rw48 (Gallery to Core) Rw48 (Cellular Space to Corridor) Rw54 (Cellular Space to Cellular Space)	Rw43 (Turbine Hall to Art Loading Bay)
Vibration	Not available	0.1mm/s-0.3mm/s (Building Services)	Not available	Not available
Finishes	Hard timber floor 60% acoustic ceiling	Hard timber floor/ carpet Acoustic ceiling	Drywall Timber Floor/ Hard Floor Acoustic ceiling (Gallery)	Hard reflective surface finishes Absorption under roof

Appendix D

Sound Insulation Mark-up



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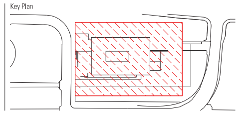
Key Plan



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Drawing Title
GENERAL ARRANGEMENT
PLAN
LOWER LEVEL 2

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JPW-SD-A-1001
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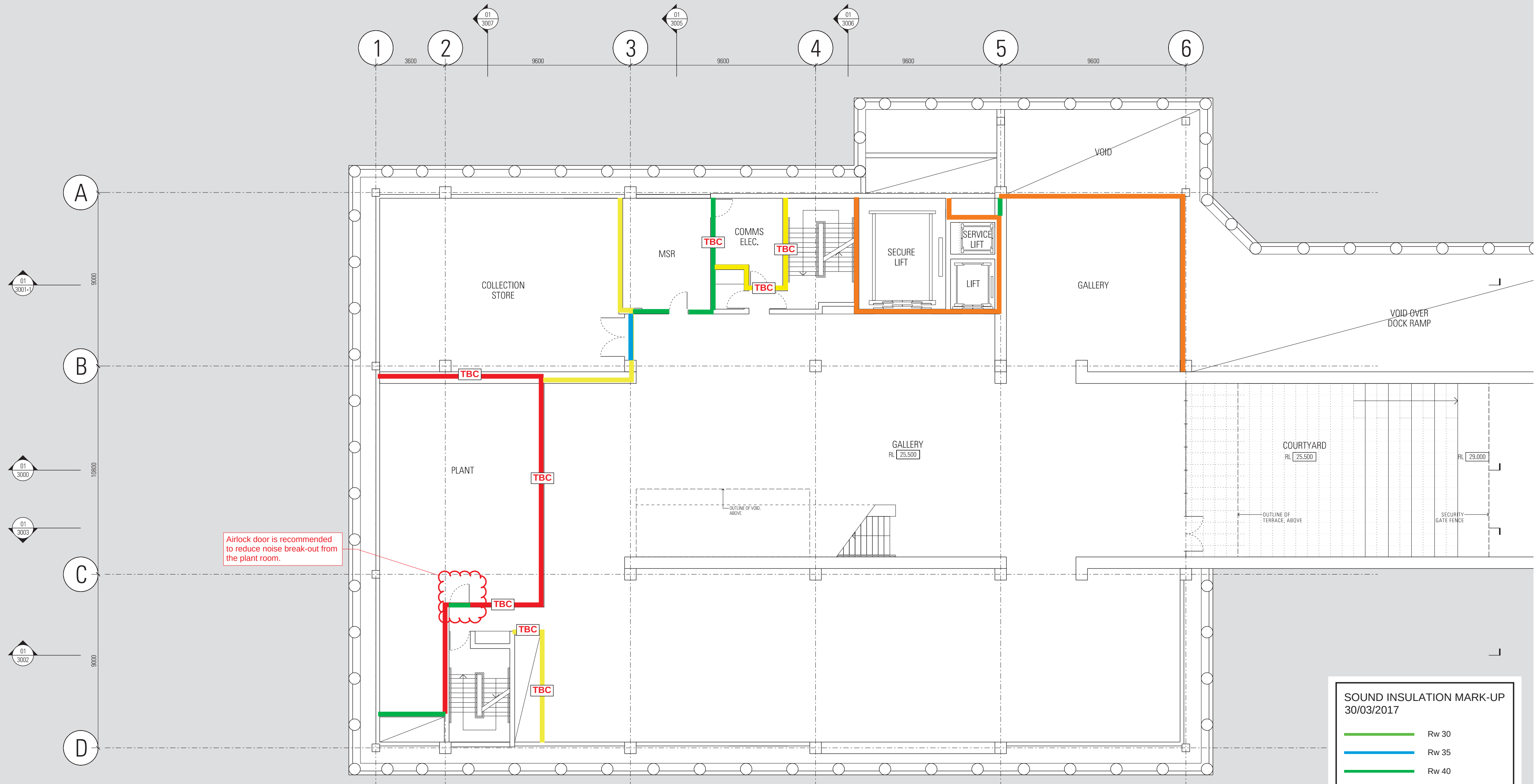

