University of Sydney

Chau Chak Wing Museum

Multidisciplinary Engineering Services – Schematic Design Report

ARP-SDR-001

Issue 2 | 18 April 2017

Job number

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Document Verification

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Job title		Chau Chak Wing Museum			**Job number**
Document title		Multidisciplinary Engineering Services – Schematic Design Report			**File reference**
Document ref		ARP-SDR-001			
Revision	**Date**	**Filename**	Report.docx		
Issue 1	13 Apr 2017	**Description**			
			Prepared by	Checked by	Approved by
		Name	All disciplines	GC	GC
		Signature			
Issue 2	18 April 2017	**Filename**			
		Description			
			Prepared by	Checked by	Approved by
		Name	All disciplines	GC	GC
		Signature			
		Filename			
		Description			
			Prepared by	**Checked by**	**Approved by**
		Name			
		Signature			
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1 Introduction

1.1 Overview

This document describes the Civil, Structural, Mechanical, Electrical, Acoustics, Traffic, Vertical Transport, Fire Services and Hydraulics and Fire Engineering proposed concepts for the new Chau Chak Wing Museum.

The new Chau Chak Wing Museum project involves the construction of a new museum building on the University lawns just west of University Avenue and east of The Quadrangle at the Universities Camperdown campus.

The development will support the cultural and scientific enquiry and provide a new benchmark for integrated cross-disciplinary teaching and learning through exhibitions and museum collections alongside study rooms. It will become the focal point for University-wide cultural outreach.

The proposed Chau Chak Wing Museum will include provisions for:

- A series of flexible exhibition spaces to accommodate both semi-permanent and temporary exhibitions and displays, with discrete areas of curatorial experimentation and research;
- Permanent galleries of material cultural, art and antiquities, science and natural history, enabling our rich and diverse collections to be directed towards units of study as well as enjoyment;
- Study workshops equipped with innovative new media for tutorials and other types of collection-based learning;
- Conservation laboratories, including one for teaching conservation as part of museum and heritage studies;
- Schools education rooms for K-12 groups in curricula-based learning;
- Lecture theatre;
- Café and specialised book/gift shop;
- Staff offices;
- Loading areas; &
- Staff and public amenities.

The proposed building occupies a footprint of roughly 35m x 55m in plan, 6 floors of 4m-5m floor to floor height spread across floors located within and above a basement. The basement depth on the west perimeter is approximately 15m deep and on the east 8m. The average height of the building above surface level is approximately 23m.

1.2 The Site

The site is located on the Sydney University Camperdown site off University Avenue and is shown in the Figure 1below.

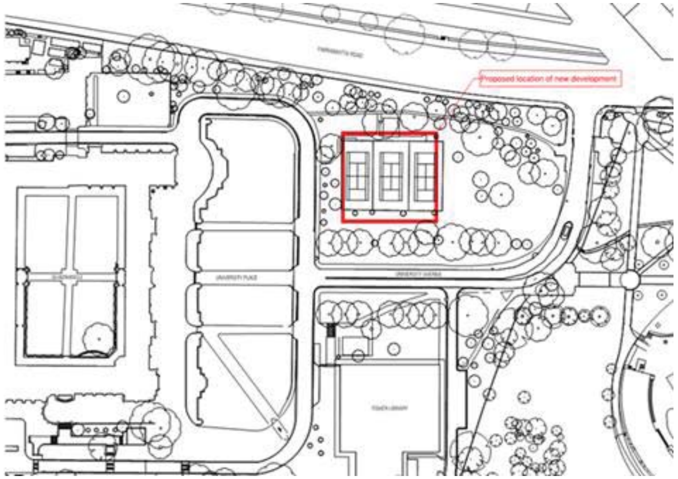


Figure 1 Site plan showing location of the proposed development

2 Civil Engineering

The civil engineering design has been developed with the intention of achieving cost effective, functional and safe outcomes. Consideration has been given to the provision of adequate drainage, earthworks cut and fill and external services reticulation. The civil works to accommodate the proposed Chau Chak Wing museum include the design and documentation for:-

- Bulk earthworks;
- External stormwater drainage;
- Erosion and sediment control;
- Pavement design; &
- In-ground utilities co-ordination.

2.1 Bulk Earthworks

The site slopes steeply from West to East at an approximate grade of 1 in 11 culminating at a short 0.5m high retaining wall before transitioning to the footpath alongside University Avenue. The proposed building has 2 basement floors, a lower ground floor which is partially below the existing ground level and a driveway from University Avenue which ramps down into the basement. This is illustrated on Figure 2.

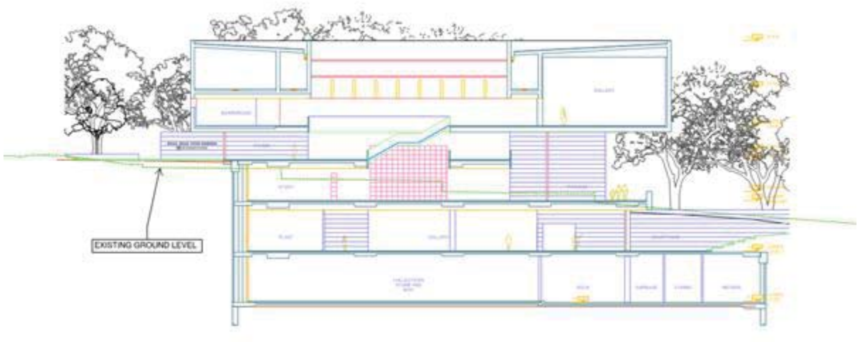


Figure 2 Section view of proposed building and existing ground level

An assessment of the bulk earthworks cut and fill has been made for schematic design. This is illustrated on drawing AP-C-200. This site is predominantly in cut as a function of the subterranean basement. A key assumption is the bulk earthworks level for the building pad which has been assumed to be 0.65m below the lowest basement floor level, RL 19.850m.

Arup note the presence of laminate, medium strength and high strength laminate at depths as shallow as 33.0m AHD in the geotechnical report by Douglas Partners, October 2016.

The external pavement types and depths have not been specified for schematic design. For the purposes of bulk earthworks modelling, Arup have considered bulk earthworks volumes between existing levels and proposed levels for the external pavement areas.

The driveway pavement design will be detailed at design development by the structural engineer. For the purpose of the schematic design bulk earthworks assessment, the driveway pavement has been assumed to tie in to the bulk earthworks level of the building pad and smoothly transition to University Avenue. Arup anticipates vertical concrete retaining walls will be specified on either side of the driveway as it transitions below ground to the basement.

The geometric design and subsequent bulk earthworks level of the on-site detention basin is discussed in section 2.2.2.1

2.2 External Stormwater Drainage

The external stormwater drainage design includes:-

- Identification, protection/relocation and/or adjustment of existing drainage services that conflict with the proposed works;
- Design of pipes, pits, channels and grates for stormwater control through the site in response to the architectural proposals;
- Collection and discharge of building roof water;
- Subsoil drainage required for landscaping and pavements (but excluding basement drainage); &
- Water Sensitive Urban Design (WSUD) including on-site detention (OSD) and water quality treatment (as appropriate).

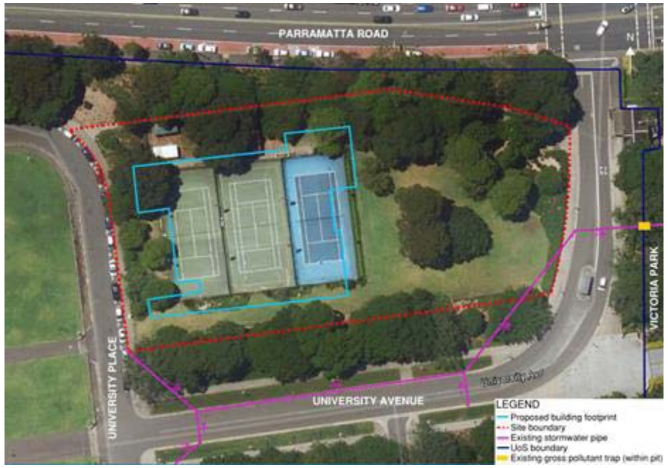


Figure 3 Site locality plan

2.2.1 Existing Stormwater Drainage

The site is located in the City of Sydney local government area and is within the boundary of the University of Sydney's Camperdown Campus. The site is bounded by University Avenue to the East and South, University Place to the West, and Parramatta Road to the North (see Figure 3). The site is located in the Blackwattle Bay Catchment as identified and described by the City of Sydney "Blackwattle Bay Catchment Floodplain Risk Management Study and Plan, Draft Report", September 2014, WMA Water.

A review of the "University of Sydney Flood Mitigation Master Plan – Final Report" October 2015, prepared by WMA Water indicates that the proposed site is not flood affected in the 100 average recurrence interval storm design event. However University Avenue to the east of the existing site experiences peak flood depths up to 0.5m in the 100 year storm event. The relevant portion of the published flood map of the proposed site is presented in Figure 4.

Figure 4 Peak flood depth and level for 1% AEP flood event from Figure 5 of "University of Sydney Camperdown Campus Flood Mitigation Master Plan", October 2015, WMA Water

Information regarding the drainage network around the site has been obtained from survey information conducted by RPS, version A (03/02/2017) and a survey of Victoria Park, which borders the site to the east, obtained from Alluvium Consulting. The existing stormwater network surrounding the proposed site has a catchment area of approximately 24,000m^2. A catchment map is provided in A1.

The downstream end of the stormwater network within the University of Sydney campus connects to a 300mm diameter pipe at the eastern boundary which outlets at Lake Northam in Victoria Park. Campus Infrastructure and Services (CIS) have informed Arup that the University of Sydney owns the existing stormwater pipe up to the campus boundary, after which ownership of the pipe is unknown although considered likely to be City of Sydney Council. A review of the DBYD plans provided by City of Sydney and Sydney Water has not identified this utility.

Arup has modelled the existing drainage network of the catchment based on the RPS survey using DRAINS software. Catchments at the western end of University Ave have been grouped together into 3 subcatchments due to incomplete stormwater survey information. The DRAINS model was run for the 20 and 100 year average recurrence interval (ARI) storm event. These are statistically significant rainfall events which have a 5% and 1% respective probability of occurring in any given year. DRAINS selected durations which produced the peak rainfall volumes.

Analysis of the existing network in DRAINS indicates it is overcapacity in both the 20 and 100 year ARI storm events. In particular, the existing stormwater pit, Pit 2 in Figure 5 Critical existing pit locations has peak overflow of 1.34m^3/s and 1.71m^3/s in the 20 and 100 year ARIs respectively. As the pit is located in a low point, the surrounding area is subject to flooding in major storm events, with peak depths of 385mm and 423mm in the 20 and 100 year ARIs respectively which is consistent with the flood model prepared by WMA Water. The results of this DRAINS analysis can be found in Appendix A2.

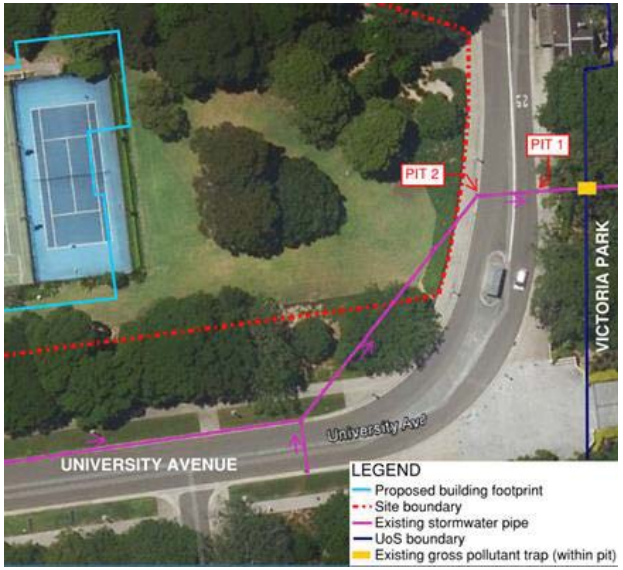


Figure 5 Critical existing pit locations

The capacity of the existing 300mm diameter pipe from the University of Sydney/Victoria Park boundary to Lake Northam is estimated to be approximately 0.340m^3/s. The DRAINS results indicate 0.173m^3/s of flow through this pipe in both the 20 and 100 year storm events. The drainage long sections, provided in Appendix A3 suggest the pipe is not being fully utilised due to the inefficiencies caused by shallow gradient of the pipe below University Avenue relative to the connecting pipes, and the 0.5m difference in invert levels in Pit 1 of Figure 5.