SOUND INSULATION MARK-UP
30/03/2017

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(blue line)	Rw 35
(green line)	Rw 40
(yellow line)	Rw 45
(orange line)	Rw 50
(red line)	Rw 55
(pink line)	Rw 60
(purple line)	Rw >65
TBC	Indicative Acoustic rating only. To be confirmed based on the equipment noise levels.

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NOTES

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Documentation Stage SD
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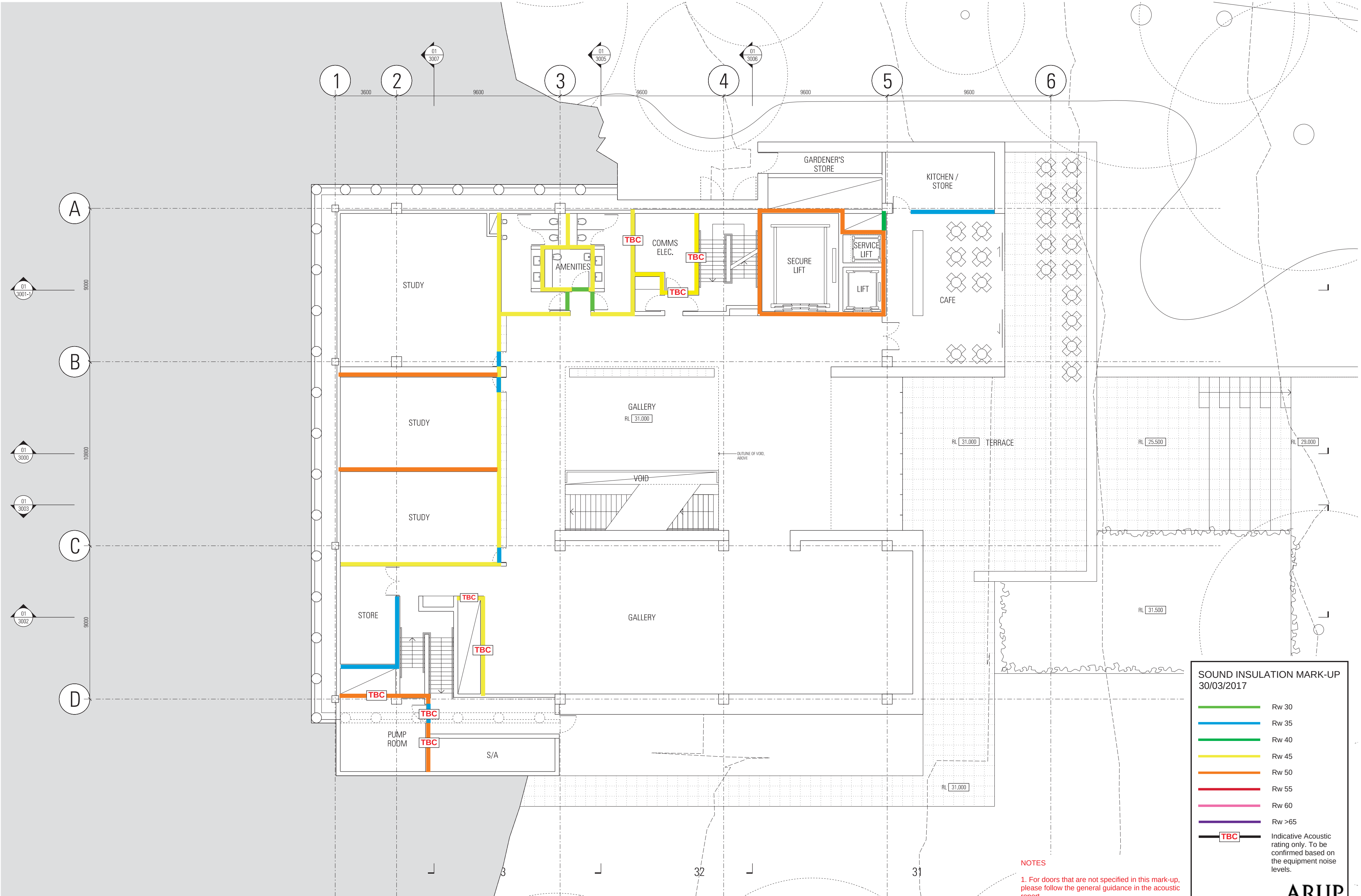

SOUND INSULATION MARK-UP 30/03/2017

- Rw 30
- Rw 35
- Rw 40
- Rw 45
- Rw 50
- Rw 55
- Rw 60
- Rw >65
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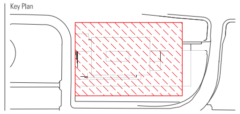

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1:100 @ A1, 1:200 @ A3
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GENERAL ARRANGEMENT
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LOWER GROUND LEVEL

Project Number: 15037
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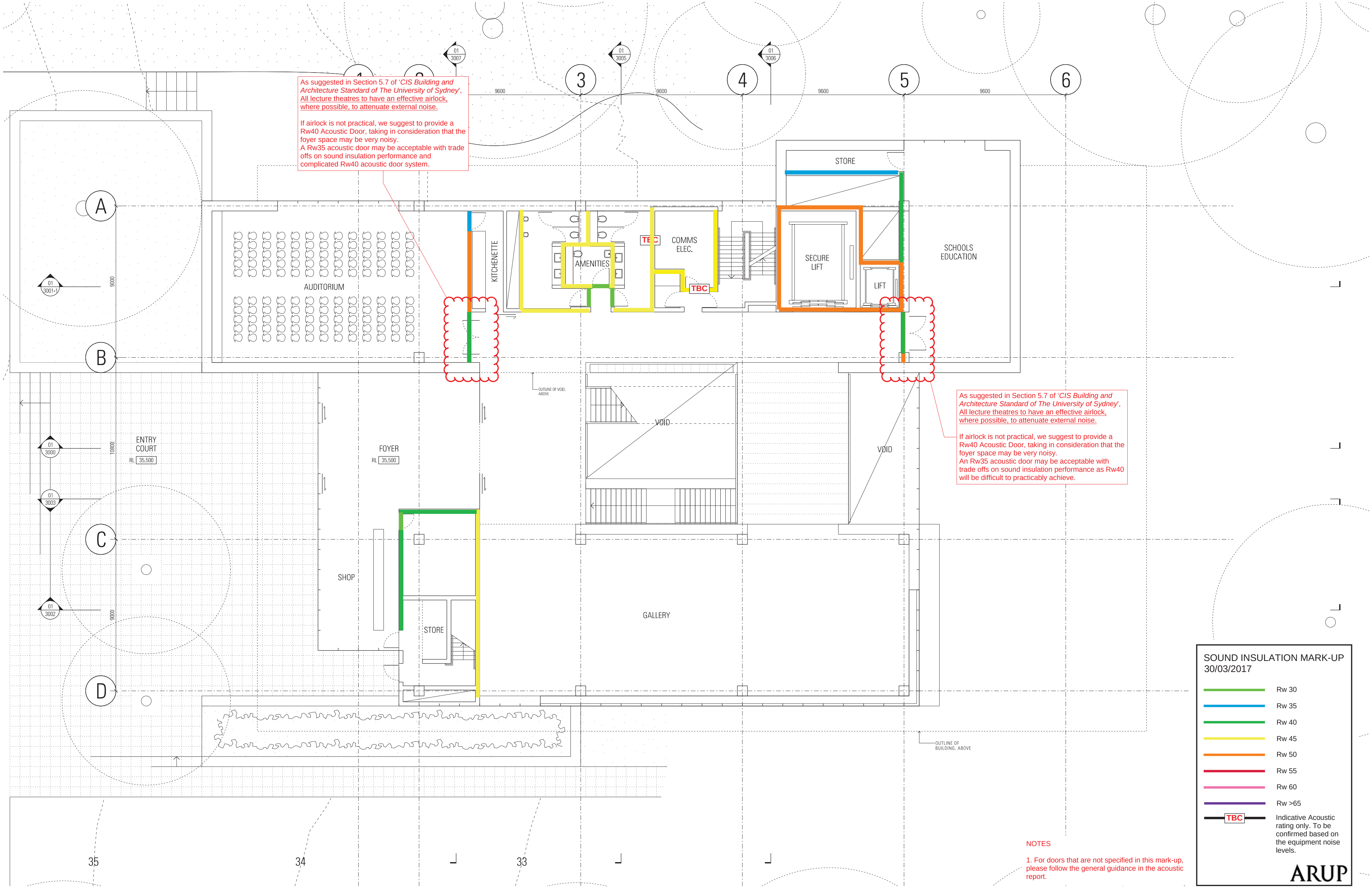