A gross pollutant trap is located at the campus boundary with Victoria Park (shown in Figure 6). CIS have advised it is maintained and working. No inspection of this has been undertaken and no specification details are known.

Figure 6 Existing GPT at boundary of University of Sydney and Lake Northam

2.2.2 Proposed Stormwater Drainage

Downpipes servicing the building will be designed and documented by the hydraulic engineer. The civil drainage design will make provision to collect discharge from these outlets as well as from external pavements into an external stormwater network and discharge this water into the downstream network. It is currently not known where the downpipes are to be located.

Stormwater drainage will be developed in conjunction with the landscape architect and is likely to consist of standard pits/grates, linear drainage and soft engineered OSD subject to detailed design.

Arup examined two options for stormwater design at the site for concept design:-

- Option A: Discharge stormwater from the proposed site development to the existing 300mm diameter stormwater pipe below University Avenue discharging into Lake Northam.
- Option B: Discharge stormwater from the proposed development into the City of Sydney stormwater network on Parramatta Road.

The respective advantage and disadvantages of these options have been discussed with CIS and Arup have been advised to proceed with Option A.

The stormwater design approach for the proposed development is to maintain or reduce the existing peak discharge conditions from the university to Lake Northam. Likewise the development must not exacerbate flooding of University Avenue. This is discussed in further detail in section 2.2.2.1 below. It is assumed the condition of the existing pipe from the University of Sydney's boundary to Lake Northam is in working condition. It is recommended this be confirmed by CCTV inspection.

2.2.2.1 Water Sensitive Urban Design (WSUD)

WSUD is intended to address the quantity and quality of stormwater runoff from the project site. The preferred stormwater design will need to satisfy the following criteria as part of the planning process:

- Water Quantity - Requirements for discharge through the existing 300mm pipe and Sydney Water permissible site discharge requirements; &
- Water Quality - City of Sydney and Sydney Water requirements.

Water Quantity and On Site Detention

The peak stormwater discharge is dependent on the capacity of the existing 300mm diameter stormwater pipe and Sydney Water's OSD requirement.

Using DRAINS modelling software, Arup have modelled the proposed drainage network. Due to the capacity constraints of the existing downstream stormwater network, Arup has designed an oversized OSD of 105m^3 to capture and detain flow so as to mitigate downstream flows and thereby not exacerbate flooding for all storm events up to and including the 100 year ARI storm event. The results of the proposed case DRAINS analysis is provided in Appendix A4.

Sydney Water's OSD policy for Blackwattle Bay includes a requirement for 'betterment', i.e. the post development discharge from site is required to be less than pre-development. A summary of the site catchment impervious areas both pre and post development as per the design as it currently stands, is provided in Table 1. These figures are subject to change during design development. The catchment maps for both cases are provided in A5.

Table 1 Stormwater catchment areas

	Existing	Proposed
Impermeable Portion	50%	70%
Permeable Portion	50%	30%

Sydney Water has advised 68m^3 of OSD is required with a permissible site discharge (PSD) of 106L/s (or 0.106m^3/s).

The OSD has been designed for the greater of the two detention volumes which is required to retain the existing 300mm diameter stormwater pipe and has a peak discharge rate of 102L/s (or 0.102m^3/s).

OSD Configuration

CIS has previously advised that it prefers soft engineered OSD solutions to hard engineering OSD solutions. Therefore an OSD basin and swale has been designed within the site boundary. For environmental, aesthetic and ecological purposes, the basin has also been designed to incorporate a retention component as a pond.

Arup have not found any state or City of Sydney regulations or guidelines regarding the geometric specifications of open OSD basins. For the schematic design, the Queensland Urban Drainage Manual (QUDM), Third edition 2013 – provisional, has been considered. Balancing the architectural aim of reducing the area of the basin while considering public safety issues, the schematic basin design has side slopes of 1 in 4. It is important to note at this gradient, steps and a handrail leading out of the basin are recommended for public safety.

A retention depth of 300mm was determined as it is the maximum depth allowable for swimming pools without fencing as stipulated in the AS 1926 – Swimming Pool Safety. While the OSD basin is not classified as a swimming pool, this maximum depth was decided upon in the interests of public safety. The nominated detention depth of 400mm was also chosen in the interest public safety (QUDM recommend restricting basin depths to 1.2m for the 1 in 20 year storm event).

From these geometric parameters, the basin has a bottom area of 140m^2 and a top surface area of 320m^2, with the top of the permanent retention area being 205m^2.

The geometric sizing of OSD basin will be developed further in coordination with the landscape design. Safety provisions and the use vertical structures such as gabion baskets can be explored to reduce the area of the OSD basin.

Water Quality

Water quality modelling of the proposed drainage system was undertaken using MUSIC software. The OSD basin was modelled as a bioretention, with the model parameters including:-

- 300mm deep retention zone
- 500mm depth of filtration media
- Basin to be lined with appropriate nutrient removing vegetation

A comparison of Sydney Water and City of Sydney's stormwater quality targets and those produced in the MUSIC model are given in Table 2

Table 2 Stormwater quality targets and proposed model results

Pollutant	Sydney Water average annual pollutant load reduction objective (%)	City of Sydney average annual pollutant load reduction objective (%)	Proposed stormwater system as modelled (% reduction)
Gross pollutants (>5mm)	90	90	100
Total suspended solids	85	85	72.4
Total phosphorous	60	65	64.9
Total nitrogen	45	45	60.4

As the catchment area of the proposed development is relatively small, achieving a large percentage reduction in pollutants becomes difficult. Arup will be seeking approval for the designed water quality measures from Sydney Water and City of Sydney on the basis that the proposed system is effective in treating stormwater flows and that the base concentration of contaminants is low.

2.2.2.2 Construction Considerations

The proposed stormwater design may require the temporary removal of a section of the retaining wall and footpath on the eastern side of the site boundary to allow installation of the proposed connecting pipe.

2.3 Erosion and Sediment Control

The design for erosion and sediment control will be developed as the design progresses. The design consists of plan and details which have been prepared in accordance with Landcom's "Soil and Construction Manual" (commonly known as the Blue Book), Volume 1, March 2004.

The schematic design addresses the design intent with the Contractor being responsible for confirming the design and phasing of the installation of the measures to suit the construction staging.

2.4 Pavements

Arup have not received external pavement specifications to date. External pavement details will be developed during the design development stage based upon the finishes specified by the landscape architect.

Pavement design of the loading dock and driveway ramp will be developed during the design development stage based upon anticipated vehicle loadings to be advised by the traffic engineer. Flood depths on University Avenue as discussed in Section 2.2.1 in the driveway will need to be considered to ensure the stormwater surcharge from the existing pit on University Avenue does not flow into the proposed development.

2.4.1 Construction Considerations

The driveway is likely to require removal of a portion of the small sandstone retaining wall adjacent to University Avenue.

2.5 Services Coordination

The proposed site has few existing services, with minor water, electrical and gas lines connecting to the tennis court changing rooms and a fibre optic line. Arup understands this fibre optic line services a number of the University's buildings. The depth of the fibre optic line is not on survey information and Arup recommend further investigation to ensure appropriate clearance between this conduit and the proposed subterranean driveway and OSD basin.

In consultation with CIS, connection points for proposed gas, water, sewer, and electrical services have been identified. These areas have been surveyed and the gas, water and electrical points have been determined to be suitable for connection to the proposed development. The existing sewer was blocked at the time of survey and therefore the size and invert levels have not been identified. Arup understands CIS are in the process of clearing the blockage and conducting CCTV of the existing sewer.

The proposed gas, water and electrical connection points are located a considerable distance from the site and will therefore require significant enabling works to link the proposed development. Arup has advised CIS of the possible enabling works required. It is understood this design scope will be managed by others.

2.6 Recommendations

At this stage of the design there is still uncertainty about key elements of the civil engineering design which require input from the wider design team and key decisions by CIS. Arup's recommendations include:-

- Continued co-ordination with CIS & the landscape architect on the geometric sizing of the OSD basin;
- External pavements to be specified by the landscape architect;
- Co-ordination with the architect to ensure the driveway ramp does not receive overland flow from stormwater surcharge of the existing pit on University Avenue; &
- Further investigation of the fibre optic line beneath the proposed site.

3 Structural Services

The CCW Museum building is proposed to be primarily conventional in situ and post tensioned concrete. This section of the report describes structural concepts proposed for the development.

The report:

- Contains a description of the project, the site and the structural works;
- Lists the assumptions about structural materials and loadings for the structure; &
- Sets out and explains the principle methods of analysis that will be used in the design.

It is useful for:

- Engineers or building professionals who are building the structure;
- Owners or tenants of the finished building; &
- Other members of the design team.

It should be noted that the report relates to the permanent condition of the structure only. All non-permanent works are considered temporary works.

3.1 Site Geology

Reference is made to the Geotechnical Investigation Report (GIR) prepared by Douglas Partners Pty (Ltd) Ref. 85385.01 dated September 2016 and preliminary topographical survey information dated August 2016 by AAM Survey.

The site is described as follows:-

- The Sydney 1:100, 000 Geological map indicates that the site is underlain by fill over Ashfield Shale typically comprising dark grey shale and laminate;
- The strata consists of an upper topsoil layer varying in thickness up to 0.3m overlying fill of clay and crushed sandstone to depths of between 0.5m-1.7m. A stiff to hard clay layer underlies this to depths ranging between 1.8m to 3.4m;
- Below this clay layer exists extremely low strength and very low strength laminate grading into medium strength laminate at depths 3.4m to 8m. The medium strength laminate is generally fractured. Some high strength was encountered in some bores dipping in the range of 30 to 70 degrees;
- Ground water seepage is anticipated after wet weather and not considered to be significant and controlled by subsurface drainage collection system in the basement;
- The GIR classifies the site as a site sub-soil class Be in accordance with AS1170.4-2007; &
- The following assessment of the geology of the site and ground conditions has been inferred from available information. No assurance is given to its accuracy.

Table 3 General ground geological units

Stratum	Thickness
Fill	0.5m – 1.7m
Stiff to hard clay	1.8m – 3.4m
Low to medium strength Laminite	3.4m – 8m

Table 4 Borehole Material Strata Depth

Borehole	Approximate depth to Medium Strength Laminite
1	6.9m
2	3.4m
3	2.5m
4	4.3m
5	3.3m
6	11m
7	6m
8	9.5m
9	5.7m
10	6.4m
11	8m
12	7.2m

A number of other GIR have been undertaken in the surrounding area namely:-

- Ref. GEOTLCOV23558AC (August 2009) Cored Borehole Log WM2/BH8 by Coffey Geotechnics Pty (Ltd);
- Ref. GEOTLCOV2583AE-AC Rev1 (May 2016) Geotechnical Report for Development Application by Coffey Geotechnics Pty (Ltd);
- Ref. 85385.00 (March 2016) Desktop Geotechnical Study for Chau Chak Wing Museum – Site A.
- Ref. 85385.01.R001 (October 2016) Report on Geotechnical Investigation.

3.1.1 Site Topology

The topography of the site falls from west towards the east across the site. The existing ground level ranges between RL +35m AHD on the west perimeter of the building to +30.4m AHD on the east.

3.1.2 Contamination

No reference is made to contamination in the Douglas Partners Geotechnical Investigation.

3.1.3 Groundwater

Seepage has been noted to be anticipated to occur during wet weather but not significantly impact the permanent works. A subsurface drainage collection system has been recommended around the perimeter of the lowest basement.

3.2 General Structural Performance Requirements

This report is to be read in conjunction with the structural drawings, draft structural specifications and the design standards described.

3.2.1 Design Life and Durability

The structure will be designed for a 50 year design life and thus specifically comply with the requirements of AS3600:2009 Concrete Structures and AS2159: 2009 Piling-Design and Installation in addition to those listed in the design standards section.

3.2.2 Client/Stakeholder Specific Requirements

The following specific design requirements were considered in the design:-

- University of Sydney Design Standards Suite. Refer: http://sydney.edu.au/about/working-with-us/contractors.shtml; &
- Chau Chak Wing Museum Project Function Brief.

3.2.2 Design Loading Criteria

Refer to Section 3.9 of this report.

3.2.3 3.2.4 Design Standards

3.2.4.1 BCA Structural Provisions

Importance Level of Building: 3 - Structures designed to contain a large number of people

• Design Events for Safety	Annual Probability of Exceedance
• Wind:	1:1000
• Earthquake:	1:1000

3.2.3.1 3.2.4.2 Codes and Standards

The following codes and standards are to be used through the project design phase:

AS/NZS 1170.0: 2002	Structural design actions – Part 0: General Principles
AS/NZS 1170.1: 2002	Structural design actions – Part 1: Permanent, imposed and other actions
AS/NZS 1170.2: 2011	Structural design actions – Part 2: Wind actions
AS1170.4: 2007	Structural design actions – Part 4: Earthquake actions in Australia
AS 1720.1: 2010	Timber Structures – Part 1: Design Methods
AS2159: 2009	Piling-Design and Installation
AS2312: 2002	Guide to protection of structural steel against atmospheric corrosion by the use of protective coatings.
AS 2327.1: 2002	Composite Construction Code - Simply Supported Beams
AS3600: 2009	Concrete structures
AS3700: 2011	Masonry structures
AS4100: 1998	Steel structures
AS4600: 2005	Cold Formed Steel Structures Code
AS4678: 2002	Earth-retaining structures
BCA	AUBRCC - Building Code of Australia

3.2.4 Materials

Structural materials to be used will be predominantly reinforced concrete and post-tensioned concrete.

3.2.5 Fire Resistance

Refer to Section 3.8.8 of this report, the BCA certifier and the Fire Engineers Report.

3.3 Structural Configuration

3.3.1 General Description

The proposed structure occupies a footprint of roughly 35m x 55m in plan, 6 floors of 4m-5m floor to floor height spread across floors located within and above a basement. The basement depth on the west perimeter is approximately 15m deep and on the east 8m. The average height of the building above surface level is approximately 23m.

The basement excavation and substructure will consists of a piled retention system with suspended basement slabs. These retention piles are drilled from the existing surface.

The superstructure consists of a system of post-tensioned banded slabs spanning between reinforced concrete columns and walls. The basement arrangement is rectangular with interior and perimeter columns located on an approximate 10m grid. The basement retention wall is located adjacent these perimeter columns.

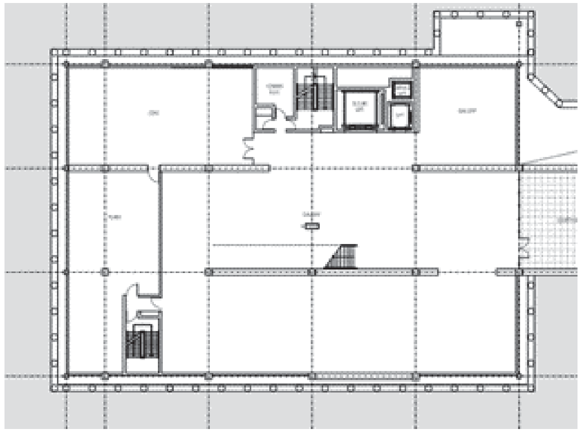


Figure 7 Typical Basement Plan Arrangement

In the portions of the building above the surface level the structure becomes a suspended cube intended to seem to float above the exterior landscaping. In order to achieve this effect the structure above the ground level floor is relatively column free around the perimeter with a central trunk consisting of the services and stair cores and some centrally located columns providing support to the suspended cube.

The suspended cube structure consisting of floor levels Upper Level, Plant and Roof Level accommodates large column free space on the west and the east sides of the Ground Floor level. The eastern portion of the cube cantilevers approximately 15m over the terrace and the west portion of the cube cantilevers approximately 12m over the foyer entrance.

In order to achieve the illusion of a floating cube a rigid structural box is proposed which extends between levels Upper Level and the Roof Level. The purpose of this box which runs around the perimeter of the building footprint is to create floor slab edge support for the suspended slabs at levels Upper Level, Plant Level and Roof Level. The floors typically deliver the floor loads to the eastern and western perimeter walls which in turn act as a deep simply supported beam to deliver the loads to the north and south perimeter walls.

Building stability and resolution of the out-of balance forces generated by the non-symmetric excavation is achieved by using a system of shear walls in the lift lobby and services riser core areas.

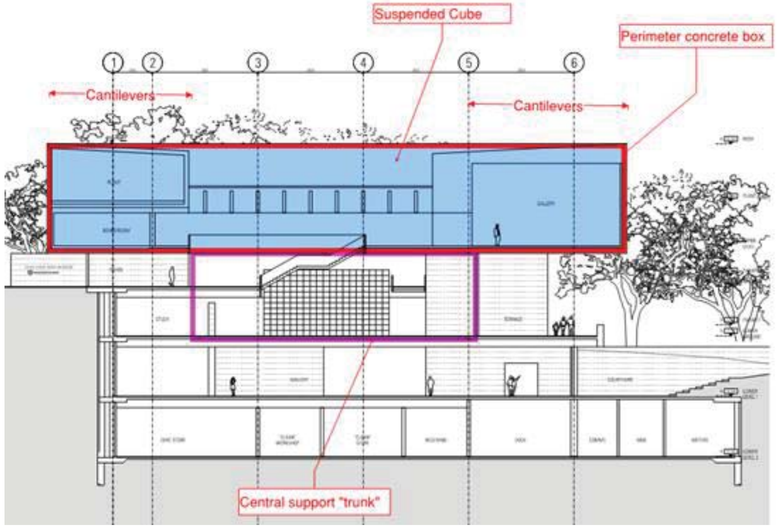


Figure 8 Typical building section describing the floating box arrangement

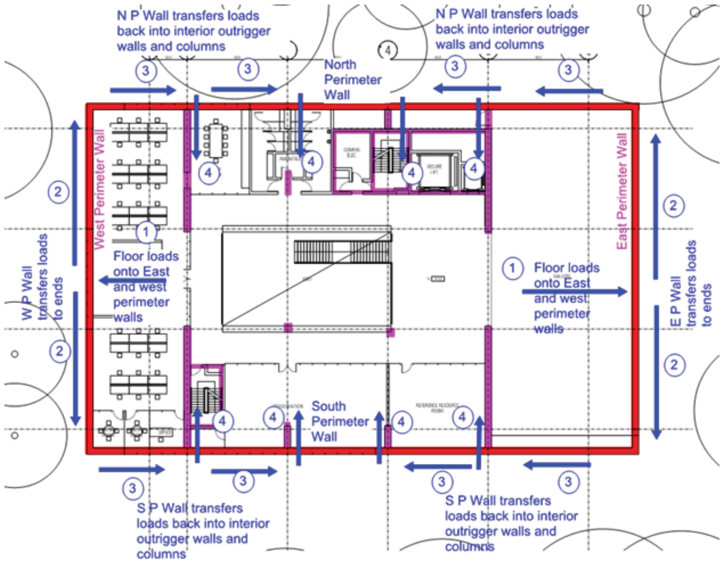


Figure 9 Arrangement of flow of forces through rigid structural box

General Building Data:

Building height above ground:	approx. 16m ~23m
Number of stories above ground:	3
Typical floor to floor height:	4000 – 5000mm
Number of basement levels:	3
Number of plant levels:	Lower level 2, Lower level 1 & Plant
Primary Grid (approx.):	approx. 10m x 10m

3.4 Stability

3.4.1 General Performance Requirements

The structure is to be analysed by static and dynamic analysis in accordance with AS 3600 and AS 1170.

The stability design of this structure is driven by:-

- Notional/Robustness loading requirement of AS 1170.0 Section 6.2. This requires 1% of the gravity service load (G+Ψc Q) applied horizontally at each level. The connection between the core walls and the structure is also designed to resist 5%G at each level;
- Seismic requirement of AS 1170.4. The Douglas GIR classifies this site as Sub-Soil Class Be.
- The wind loading requirements of AS 1170.2; &
- The above actions in combination with lateral forces generated from unbalanced lateral earth pressures between the western and eastern perimeter walls.

The parameters for the above lateral loads are described under the horizontal loads portion of the design criteria Section.

3.4.2 Stability System

The structure is a concrete framed building with the stability system provided by in-situ reinforced concrete shear walls provided by the central lift lobby and services riser zones. The effect of columns have been ignored.

The core walls provide stability in both orthogonal directions. The building frame system will be designed to AS 3600 and the shear walls detailed in accordance with AS 3600 Appendix C as ductile shear walls including the provision of boundary elements in accordance with this clause.

The shear walls are supplemented by slabs at ground level and lower level 1 that act as a diaphragms to tie the perimeter retaining wall system and transfer unbalanced lateral earth pressure loads into the cores. Lateral forces are to be resisted by the building core walls.

3.5 Substructure

3.5.1 General Performance Requirements

A contiguous piled retention system has been advised by the GIR and shall be detailed designed by the specialist subcontractor.

Internal piles or spread footings shall support building column loads within the basement perimeter. A number of perimeter basement columns are located close to the perimeter piled shoring wall and these will need to be constructed as piled footings in order to avoid influencing the shoring piles.

3.5.2 Site Preparation

Site preparation shall be carried out in accordance with the project specific geotechnical report and specification requirements prepared by Douglas Partners Pty Ltd.

3.5.3 Superstructure Foundations

The geotechnical information from Douglas Partners indicates that spread footings or piled foundations are the most appropriate solution for the site. If piles are preferred a system of piles can be designed by the specialist piling subcontractor socketed into the medium strength laminate or spread footings onto the same stratum.

If piling is undertaken from the surface, single columns on single piles with pile caps, footing beams at wall locations and pile caps above pile groups such as in the stair core can be provided. If piling is undertaken from the excavated basement single pile caps can be avoided and single columns fixed into single piles. The latter is the preferred and most efficient structural configuration.

The design of internal bearing piles shall be undertaken by a specialist trade subcontractor based on Arup loads and performance requirements.

Design parameters from the GIR for piling are described below:-

- Allowable bearing pressure of 3500kPa in the Medium Strength Laminite;
- 350kPa allowable skin friction in compression for piles in the Medium Strength Laminite; &
- 200kPa allowable skin friction allowance in tension for piles in the Medium Strength Laminite.

Pile design shall be undertaken in accordance with AS 2159-2009, Douglas Partners Geotechnical Investigation, the concrete cover and crack control requirements of AS3600 and the following supplementary design considerations:-

- Piles are design as free-headed at the basement slab on grade level;
- Minimum pile spacing to be 2 pile diameters to engage skin friction and end bearing. Piles spaced closer than 2 diameters will engage end bearing only;
- Pile settlement under service loads limited to 1% of pile diameter; &
- No hydrostatic uplift effects due to any groundwater.

The Geotechnical Investigation describes seepage during wet weather is expected and can be controlled by providing perimeter subsurface drainage below the lowest basement slab.

The basement slab shall be designed as a ground bearing slab undertaken in accordance with AS 3600 the concrete cover and crack control requirements.