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Key Plan

Scale / North Point: 1:100 @ A1, 1:200 @ A3 — 0 1 2 3 5m

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Drawing Title: GENERAL ARRANGEMENT PLAN GROUND LEVEL

Project Number: 15037 | Documentation Stage: SD

Drawing Number: JPW-SD-A-1004 | Revision: 00

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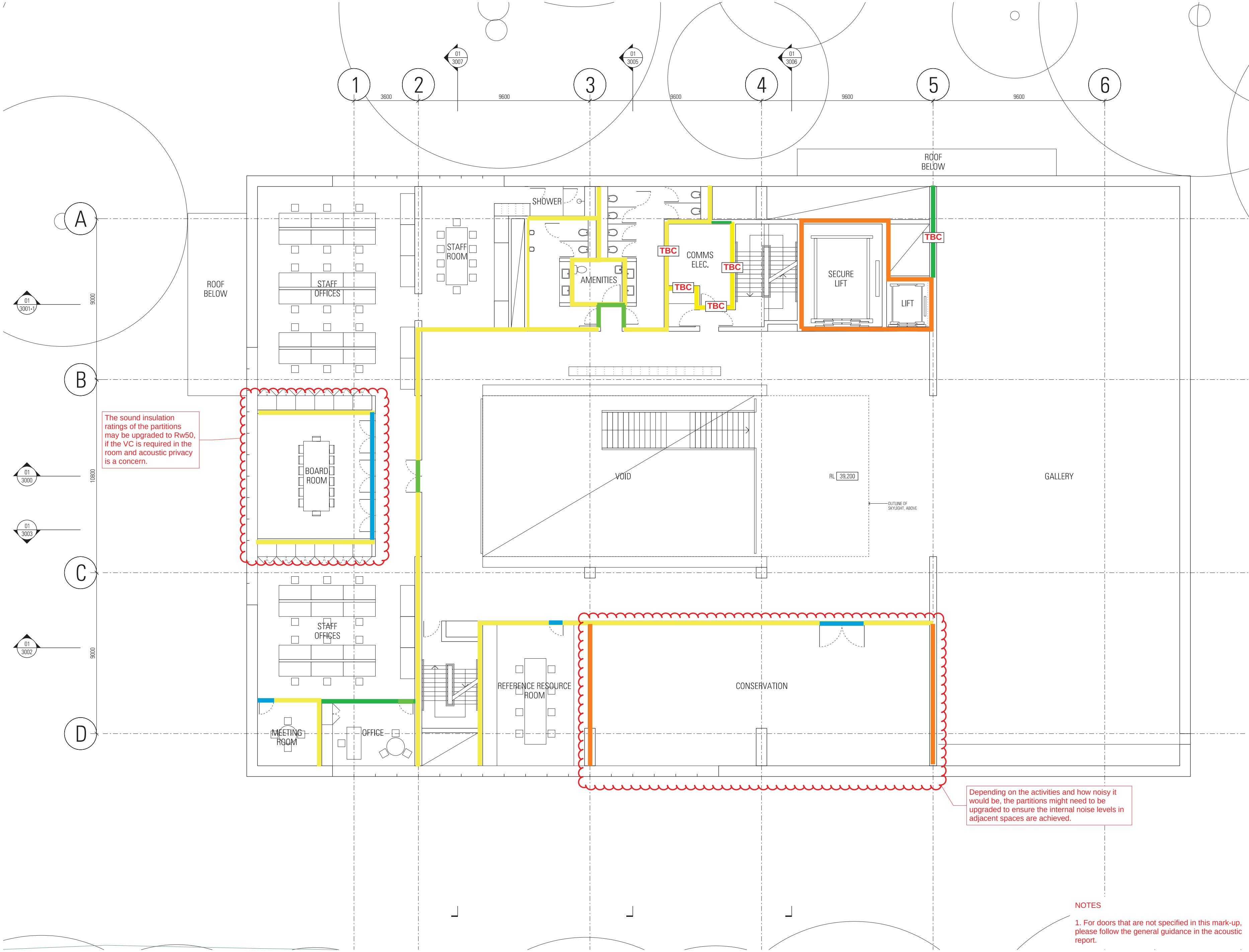