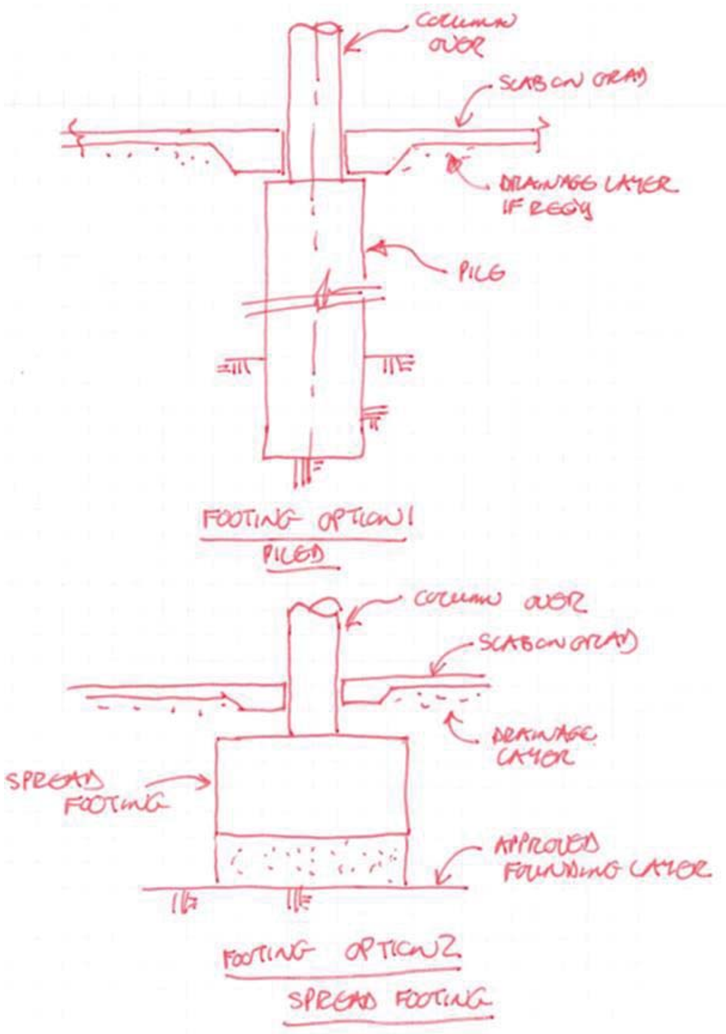


Figure 10 Typical foundation options.

3.5.4 Basement Piled Retaining Wall

The geotechnical information from Douglas Partners describes that a suitable lateral support system for excavations and the permanent basement is of contiguous pile type with infill shotcrete.

The system for temporary support of the excavation will consist of a combination of temporary anchors which will be subsequently permanently propped by the ground and lower level 1 slabs.

Design of the retaining walls will be undertaken by a specialist piling subcontractor based on performance and minimum load effect requirements provided by Arup.

The retaining wall shall be designed in accordance with the design actions provided from the geotechnical wall modelling and the structural stability model.

The geotechnical investigation describes medium to high strength laminate at approximately RL25m which implies that within the basement space which has lower level 2 at RL20m, excavation within the medium to high strength laminate will occur over a depth of approximately 5m. This also means that the toes of shoring piles will need to be socketed into the laminate and bearing onto a laminate rock shelf. An allowance for stabilising this rock layer below the pile footing toes will need to be made- this can include rock bolts and/or shotcreting. The excavation will need to be inspected by a qualified geotechnical engineer during construction and strengthening nominated during these works.

Pile design shall be undertaken in accordance with AS 2159-2009, Douglas Partners Geotechnical Investigation, the concrete cover, crack control and crack width requirements of AS3600 and the following supplementary design considerations:-

- Temporary excavation & permanent propped condition and the associated effects of temporary hydrostatic pressures;
- The principal of superposition in considering the effects of floor loads on the top of the pile wall; &
- The load effects on the piles from the building stability model ignoring soil spring stiffness behind the wall up to the basement level.

The pile wall shall consider the lateral/propping loads provided from the geotechnical wall modelling.

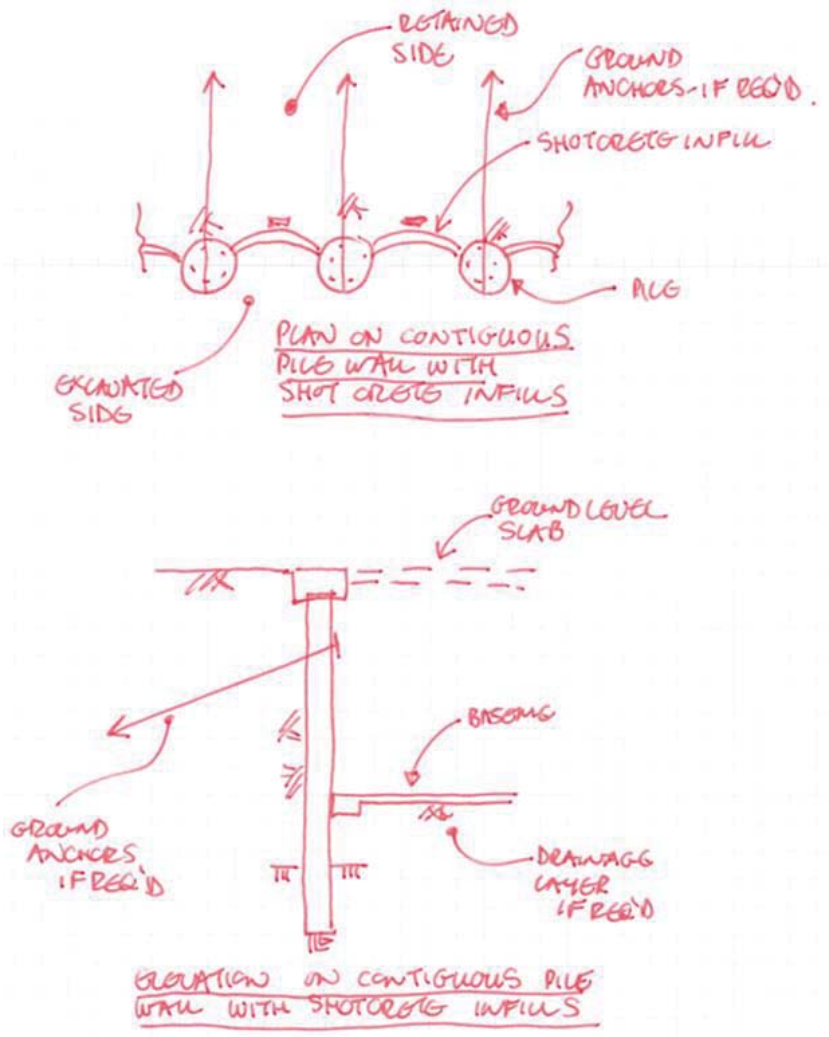


Figure 11 Typical configuration of shoring wall.

3.6 Superstructure

The superstructure will extend above ground floor level and comprise a footprint of approximately 55m x 35m.

3.6.1 Horizontal Structure

3.6.1.1 Floor Slabs

The floor structures for slabs above lower level 2 is proposed to be post-tensioned banded slabs. The basement lower level 2 slab is reinforced concrete slab on grade.

Specific consideration of the following items has been given to the design of the floor slab systems:-

- Shortening effect of post-tensioned slabs;
- Shrinkage and creep of slabs, in particular post-tensioned slabs;
- Restraint of reinforced and post-tensioned slabs;
- In plane forces in reinforced and post-tensioned slabs; &
- Slab/wall connection details including proprietary cast-in systems.

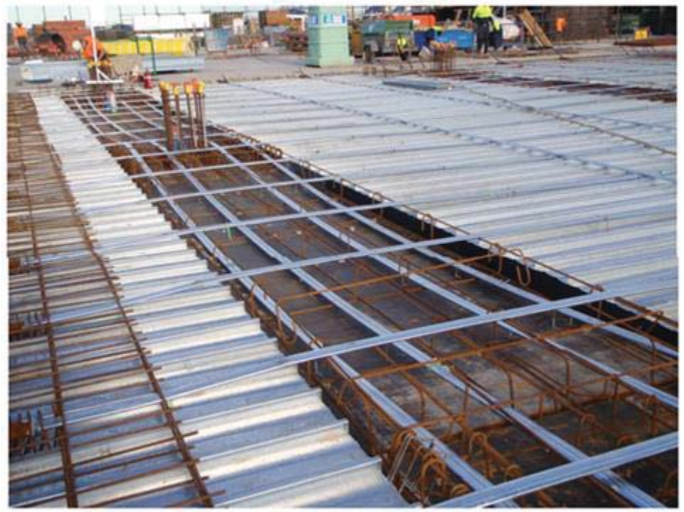


Figure 12 Post Tensioned Banded Slab.Figure 12

3.6.2 Vertical Structure

Vertical loads will be supported by a combination of the reinforced concrete walls and reinforced concrete columns.

A system of internal and perimeter columns are provided to support vertical floor loads. In some instances due to architectural layout, columns need to be transferred using a system of transfer beams. These are typically located at the ground level floor above the dock areas on Lower Level 2.

3.6.2.1 White Concrete

The floating concrete cube, as the main feature of CCW museum building is intended to be constructed in white concrete enclosing the upper exhibition space (approximately 55m long x 35m wide x 9m tall x 400mm thick wall). The white concrete box will not be cladded and will form the façade of the building and be directly visible. The white concrete box also acts as structural deep beams supporting all the upper level slabs and thus is a major structural element. The white concrete box will be post tensioned and reinforced to achieve a strong degree of crack control for appearance to AS3600. It is anticipated that the white concrete box will be specified as Class 2C colour off form finish to AS3610. This is to be confirmed with the architects.

Boral has been consulted on the feasibility of using white concrete and on design and construction considerations. Both Off White cement and ENVISIA have been put forward as possible cement to achieve the white concrete appearance with the aspect of sourcing considered. Boral has advised Pure White cement is expensive and is not available.

Photo of samples can be seen below. It is to be noted that the upper face of the colour samples (the one with the stickers/ labels) is less representative than the underside representing off form finish. (the one without the stickers/ labels). Off White is said to show a lighter beige colour. It is said ENVISIA with the addition of Arctic Oxide could also be used to lighten up the colour again. Boral will have to be further consulted to understand the colour result.

It is to be pointed out that the CCW museum bears resemblance to the National Portrait Gallery in the parliamentary precinct of the Australian Capital Territory, which JPW won an international competition in Nov 2005 to design the building with Arup being the structural consultant. The project used Boral's off white cement in its construction of the feature cantilever walls at the entrance. Please see below for photos of the National Portrait Gallery.

Off White Cement is traditionally often selected for exposed concrete architectural finishes in prestige public buildings and landmark commercial developments. Off White Cement is lighter coloured than traditional dark grey General Purpose Portland cements. When used with selected sands and aggregates it produces a concrete that is much lighter than normal concrete. It is called Off White to distinguish it from White Cement. Off White Cement has performance characteristics that conform to the requirements of AS 3972 and AS 3600 and are suitable to be used in post tensioned construction.

ENVISIA is an alternative binder to Off White cement that can equally achieve white colour finish. It has started to become more widely used in recent years.

In terms of pricing, Boral has advised it can be requested from their sales team.

Construction joints will be required along the length of the white concrete walls. Post tensioning couplers will be used at the construction joints in conjunction with conventional reinforcement to ensure the entire length of walls are consistently compressed to reduce the risk of cracking at joints. The pouring sequence will be planned in an alternate pattern with joint locations agreed with the architects to allow movement to occur in a newly poured wall without being locked by adjacent wall portion. Other measures which will be considered to safeguard the appearance of the featured white concrete walls can include cooling the concrete prior to placing. This is to be developed in consultation with the concrete supplier, contractor and concrete specialist.

The overall impression of the colour of the finished concrete is determined by the cement used and the inherent colour of the sand and aggregates as well as other delivery and construction factors. Due to the large scale of the white concrete walls in the CCW Museum project, to maintain an overall impression of colour consistency, early involvement of contractor and concrete supplier are recommended to ensure sufficient single sourcing of sand and aggregates can be planned and set aside for the project to completion. Dedicated quarry stockpiles for sands, water/cement ratio controls, sand moisture controls, delivery service, truck spacing, skills of builders and concrete placers, and site supervision are all important considerations to achieve a good result. All parties need to be involved to decide on the process that will achieve the colour consistency. Sample panels can be arranged, but depending on lead times it would not be possible to hold the quarry materials until the actual pour dates.

In short early involvement of the contractor and the concrete supplier and close liaison of the contractor and the concrete supplier with the design team in the concrete selection process and construction methodology will ensure an end result of successful application of white concrete in the project.