SOUND INSULATION MARK-UP 30/03/2017

- Rw 30
- Rw 35
- Rw 40
- Rw 45
- Rw 50
- Rw 55
- Rw 60
- Rw >65
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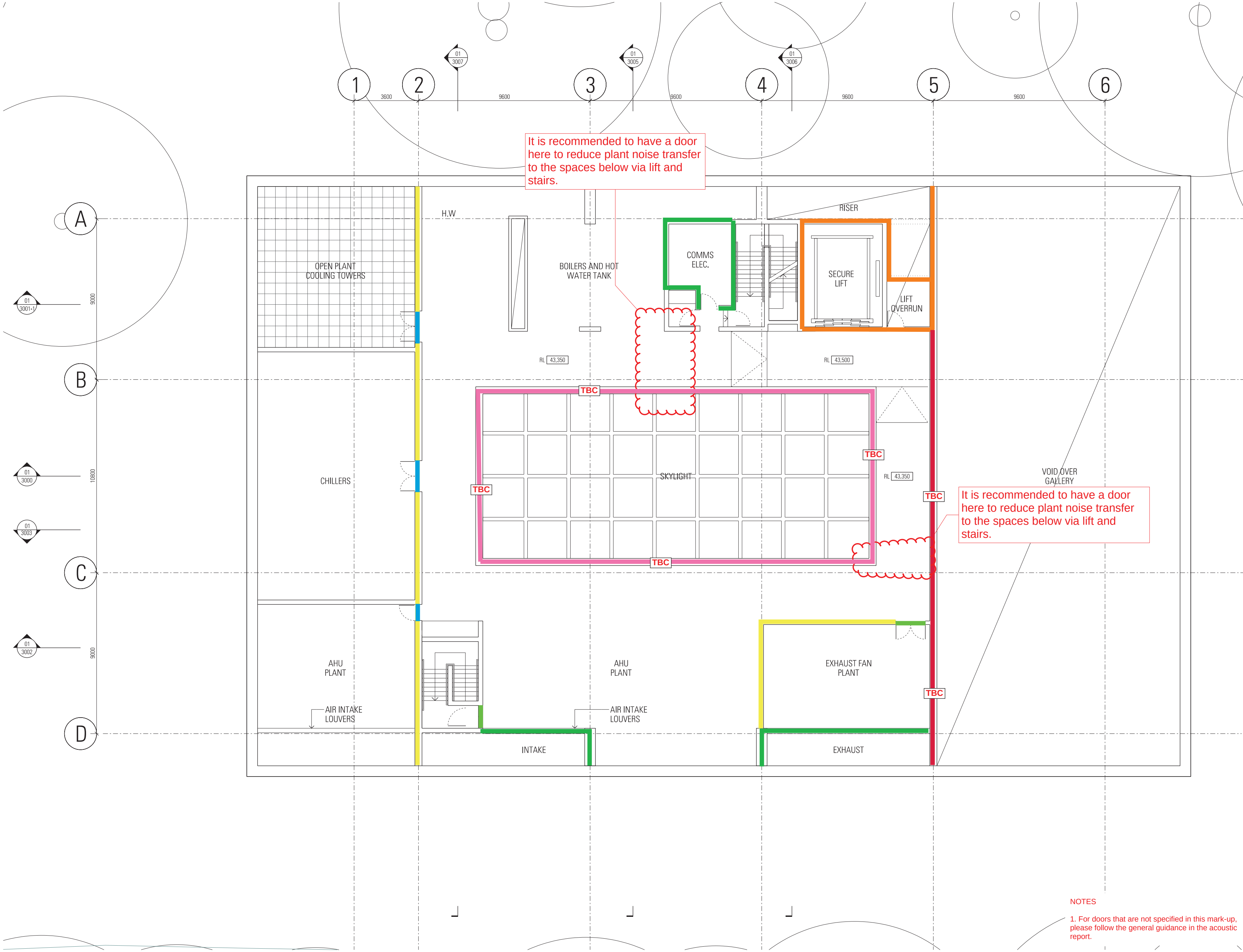

SOUND INSULATION MARK-UP
30/03/2017

Legend	
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PLANT LEVEL

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Documentation Stage
SD

Drawing Number
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Revision
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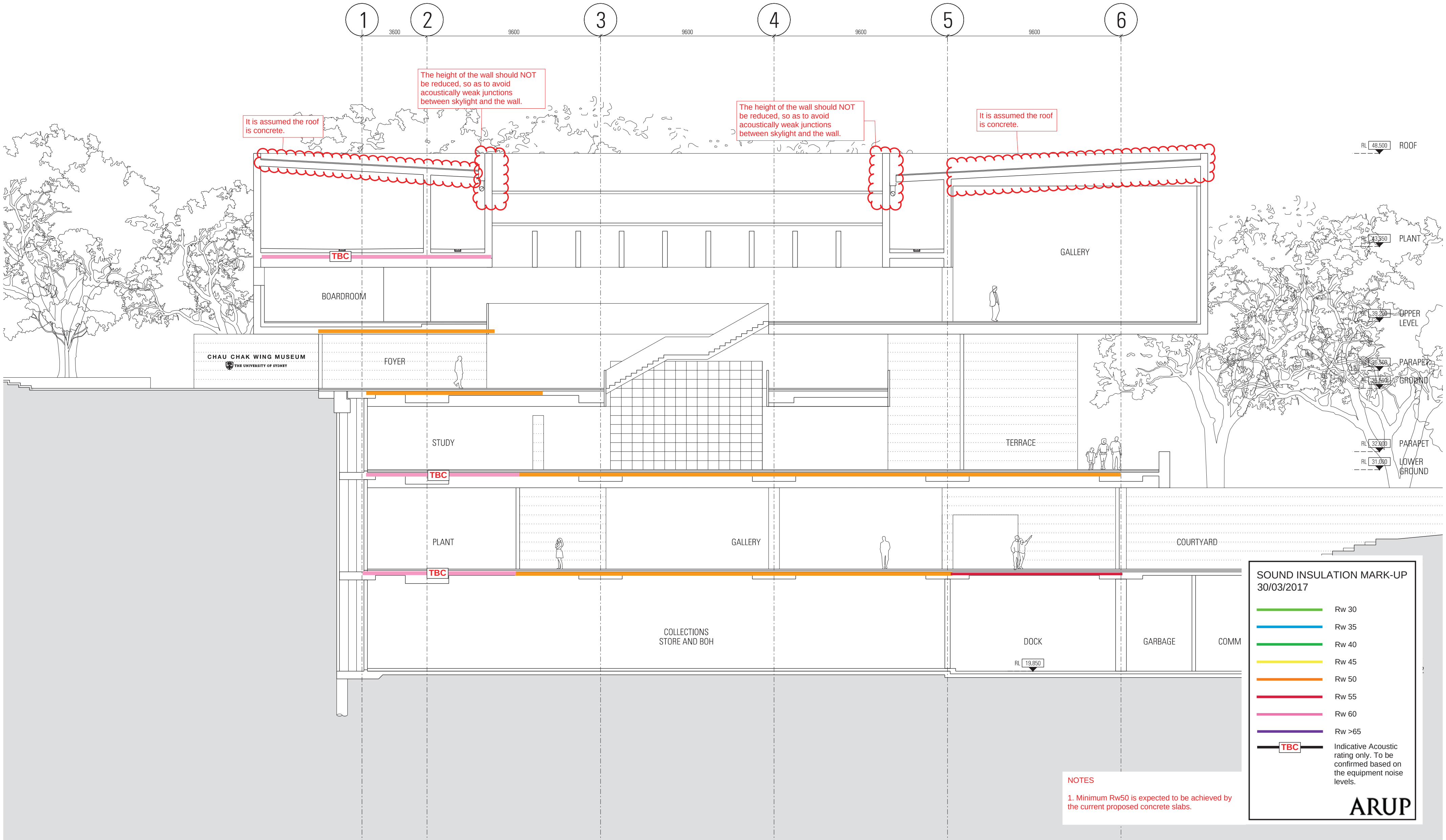