3.6.3 Facade

The facade configuration is yet to be developed and the current allowance if for a lightweight glazed curtain wall or stick façade. The facade will spans vertically between floors and is supported at each level on concrete edge beams.

3.7 Subcontractor Design

Currently the following packages shall be sub-contracted to the industry;-

- Retaining wall pile design; &
- Internal bearing piles.

3.8 Specific Performance Requirements

A number of specific performance requirements have been considered in the design of the structure and are described below.

3.8.1 Safety-in-Design

The design shall adequately consider the safety of personnel, plant and equipment during the construction of the structure and the installation of plant, equipment, fixtures and fittings. The design process shall conform to Arup Safety in Design procedures. Reference is made to the Arup Safety in Design Risk Register.

3.8.2 Serviceability Parameters

Unless noted otherwise in the specific sections discussed below, serviceability requirements for reinforced concrete and structural steelwork shall generally be in accordance with AS 3600, AS 4100.

3.8.3 Vertical Movements

In addition to the general parameters described previously a number of areas shall be given particular attention:-

- Column shortening; &
- Concrete beam and slab deflection.

3.8.3.1 Concrete Deflections

Deflections shall be calculated using Rapt incorporating all loads on the span. The facade load shall be applied as additional self-weight and the incremental deflection interrogated.

The following deflection limits shall be incorporated into the design:-

Element	Deflection limit under Total Load	
	Spans	Cantilevers
Beams and slabs:		
Generally	L/250 or 35mm max	L/125 or 35mm max
Live load only	L/360	L/180
Supporting articulated masonry	L/500 (incremental)	L/250 (incremental)
Supporting light facade (glazing)	L/500 (incremental)	L/250 (incremental)
Transfer structures*	L/1000 or 15mm max	L/500 or 15mm max
Storey drift under seismic load	H/66 or 1.5%H (ULS)	
Overall sway under wind load	H/500	
Pile Settlement	1% of Pile diameter	
Differential Pile Settlement	Grid spacing/1000 or 10mm whichever is least.	
Horizontal Pile Movement	H/500	

*denotes cumulative deflection at column/wall location

Typically due to the sensitive nature of perimeter facades, particular attention shall be given to deflection in these locations.

Deflection limits described in the above table are calculated under the following load combinations:-

Deflection Type	Combination	Time
Initial Deflection (ID)	G + SDL1	Before loading
Short Term Deflection (ST)	G + SDL1 + 0.7Q	At first loading
Long Term Deflection (LT)	G + SDL1 + SDLextra + 0.4Q + Creep + Shrinkage	30 years
Incremental Deflection (Inc.)	LT-ID	

G Self weight

SDL1 Hobs, Upstands, 1kPa floor finish

SDLextra Facade, 0.7kPa internal partitions, services

3.8.4 Horizontal Movements

Particular attention shall be given to the following:-

- Seismic (ULS);
- Wind (SLS);
- In-plane shrinkage and creep effects of banded slabs; &
- In-plane effects due to out of balance lateral earth pressures between the eastern and western retaining walls.

Horizontal movements associated with seismic SLS loads are not required to be considered.

3.8.5 Floor Vibration

Vibration of the superstructure floors is controlled by checking the natural frequency and associated response factor. Verification calculations will be conducted to the SCI (Steel Construction Institute of Great Britain) publication `Design Guide on the Vibration of Floors'.

Currently, there are no client specified criteria. However, if there are any areas where vibration control of the structure is particularly critical, or there are specific requirements for pieces of equipment or artworks, this will need to be identified and incorporated in the developed design.

The following areas could be susceptible to structural vibration, and will need to be considered further in the next design stage:-

- Special use areas with sensitive equipment;
- Motion resulting from footfall-induced vibration shall be limited to a Response Factor (RF) of 8 in the office areas. (To be clarified in subsequent design);
- Internal stairs and walkways shall be designed for a RF of 64; &
- External stairs and walkways shall be designed for a RF of 128.

3.8.6 Durability

3.8.6.1 Concrete

The concrete structural elements will be designed for the durability requirements described and for the site classification of AS 3600, AS 2159 and the Geotechnical Investigation.

Exposure classification:

Surface location	Class	Minimum f'c
Exterior Element	B1	40 MPa
Interior Element	A2	40 MPa
In Ground (From existing surface to 1m below)		
B1	40 MPa	
In Ground (Piling)	B1 (Mild)	32 MPa

Structural requirements for certain elements may increase concrete strengths above the minimum required for durability. Concrete strengths shall be described in the specifications document and the structural drawings.

3.8.6.2 Concrete Grades:

The concrete components on this project shall be of the following grades:

Element	f'c (MPa)
Blinding concrete	N25
Piles	S40
Pile caps/footings (exposed)	S50
Slab on Ground	S32
Suspended slab, bands and beams	S40
Columns	Varies - S40 to S65
Walls	Varies - S40 to S65

3.8.6.3 Concrete Covers

The minimum concrete covers to any reinforcement to meet the specified durability and fire resistance for the specified concrete grade shall be in accordance with Section 5 and Table 4.10.3.2 of AS 3600.

A summary of the minimum specified nominal clear cover to all reinforcement including fitments for various elements unless noted otherwise on the drawings are as follows:

Element	Cover (mm)	Exposure Classification
Footings	50	A2
Retaining Walls	40	A2/ B1
Slab on Grade	40	A2
Walls	30	A2/ B1
Columns	30	A2
Suspended Slabs	30	A2
Beams	30	A2
Precast Panels	30	B1

*Protected with a damp proof membrane

3.8.6.4 Crack Control

The degree of crack control to be provided in structural concrete slabs, beams and walls (refer AS 3600 clauses 8.6, 9.4 and 11.7.2) will be as follows:

Element	Location/ Exposure	Degree of Control
Slabs and beams	Internal	Minor
Slabs and beams	External	Strong
Walls	External	Strong
Walls	Internal – hidden from view	Minor
Walls	Internal – exposed to view	Moderate/ Strong

3.8.7 Structural Steelwork

3.8.7.1 Corrosion Protection

The corrosion protection for the structural steelwork will be dependent on the location of the steel elements within the building. Systems will be selected in accordance with AS/NZS 2312 as a minimum specification.

As a minimum a three coat paint system should be considered and specified by the architect.

3.8.8 Structural Fire Resistance

Fire Resistance Levels (FRL's) for structural elements shall be determined in accordance with the BCA and any subsequent approved relaxations. The BCA consultant has advised that various parts of the building fall into class 5 office, class 6 cafe (180/180/180), class 7b storage (240/240/240) and class 9b assembly building of the BCA, with the design FRL's required for these classes being generally 120/120/120 unless noted otherwise above.

Fire Safety Engineer to confirm the reduction to 120/120/120 on the Lower Ground level and Lower Level 2.

3.8.8.1 Concrete

Concrete covers are to be in accordance with AS 3600 Section 5. The fire rating of blockwork walls is to be shown on the architect's schedule.

3.8.8.2 Structural Steelwork

A fire engineered approach will need be undertaken to minimise or alleviate the requirement for passive protection to structural steel wherever possible. Fire protection of steelwork will be required for any hanging structure on the roof and Upper Level floors.

3.9 Design Criteria

3.9.1 Vertical Loading

In addition to the details provided below refer to the Arup loading plans.

3.9.1.1 Superimposed Dead and Imposed Live Floor Loads

The structure will be designed for the following imposed loads:

Area	Superimposed Dead Load	Live Load
Offices	1.0 kPa moveable partitions 0.2 kPa floor finishes 0.5 kPa ceiling and services	3.0 kPa 7.5 kPa for compactus zones
Lounge/Cafe area Kitchens	1.0 kPa moveable partitions 0.2 kPa floor finishes 0.5 kPa ceiling and services	3.0 kPa
Auditoriums/Gallery Spaces	0.5 kPa ceiling and services 1.5 kPa raked seating	4.0 kPa
Lobby/Foyer	0.5 kPa ceiling and services 1.2 kPa finishes	4.0 kPa
Toilets	1.0 kPa moveable partitions 0.2 kPa floor finishes 0.5 kPa ceiling and services	2.0 kPa
Storage	1.0 kPa moveable partitions 0.2 kPa floor finishes 0.5 kPa ceiling and services	5.0 kPa
Terraces (including trafficable roofs)	0.5 kPa ceiling & services 4.5 kPa finishes	4.0 kPa
Stairs and corridors	1.6 kPa 75mm asphalt tiles Or 0.55 kPa 25mm tiles Or 0.2 kPa light finishes 0.5 kPa balustrades	4.0 kPa
Carparking and ramps	-	2.5 kPa 5.0 kPa in areas of medium

Area	Superimposed Dead Load	Live Load
		vehicle traffic areas
Loading Dock	2.0 kPa finishes	7.5 kPa
Plant Areas	2.0 kPa finishes 0.5 kPa ceiling and services	As calculated for relevant use. 7.5 kPa minimum
Electrical Rooms	As calculated for trenches, plinths, and fire rated walls if required	7.5 kPa
Non-trafficable concrete roofs	0.5 kPa ceiling & services 2.0 kPa finishes	1.5 kPa
Lightweight roofs	As calculated	Generally 0.25 kPa Street awnings 1.0 kPa

Superimposed dead loads (SDL) include ceiling, services, partitions and finishes (i.e. permanent loads additional to the self-weight of the structure).

The live load allowance for typical and non-typical areas are in accordance with AS 1170.1. Concentrated loads in accordance with the code are not combined with uniform load.

Areas where special load conditions occur shall be identified during the design process, including but not limited to:-

- Heavy storage/equipment;
- Compactus storage;
- Operable doors and walls;
- Plant installation and maintenance load conditions; &
- Tanks.

These loads and their locations, where known, will be shown on the Arup Loading Drawings.

Deflection and Vibration Limits for specialised equipment and sensitive areas require confirmation. Independent, structurally isolated support may be specified in accordance with the manufacturer's recommendations.

3.9.2 Live Load Reduction

Live loads are generally reduced when considering columns and foundations supporting several floors, in accordance with the Australian Standards.

The following loads do not qualify for reduction:-

- Loads that have been specifically determined from knowledge of the proposed use of the structure;
- Loads due to plant or machinery; &
- Loads due to storage.

3.9.3 Facade/Cladding Dead Loads

Facade	Description	Dead Load on Elevation (kPa)
Heavy Facade	Masonry	3.0
Light Facade	Glazing	0.75

3.9.4 Horizontal Loads

3.9.4.1 Wind Loading

For the structural design of components, wind loading applied to the structural elements will be assessed in accordance with AS/NZS 1170. 2. Terrain categories will be calculated based on the roughness length calculation.

In absence of wind tunnel test results, the following overall design parameters apply:-

- Region = A2
- Importance Level (BCA Table B1.2a): = 3
- Annual probability of exceedance: = 1:1000
- Regional wind speeds:
- Ultimate- V1000 = 46m/s
- Serviceability- V20 = 37m/s
- Terrain category (direction dependant) = Category 3
- Maximum Structure Height - Z = 23m
- Variation of wind speed with height - M(z, cat) = 1.00
- Topographic multiplier - Mt = 1.00
- Shielding multiplier - Ms = 1.00
- Wind direction multiplier - Md = 1.00

Summary

- Design wind speed (ultimate) = 46m/s qu=1.270kN/m² Cfig Cdyn
- Design wind speed (serviceability) = 37m/s qs=0.820kN/m² Cfig Cdyn

Apply local pressure coefficients or area reduction factors as required.

3.9.4.2 Seismic Loading

Earthquake loading applied to the structural elements will be assessed in accordance with AS 1170.4. The following design parameters apply:-

• Importance Level (BCA Table B1.2a)	I	=	3
• Probability Factor	kp	=	1.3
• Hazard Factor	Z	=	0.08
• Site Sub-Soil	Class	=	Be
• Earthquake Design Category	EDC	=	III
• Structural System		=	Ductile Shear Walls
• Structural Ductility Factor	u	=	3
• Structural Performance Factor	Sp	=	0.67
• Building Height	hn	=	23m
• Factor for determining building period	kt	=	0.05 (all other structures)
• Codified Fundamental Natural period	T1	=	0.9 sec
• Spectral Shape Factor	Ch(T1)	=	0.98

3.9.4.3 Earth Pressure Loading

The basement excavation and permanent retaining wall shall be designed in accordance with the recommendations in the Geotechnical Investigation. The preliminary assessment indicated that a tanked retaining walls system in the form of contiguous piles be adopted. These walls will require temporary support in the form of ground anchors or internal propping.