Rev	App	Ckd	Revision or reason for issue	Date
00	KL	DW	Coordination Issue	17/03/2017

Legend

Structural & Civil
ARUP
10/102 Kent St
Sydney NSW 2000
02 9320 9320

Building Services
ARUP
10/102 Kent St
Sydney NSW 2000
02 9320 9320

Fire Engineering
ARUP
10/102 Kent St
Sydney NSW 2000
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ESD & Facades
Steensen Varming
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02 9967 2200

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1300 272 671
enquiries@arborsafe.com.au

Town Planner
MG Planning
Suite 1.4, 135 Victoria Rd
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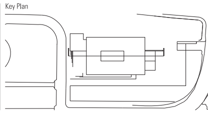
02 9719 3118

Accessability
Philip Chun
Suite 404, 44 Hampden Rd
Artarmon NSW 2064
02 9412 2322

BCA
Group DLA
Level 3, No 10 Bridge St
Sydney NSW 2000
02 8355 316

Key Plan



Scale / North Point
1:100 @ A1, 1:200 @ A3 — 0 1 2 3 5m

General Notes
Do not scale from drawing. Use marked dimensions.To be read in conjunction with all other Consultant's drawings.The Architect to be immediately notified of any discrepancies. Copyright on this drawing retained by the Architect.

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Project Title
UNIVERSITY OF SYDNEY
CHAU CHAK WING MUSEUM

Client
The University of Sydney
Sydney
NSW
2006

Drawing Title
SECTION
NORTH 01

Project Number: 15037
Documentation Stage: SD
Drawing Number: JPW-SD-A-3000
Revision: 00