The walls will be designed for earth pressure and surcharge loads, adopting soil pressure coefficients recommended in the Geotechnical Report.

As a minimum the following will be used:-

- Ka = 0.3; &
- Ko = 0.15.

Surface surcharge live loads: 20kPa

3.9.4.4 Water Pressures

Specific reference shall be made to the Geotechnical Investigation for a description of the lateral water pressure likely to occur. As described in the geotechnical Investigation only minor seepage is expected through the retaining walls. The shotcrete infill sections of the shoring wall will be provided with a vertical wick-drain and as such the basement is considered a conventional drained basement.

3.9.4.5 Accidental Horizontal Loads

• Handrails (Offices and fire stairs)	=	0.75 kN/m or 0.6kN in any direction
• Terraces:	=	1.5 kN/m or 0.6kN in any direction
• Maintenance walkways & stairs:	=	0.35 kN/m or 0.6kN in any direction
• Carpark parapets, walls, barriers:		In accordance with AS/NZS 1170.1.
	=	30 kN generally
	=	40 kN loading dock
	=	240 kN at base of ramps > 20m long
• Delivery area columns:	=	40 kN

3.9.4.6 Minimum Lateral Loads

Interior walls, permanent partitions and their fixings and supports, shall be designed to resist all loads to which they are subjected, but not less than a lateral force of 0.25kPa applied perpendicular to the walls.

3.9.4.7 Vehicle Impact

Some columns in the basement level and loading dock zone may need to be designed for impact loading in accordance with AS 1170.1. Alternatively, protective measures may be adopted to prevent impact loads on the structural elements. In the case of the loading dock, it is assumed sacrificial barriers will be included to minimise damage of the structural columns.

3.9.5 Imposed Movements

The effect of imposed movements on the structure will be considered in the calculations.

These include:-

• Settlement:	1% of footing width at allowable bearing pressure;
• Heave:	Either absolute or differential;
• Temperature range:	Exposed structure +65°C and -10°C from mean temp 20°;
• Shrinkage:	Floor slabs - design shrinkage 650 microstrain;
• Vertical structure:	Design shrinkage 650 to 850 microstrain;
• Creep:	Floor slabs and vertical structure; &
• Elastic shortening:	Vertical structure and elements under prestressing.

3.9.6 Structural Robustness

The structures shall provide load paths to the foundation for forces generated by all types of actions from all parts of the structure, for the minimum actions as given in Clauses 6.2.2 to 6.2.5 of AS 1170.0. The key minimum actions are described below.

3.9.7 Minimum Resistance

The structure shall have a minimum lateral resistance equivalent to 1% of $(G + \Psi cQ)$ for each level, applied simultaneously at each level for a given direction.

3.9.7.1 Minimum Lateral Resistance of Connections and Ties

All parts of the structure shall be interconnected. Connections shall be capable of transmitting 5% of the value of $(G + \Psi cQ)$ for the connection under consideration.

4 Mechanical Services

The design of the mechanical services will be centred on a minimalist, unobtrusive approach, with particular consideration given to measures that will help deliver the tightly controlled internal environments demanded by Galleries & Museums whilst balancing occupant comfort and associated energy considerations.

4.1 Standards, Codes, Authorities and Guidelines

The mechanical services design and works will meet all requirements of all national and local Statutory Authorities and will be in accordance with the following:-

- University of Sydney Design Standards:
- Mechanical Services Standard;
- Building Management and Control Systems Standard;
- Essential Fire Safety Measures Standard;
- Advanced Utilities Monitoring System Standard;
- Sustainability Standard;
- Sustainability Framework;
- Specific requirements from the University of Sydney and the building users;
- National Construction Code (NCC) / Building Code of Australia (BCA);
- AS1668.1 – The Use of Ventilation and Air-Conditioning in Buildings, Part 1: Fire and Smoke Control in Multi-Compartment Buildings;
- AS1668.2 – The Use of Ventilation and Air-Conditioning in Buildings, Part 2: Mechanical Ventilation in Buildings;
- AS 2107 – Recommended Design Sound Levels and Reverberation Times for Building Interiors;
- AS/NZS 3000 – Australian/New Zealand Wiring Rules;
- AS 3500 – National Plumbing and Drainage Code;
- AS 3666.1 – Air-Handling and Water Systems of Buildings – Microbial Control – Design, Installation and Commissioning;
- The American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE) HVAC Applications Handbook;
- WorkCover requirements;
- OH&S regulations;
- Fire Brigade requirements;
- All Local Council regulations;
- City of Sydney regulations;
- Gas Authority requirements;
- Applicable fire engineered solutions; &
- Building permit conditions.

4.2 Design Criteria

4.2.1 External Design Conditions

The following seasonal design conditions have formed the basis of our design in accordance with the University of Sydney Design Standards:

Summer: 35.0°C DB / 24.0°C WB / Full Solar Load

Winter: 6.0°C DB / No Solar Load.

This criteria has been selected based on established historical and benchmark design data for Sydney.

The above external conditions are typically only exceeded for 3-5% of the year. They are used as a peak weather condition for the purposes selecting plant and equipment.

If external conditions exceed the design criteria stated, the systems will not fail. It is likely that inherent diversities will allow the systems to cope with more extreme external conditions. For example, plant capacities will be selected to allow for all areas of the building to be fully catered for simultaneously at the above external design conditions. The likelihood of this occurring in practice is very small.

That said, diversified usage profiles of the functional areas will be an important consideration when finalising the peak heating and cooling demands and hence maximum plant capacities for the facility.

4.3 Environmentally Sustainable Design

Arup has been working closely with the ESD team at Steensen Varming to ensure, where possible, the targets in the sustainability framework are met. In line with the sustainability framework we will be targeting the following initiatives;

- Sustainable plant; chillers, boilers, fans, humidification (ultrasonic)
- Inclusion of thermal mass
- Metering
- Seasonal adjustment of temperature and humidity setpoints in gallery spaces
- CO2 monitoring and control in non-critical spaces
- Space in risers and plantrooms for infrastructure future proofing

4.3.1 Internal Design Conditions

Generally all systems have been designed to provide the internal conditions detailed in the following table. Individual room requirements will be continually reviewed and developed further during the design development process so to confirm functional requirements.

Table 5 Conditions Schedule

Space Type	Room Temp	Relative Humidity	Estimated Occupancy	Air Changes per Hour	Min. Outside Air	Min. Exhaust Air	Occupant Heat Load		Lighting Load (4)	Equipment Load (5)	24 Hour Operation	Notes
				ACH			Sensible	Latent				
	(°C DB)	(%)	(m2/person)	(/hr)	(L/s/person)	(L/s/m2)	(W/person)	(W/person)	(W/m2)	(W/m2)	(Y/N)	
Gallery Spaces												
General Galleries	21 ± 2	50 ± 10%	5	10	7.5*	-	70	60	20	5	Y	ASHRAE Class A Control
Arrival Gallery/Foyer	19-26	30 - 70% (2)	5	-	7.5*	-	70	60	20	5	N	
Temporary Galleries/Loan Rooms	21 ± 2	50 ± 5% (1)	5	10	7.5*	-	70	60	20	20	Y	ASHRAE Class AA Control
Study/Schools Education Rooms	21 ± 2	50 ± 10% (3)	3	-	7.5*	-	70	60	12	20	N	
Art Storage and Quarantine Spaces	21 ± 2	50 ± 10%	-	4	-	-	70	60	10	5	Y	ASHRAE Class AA Control
Receiving	23 ± 2	50 ± 10%	-	4	-	-	70	60	10	5	Y	ASHRAE Class A Control
General Office Spaces												
Open Plan Offices	20 – 24	30 - 70% (2)	8	-	7.5	-	70	60	9	15	N	
Private Offices	20 – 24	30 - 70% (2)	10	-	7.5	-	70	60	9	15	N	
Meeting Rooms	20 – 24	30 - 70% (2)	2	-	7.5	-	70	60	9	15	N	
Lecture Theatre	20 – 24	30 - 70% (2)	1	-	7.5	-	70	60	9	15	N	
Corridors	20 – 24	30 - 70% (2)	-	-	1 L/s/m2	-	-	-	-	-	N	
Staff Room	20 – 24	30 - 70% (2)	5	-	7.5	-	70	60	9	15	N	
Cafe	20 – 24	30 - 70% (2)	2	-	7.5	-	70	60	9	15	N	Kitchen exhaust rate to be confirmed
Building Support Spaces												
Plant Rooms	NC	NC (4)	-	-	-	5	-	-	5	-	N	
Store Rooms	NC	NC (4)	-	-	-	5	-	-	5	-	N	
Cleaners Cupboard	NC	NC (4)	-	-	-	10	-	-	5	-	N	
Toilets / Change Rooms	NC	NC (4)	-	-	-	12.5	-	-	8	-	N	
Serveries and Kitchenettes	NC	NC (4)	-	-	-	5	-	-	10	30	N	Kitchen loading and exhaust rate to be confirmed

Legend: NC = Not controlled TBC = To be confirmed

Notes:

1. Temporary gallery to achieve loan conditions during visiting exhibitions. In this mode, separation from adjacent spaces may be required in order to keep conditions. Out with these exhibitions temperature and humidity bands can be relaxed in line with other gallery spaces.
2. Humidity band not actively controlled. Normal air conditioning process should inherently keep humidity between 30-70% for the majority of the year.
3. Study rooms to be conditioned as A Galleries. Art pieces may be held in these spaces.
4. No air conditioning proposed. Ventilation only. Temperature and

*Actual Min, Outside Air rate to be greater of 10% of ACH or L/s/person

In order to satisfy the University of Sydney Design Standards all toilets shall be provided with a 25% higher exhaust rate to ensure they remain negatively pressurised.

4.3.2 Air Filtration

Air filters are to be installed in air handling units and outside air intakes so as to protect plant equipment and maximise service life. These filters shall be Type 1, Class B, in accordance with AS 1324. Air handling units which serve gallery areas shall be provided with space for installation of active carbon filters to remove gaseous contaminants. Carbon filter requirement will be assessed during the next design stage.

Filtration levels to the individual spaces shall generally be as detailed below:

Table 6 Filtration Level Schedule

Space Type	Pre Filter	Fine Filter	Other Filtration
Lobby / Office Areas	G4	F7	
Gallery Areas	G4	F8	Space allowance for active carbon
Other Spaces	G4	F7	

4.3.3 Ductwork Sizing Criteria

All ductwork shall be sized so as not to exceed the values listed below:

- Plant Rooms & Risers 7.5 m/s
- Main Horizontal Duct Runs 5.5 m/s
- Branch Ducts: 3.5 m/s
- Terminal Flex Ducts: 2.0 m/s
- Maximum pressure drop: 0.8 Pa/m
- Louvre face velocity: 1.5 m/s

Lower velocities than those listed may be necessary as per acoustic considerations.

4.3.4 Pipework Sizing Criteria

All pipework shall be sized so as not to exceed the values listed below:

- Velocity: 1.5 m/s
- Pressure Drop: 200 Pa/m

4.3.5 Acoustic and Vibration Control

All mechanical systems shall generally be designed to meet the requirements of AS 2107, unless specific requirements dictate otherwise. Mechanical equipment shall be provided with suitable vibration isolation to comply with AS 2625 at a minimum.

Refer to Acoustic Engineer for further information on Acoustic Control.

4.4 Key Design Considerations

This section discusses some of the key design considerations relating specifically to Museums and Galleries.

4.4.1 Class of Control

The ASHRAE HVAC Applications Handbook establishes a “Class of Control” rating system ranging from D to AA, with correspondingly closer control for each step.

Based on the required loan agreement conditions provided as part of the briefing process, the gallery areas will require Class AA control. The table below details the allowed fluctuations in both temperature and relative humidity in order to satisfy Class AA control:

Table 7 Class AA Fluctuation Allowances

Item	Temperature	Relative Humidity
Short Fluctuations plus Space Gradients	± 2°C	± 5%
Seasonal Adjustments in System Set Point	Up 5°C / Down 5°C	No Change

- Building Fabric Thermal Performance – a thermally stable and substantially air-tight façade will assist in helping to maintain internal set points by buffering the effects of the external environment;
- Glazing Performance – solar gains are bad for artwork and will impact space conditions. It is anticipated that glazing will be selected to balance the need for natural light with the sensitive nature of the exhibits;
- Variable Building Occupancy – building occupants are a significant source of latent gains which affect room humidity levels. The mechanical system needs to capable of dealing with varying space latent gains; &
- Sensor Accuracy – humidity sensors are typically only accurate to ± 3% and are known to drift. It is anticipated that dual sensors will be used to identify any suspected drift. A testing program will also need to be implemented to periodically recalibrate units.

4.4.2 Security and Access Considerations

In museums and galleries which take ownership of valuable loaned collections security is a key issue to be factored for. These requirements have to be considered alongside proposed gallery layout.

A balance needs to be struck between easily accessible gallery spaces and the additional costs associated with access points which require individual staffed security.

4.4.3 System Redundancy and Resilience

Given the critical nature of temperature and humidity control for art preservation, it is highly desirable to have a robust and resilient mechanical system design.

Ideally N+1 units for all central plant would be provided, however this would double the associated plant costs and require considerable, additional plant space.

Alternatively it is proposed to provide multiple units for each system which all contribute to providing the total required capacity load (i.e. 2 chillers each providing 50% of the total load and 1 low load machine ensures some spare capacity and a continued significant quantity of cooling). Therefore failure of any single unit will not compromise the entire system as a percentage of the load will continue to be met by the functioning units.

4.4.4 Energy Efficiency and Running Costs

Museums & Galleries typically use larger amounts of energy relative to other building types. Furthermore, the higher control requirements to specific spaces will result in greater energy use and associated running costs.

Increased dehumidification (and associated reheat) in the summer months, along with increased humidification (and associated heating) in the winter months are examples of ways the required tight control bands will increase energy use. As well as this large volumes of air need to be tempered to meet demanding cooling loads and to ensure a good level of mixing to ensure uniform temperature and humidity levels within the space being serviced.

In order to counter act some of these higher energy uses it is proposed that the following strategies will be explored during the Schematic design phase:

- Use of high-efficiency central plant;
- Provide variable speed drives or inverters (DC power supply) on all fans and pumps;
- Air handling systems to be designed with low face velocity and pressure drop;
- De-couple temperature and humidity control systems where possible by dual cooling coils or desiccant wheels;
- Provide “free reheat” where possible via run-around coils or face and bypass dampers; &
- Control systems to be considered: Seasonal adjustments to set points, dew point control.

4.5 Proposed Central Plant Systems

The following provides an overview of the proposed central plant systems, which will be further developed during the schematic design phase.

4.5.1 Chilled Water System

High-efficiency, water-cooled chillers located on the roof shall be sized and installed to meet the peak chilled water demand. Two main chillers are proposed to cater for all of the building’s cooling requirements with an additional smaller machine for low-load operation. Each full load chiller will be sized to meet 50% of the required capacity, the smaller machine will cover a base load of 20%.

Dedicated variable speed pumps will distribute chilled water efficiently throughout the building, installed in a primary-only pumping configuration. Chilled water pipework serving air handling units and other local terminal units shall be installed at high level and arranged so as to allow for control via 2-port motorised valves linked to the building BMCS.

Heat rejection shall be provided via two cooling towers installed on the roof to reject waste heat from the chilled water plant. Plant will be shielded acoustically and visually in such a way as to limit the impact on the adjacent roof terrace.

All chilled water plant selections shall be made in accordance with the University of Sydney’s Mechanical Service Standards and BCA Section J energy efficiency requirements. In order to adhere to legislation no CFC or HCFC refrigerants will be allowed within the refrigeration systems.

4.5.2 Heating Hot Water System

Heating hot water will be generated by two high efficiency, gas-fired hot water heaters located on the roof. Each hot water heater will be sized at 60% of the required capacity. Heater flues will discharge flue gas to atmosphere in accordance with AS 5601.

Dedicated variable speed pumps will distribute heating hot water efficiently throughout the building, installed in a primary-only pumping configuration. Heating hot water pipework serving air handling units and other local terminal units shall be installed at high level and arranged so as to allow for control via 2-port motorised valves linked to the building BMCS.

4.5.3 Humidification System

Dedicated humidifiers will be provided in gallery AHUs. Humidifiers will take the form of electric resistive-type units or ultrasonic type systems. Reverse osmosis (RO) water plant located on the roof will serve to increase system performance and reduce scale build-up; resulting in a longer service life of the humidifier. 2no. humidifiers each sized to provide 50% of the peak demand will be incorporated per system to provide a degree of redundancy.

System to be further developed during the next design stage.

4.6 Air Handling Systems

4.6.1 Gallery Spaces

4.6.1.1 General Galleries & Loan/Temporary Galleries

Dedicated air handling units will be provided to gallery spaces. Industry best practice recommends 10 air changes per hour in galleries and museums. Of this, approximately 10% will be outside air and shall be drawn from atmosphere and passed through a filter before receiving either heat or cool from heating/cooling coils. Additional heat recovery will be provided by a run-around heat recovery coil, and be driven by a centrifugal fan with associated variable speed drive. Isolation damper and mixing box for partial recirculation of exhaust air from the space shall also be provided. Exhaust air shall be extracted from the space by a centrifugal fan with variable speed drive and pass through an air filter and run around heat recovery coil.

This strategy also applies to all areas that shall be housing art such as the study rooms and conservation room.

Air distribution strategy will be developed to compliment architectural intent and will be further developed during the next stage, however, currently the team is exploring the option of concealed wall distribution.

4.6.1.2 Foyer

The foyer forms the main entrance to the building and as such will be subject to greater influence from the external conditions. Maintaining close control conditions within this space is impractical and so this area is instead intended to act as a buffer space between the external environment and the adjacent climate controlled galleries within.

Fan coil units mounted in the ceiling voids of the adjacent spaces deliver heating and cooling to the space. Given its proximity to the outside and transient nature of the space, temperature set points shall be relaxed.

4.6.2 CERC Spaces

4.6.2.1 Lab

The laboratory is currently under architectural review. However, we understand it will comprise the following space types;

- Receiving; this area will be served by dedicated air handling plant. This space is generally used for receiving works from transportation. To avoid thermal shock (sudden increase/decrease in temperature or humidity this space is generally kept slightly warmer than the main galleries. The warmer temperature also encourages any bacteria that may be lying dormant in the art pieces to show.
- Quarantine; Area used for keeping works that are infected with bacteria or pests. Room will be provided with dedicated air handling plant and will have a separate, filtered exhaust at roof level.
- Clean Workshop; this area comprises a number of specialist functions centring around art conservation. A site walk has been carried out and a wealth of useful data collected from museum conservation staff regarding processes, chemical types etc. This will be analysed in the next stage of design and the associated infrastructure required to support these processes detailed for review and costing. Note that these spaces currently include 2 no. fume cupboards and a number of chemical exhausts.
- Dirty Workshop; space will be dedicated to practical workshop processes such as wood cutting. A site walk has recently been carried out and a wealth of useful data collected from museum conservation staff regarding works to be carried out in this space. This will be analysed in the next stage of design and the associated infrastructure required to support these processes detailed for review and costing.

4.6.2.2 Store

The Art Store is located in the Basement and will utilise thermal mass from the surrounding earth and encompassing high density concrete walls to stabilise conditions within. High density, thermal mass has the ability to reduce cooling demands in the summer months as the thermal mass will cool down during the night and act to cool the internal air during the warmer days. Outside air shall be minimised, and the air circulation rate recued form that of the galleries above, owing to the low occupancy rates and internal gains.

4.6.3 Auditorium

The Auditorium will be serviced via a high level air distribution system.

A dedicated air handling unit with both heating and cooling coils shall be located within the Roof Plant Room to service the Auditorium. A run-around heat recovery coil will also be installed to recover heat from the return air stream.

Note that this system has area has been noted as having the possibility to also house works of art. Display using dedicated cabinets should be explored in order to avoid adding additional cost top the main air handling system.

4.6.4 Staff/Admin Areas

Staff areas which do not require close control will be provided with 4-pipe fan coil units capable of providing both heating and cooling. Fan coil units shall be located in the roof top plantroom to allow for ease of maintenance. Ventilation shall be delivered to the back of each unit and shall be modulated to suit the population density. Systems shall come with an afterhours push switch that shall allow the system to operate as and when required. C02 control shall also be employed in line with the sustainability framework to minimise energy costs.

4.6.5 Café/Kitchen

Currently a dedicated air handling unit located on the roof has been provided to serve the café area. In this instance air would be delivered to the café at high level and extracted through the adjacent kitchen, which would act as make up air for the exhaust system.

Should the design and delivery of the air conditioning systems within the kitchen fall under the ‘fit out’ works, capped connections will be provided under the base building works.

Further kitchen brief development is required during the next design stage.

4.7 Preliminary Plant Sizing

For the purposes of concept space planning, the following plant loads have been assumed for equipment sizing:

Table 8 Preliminary Plant Loads

System	Installed Capacity	Minimum Capacity on Loss of 1 Unit	No. of Units
Chilled Water	960 kW	70%	3No.
Heating Water	350 kW	60%	2No.
Cooling Towers	1200kW	60%	2No.

4.8 Smoke Control System Assumptions

The current assumptions and provisions for fire and smoke control systems are summarised below:

- The building is less than 25m in effective height;
- A shutdown type system will be employed in accordance with AS1668.1; &
- No stair pressurisation has been allowed for in the current design.

4.9 Building Management & Controls System (BMCS)

To take advantage of the new high efficiency systems BMCS should be provided to automatically control and monitor the facility. The BMCS will comprise a peer-to-peer network of freely programmable Direct Digital Controllers (DDC's) for main plant control and application specific unitary controllers for the control of terminal units e.g. AHUs/FCU's. Each controller will have the ability to operate stand alone, however communication between controllers over a high speed Ethernet IP network will be used to enhance control and allow operator interface. Sensors will be installed and connected to the BMCS as required to ensure effective control and monitoring of the plant.

The BMCS will have a front end computer for the operator to interface with the various systems being monitored and controlled. The following features will be available:

- Graphical representation of all monitored systems in a user friendly manner including floor layouts, plant schematics, sensor values, plant status, active control mode, etc.
- Graphical single line representation of all monitored essential switchboards.
- Multiple user secure log-in.
- Remote access via the internet.
- User action audit trail.
- Set point adjustment.
- Time schedules.
- Historical trend logging.
- Alarm monitoring and reporting e.g. SMS and email alert.
- Energy and water monitoring system.
- The BMCS will be an open building control system using Lon Mark, Lon Works, Modbus or BACnet standards with full interoperability

4.9.1 Market Trends

The system details should be developed to compliment the design as it progresses, however, an indication of the best system types on the market and current trends are noted below.

Tier 1

- Schneider (StruxureWare Building Operation)
- Honeywell (EBI R500)
- Johnson Controls (Metasys)
- Siemens (Desigo CC)

Tier 2

- DAC - Doust Automation
- Tridium (more open brand serviceable by multiple vendors)
- Automated Logic
- Delta Controls
- Alerton

Generally all systems will offer a similar level of functionality, however, full integration of security, BMS, lighting control, etc. is required then typically the Tier 1 providers are not the best at interfacing with other systems and typically cannot be serviced by anyone other than the manufacturer which can drive up maintenance costs.