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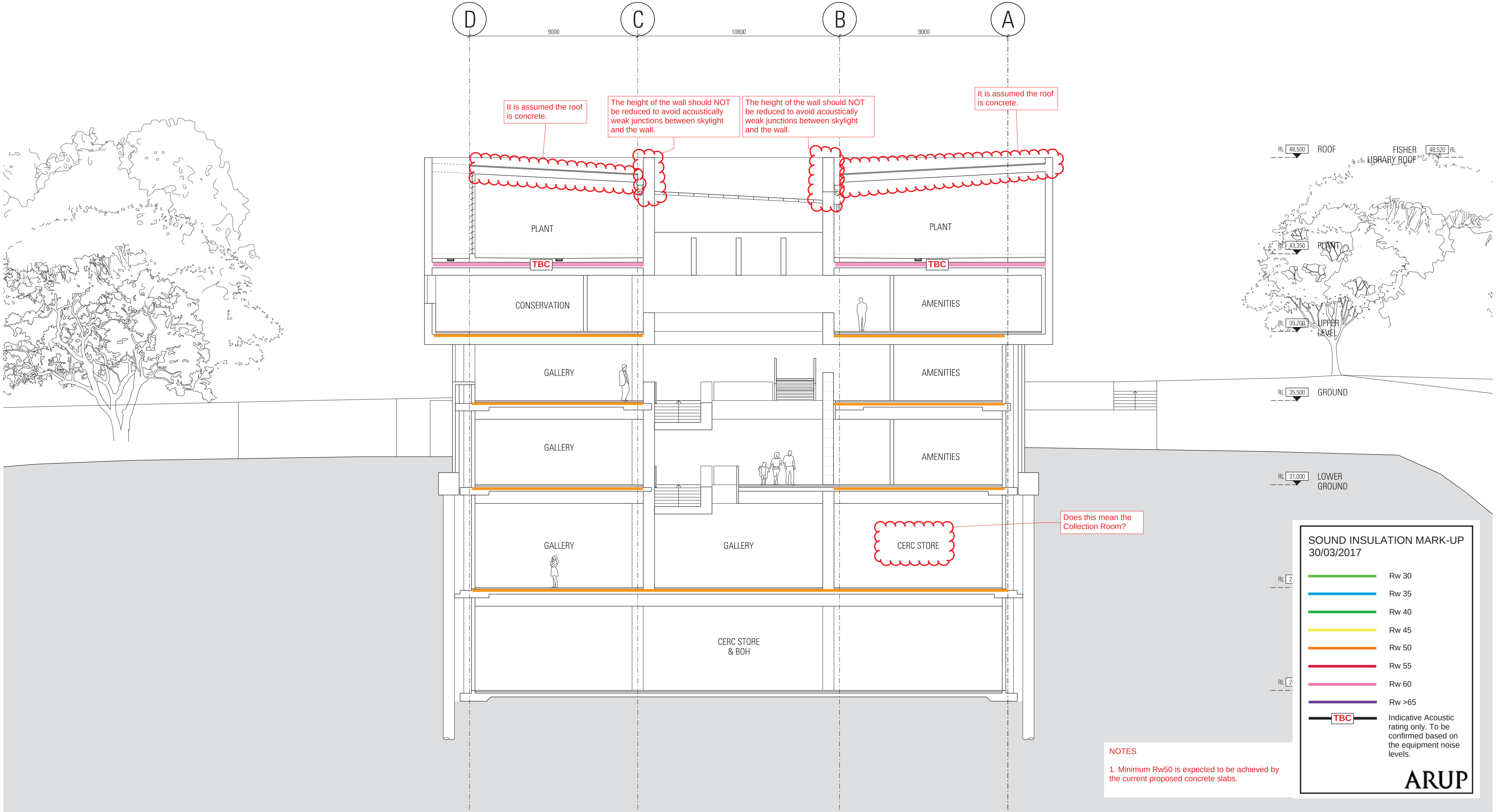
$TIME$



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00	KL	DW	Coordination Issue	17/03/2017

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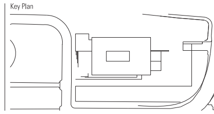
Key Plan



Scale / North Point

1:100 @ A1, 1:200 @ A3 — 0 1 2 3 5m

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CHAU CHAK WING MUSEUM

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Sydney
NSW
2006

Drawing Title
SECTION
WEST 01

Project Number
15037

Documentation Stage
SD

Drawing Number
JPW-SD-A-3005

Revision
00

$FILE$ $DATE$ $TIME$