That said, Schneider graphics are clean and easy to use and their trending options are a very good part of their StruxureWare system. This system has been on the market for some time and is a fairly mature product. Siemens are releasing a new platform in Australia called Desigo CC (been around globally for a few years) which looks cleaner and more modern with some nice features such as automatically trending based on what you are looking at on the graphics. Siemens, Honeywell EBI R500 and Schneider StruxureWare support HTML5 graphics, meaning that graphics automatically resize if using portable devices etc. For energy monitoring/management they typically offer bolt on packages which provide more specialised trending/reporting designed for metering etc.

Consideration shall be given to interface requirements and controls, head end locations, alarm types, trending requirements, monitoring and graphical representation as and when the systems are developed further.

4.9.2 Sub-metering

With the correct metering strategy (including gas metering and electrical meters on appropriate pumps, chillers, cooling towers etc.) energy associated the production of chilled/hot/condenser water can be monitoring and the energy expenditure targeted to bring down the overall usage.

The electrical distribution to HVAC systems will be designed with this in mind, enabling the simple breakdown of electrical energy and costs. Thermal energy associated with the centralised plant must also be assessed.

Thermal meters would be used in much the same way you would use electrical meters as they simply measure thermal energy. With the central plant strategy employed at CCW, it is generally good practice to thermally meter each branch buildings.

The strategy and location of these meters needs to be assessed and agreed during the design development.

Thermal meters are comprised of two key components; the flow meter and matched and calibrated temperature probes which accurately measures the difference between flow and return temperatures. These components monitor, record and trend the following information via a high level interface to the BMS;

- Current Power (kW)
- Totalised Consumption (kWh)
- Current Flow Rate
- Current Flow and Return Temperatures and deltaT

This data con then be used by the facilities manager to make system improvements or alterations, as well as be used as the basis for compiling tenant billing data.

The equipment that facilitates these readings can generally be categorised into two main types, depending on size:

Smaller ultrasonic thermal energy meter (this is an all in one unit)

Figure 13 Ultrasonic Meter (Siemens UH-50)

Larger MagFlow meters with a separate thermal energy calculator

Figure 14 Energy calculator (Siemens FUE-950) and magflow (Siemens)

The holistic strategy (both thermal and electrical), location and type of metering devices shall be developed in line with the design to ensure the outcome matches University's operational requirements and sustainability objectives.

5 Electrical Services

5.1 Introduction

This section documents the electrical services concept design for the new Chau Chak Wing Museum at The University of Sydney, Camperdown NSW 2050. The design includes incoming power and communications connection to the building, back of house general lighting, landscape lighting, general power, communications and security services.

The services will be designed to provide a safe and comfortable environment for staff, students and the general public while meeting the functional requirements of the spaces. Wherever possible, the design will seek to minimise energy use and carbon emissions in a cost effective manner.

All new electrical systems are proposed to suit the development criteria, unless noted otherwise within this document.

The electrical services design and equipment will be sized for approximate preliminary building areas as stated below:

Table 9 Area Schedule for Electrical Sizing

Chau Chak Wing Museum Building	
Level LL-02; Collections Education Research & Conservation (CERC) facility, plant rooms, storage rooms, circulation and loading dock	1250m^2
Level LL-01; Gallery space, plant room and collection store	1050m^2
Level LG; Gallery, café/kitchen, storage, plant room, study and amenities	900m^2
Level GL; Gallery, foyer, auditorium, amenities, storage and school education	965m^2
Level UL; Offices, resource reference, conservation, gallery, circulation and amenities	1350m^2
Level PL; Plant room	900m^2
Total approximate net area	6415m^2

5.2 Design Considerations

The electrical services will be designed to provide a safe and comfortable environment for occupants while meeting the functional requirements of each space. The following items are priorities to be considered in the design:-

- Take a long term balanced view of capital costs, energy costs, maintenance costs and longevity of systems and plant;
- Systems to be designed for future flexibility – allowing for changes to spaces and within the life of the building; &
- Consideration of access & maintenance requirements for all items of plant and equipment.

5.3 Innovation

The following innovation will be considered as a minimum:-

- Material and natural resources minimisation;
- User / student interaction with, and the visibility of, the built environment electrical infrastructure;
- Quality of user environment enhancement;
- Energy use management;
- Consumption monitoring (additional to the Advanced Utilities Monitoring System AUMS);
- System flexibility, extendibility and modularity;
- Safety enhancements; &
- Ease of operations and maintenance enhancement.

5.4 Ecologically Sustainable Development (ESD) Initiatives

To maximize the return on investment, the design will focus on applying simple, cost effective sustainability initiatives. As such, the building will be designed to align with the University's Sustainability Framework. The following ESD measures are anticipated and will be discussed with the ESD consultant to assess viability in the next stage:-

- Long life, low energy LED lighting in the building;
- Programmable intelligent lighting control system for internal and external lighting;
- Energy management, monitoring and metering system at the Main Switchboard & Distribution Boards;
- High efficiency electrical distribution utilizing low loss copper busbars/cables;
- Photo-Voltaic (PV) system;
- Provision of Public Information Display at the building foyer; &
- PVC minimisation.

5.5 Regulations, Standards and Authorities

The electrical and communication services systems will be designed in accordance with the latest revision of the following design standards and documents:-

- National Construction Code (NCC);
- NSW Services and Installation Rules and Ausgrid Guidelines;
- AS/NZS 3000-2007 Electrical installations (also known as the Australian/New Zealand Wiring Rules);
- AS/NZS 3008.1.1 Electrical installations – Selection of cables – Cables for alternating voltages up to and including 0.6/1kV – Typical Australian installation conditions;

- AS/NZS 3080 Telecommunications installations – Generic cabling for commercial premises;
- AS 3084 Telecommunications installations – Telecommunications pathways and spaces for commercial buildings;
- Communication supply authority guidelines;
- AS/NZS 3439 Low Voltage Switchgear and Control Gear Assemblies;
- AS/NZS 61439 Low Voltage Switchgear and Control Gear Assemblies;
- AS/NZS 1680 Interior Lighting;
- AS/NZS 1768 Lightning Protection;
- AS 2053 Conduits and fittings for electrical installations;
- AS 2293.1 Emergency escape lighting and exit signs for buildings – system design, installation, and operation;
- AS/ACIF S009:2006 Installation requirements for customer cabling (Wiring rules);
- University of Sydney - CIS Electrical Services Standard;
- University of Sydney - CIS Lighting Standard;
- University of Sydney - CIS Advanced Utility Monitoring System (AUMS) Standard;
- University of Sydney – CIS Security Standard;
- University of Sydney – CIS Building and Architecture Standard;
- University of Sydney – CIS Wireless Installation Standard;
- University of Sydney - Communications Cabling Standard and parts list;
- Work Cover Requirements;
- WH&S Regulations;
- Safety in Design guidelines; &
- All other applicable Australian Standards.

5.6 Early Works

As per available survey information, there are some existing underground power and communications services within and around the footprint of the proposed museum building. These existing services will be disconnected, removed or rerouted as part of the site demolition works. The site demolition works will be part of the architectural package and for which the electrical input will be provided by ARUP.

The University's underground assets do not generally appear on Dial Before You Dig (DBYD) plans. In this regard, the University had engaged a surveyor company to locate, identify and map all existing services in a wide area around the new building. Detailed survey drawings were prepared and submitted by the survey company and existing services identified.

Figure 15 In-ground survey extract indicating existing underground cables within the site

5.7 Maximum Demand

Based on the area of various spaces within the building and the function of each space, ARUP have prepared the building's electrical maximum demand. This estimation is calculated and tabulated in the maximum demand table below.

Table C3 of the 'Electrical Installations' Australian Standard AS/NZS 3000-2007 provide guidance of VA/m² rating of various space types in commercial buildings. For a typical space, multiplying the area of that space by the corresponding VA/m² yields the VA rating of that space.

The electrical maximum demand calculation of the proposed Chau Chak Wing Museum is approximately 669KVA which is calculated below. This calculation includes 20% spare capacity as required by the University of Sydney - CIS Electrical Services Standard.

Table 10 Estimated maximum demand schedule

Project: Chau Chak Wing Museum Project
Subject: Electrical maximum Demand
Date: 12-04-2017
Rev: 04
Prepared by: MH/NK

Level	Description	Area (m²)	Approx VA/m²	Total VA
LL-02	Collections Education Research & Conservation (CERC) Facility	766	50	38,300
	Plantroom	515	40	20,600
	Storage	333	40	13,320
	Circulation and Loading Dock	357	10	3,570
	Circulation	52	40	2,080
LL-01	Plantroom	160	40	6,400
	Gallery	875	120	105,000
	Void	35	25	875
LG	Gallery	445	120	53,400
	Café	60	80	4,800
	Kitchen	22	150	3,300
	Storage	46	40	1,840
	Plantroom	28	40	1,120
	Study	192	80	15,360
	Amenities	45	40	1,800
	Void	85	25	2,125
GL	Gallery	465	120	55,800
	Foyer	130	80	10,400
	Auditorium	145	120	17,400
	Kitchenette	16	80	1,280
	Amenities	44	40	1,760
	Storage	42	40	1,680
	Schools Education	76	80	6,080
	Void	85	25	2,125
UL	Offices	395	80	31,600
	Amenities	61	40	2,440
	Circulation	310	40	12,400
	Conservation	152	80	12,160
	Gallery	430	120	51,600
Plant	Plantroom	940	15	14,100
				-
	Total VA			494,715
	20% Spare Capacity required by the University			98,943
	Total KVA			593.7

5.8 Electrical Supply to the Development

As part of the new museum building works, Ausgrid have advised that there is a requirement to establish a new incoming power supply to the building.

Arup has undertaken a desktop study of the available existing drawings and information as well as undertaken a site visit to determine feasibility of connecting the new building to existing substations.

Based on a comparison study between a basement substation, surface substation and a kiosk, it was concluded that a kiosk substation would be the most cost effective and viable solution.

The University has engaged a L3 ASP designer company which will commence the design upon receipt of Design Information Package (DIP) from Ausgrid. DIP packages are still awaited to be received from Ausgrid.

Final location will be determined in coordination with the University of Sydney, the architect and the L3 ASP. The approximate location will be near University Ave or University Place due to the availability of heavy vehicular access and Ausgrid's existing HV lines at both locations.

For other locations, additional heavy vehicle access would need to be provided from the roadway to the substation location.

The L3 ASP design will identify the most feasible existing HV lines which have capacity to connect the new building.

5.9 Main Switch Room (MSR)

A main switch room will be established within the building.

The MSR will be fire rated to 120/120/120, have provision for two diverse outward swinging emergency egress doors from the room, provided with a University Bi-lock and WHS compliant warning signs and be provided with a fan assisted system of ventilation from outside and cooling if required by the switchboard manufacturers as part of warranties and agreed by the University. The MSR will be sized in accordance with MSB manufacturer's requirements, the Australian Standard AS/NZS-3000:2007 'Electrical Installations' and the University of Sydney (UoS) Guidelines.

A minimum of 1m wide access will be maintained all around the equipment and between egress doors. The main switch room will house the building Main Switchboard (MSB), Main Distribution Board MDB, Power Factor Correction (PFC) unit, House DB (EDB-LL-01), Photo-Voltaic System DB (DB-PV) and PV System Inverters, Meters and associated systems.

5.10 Building Main Switchboard

Figure 16 MSB and Temporary Generator Connection Facilities

One new building main switchboard (MSB) will be established to receive power from the substation.

The MSB will be Form 4B, IP42, welded type, in accordance with the CIS Electrical Services Standard. The MSB will be approximately 7mtr long, 0.6mtr deep and 2.1mtrs high and will be located in the MSR located on the plant level.

The Building MSB will be constructed to withstand the prospective fault levels subject to the final supply arrangement to be determined during the design. The switchboard will incorporate energy usage metering in accordance with the University Standards for all outgoing submains, other than those loads or switchboards with integral energy metering.

Facilities to connect a temporary mobile generator to the main incoming section of the main switchboard will be provided. This will include key interlocked manual transfer arrangement and external accessible terminal cubicle located to suit truck delivered containerised temporary generator. Load control will be manual. Standby power provisions outlined in Part G3 'Atrium Construction' of the NCC are not considered a requirement and will be addressed through fire engineering in this case.

All switchboards will be supplied from the University's deemed-to-comply switchboards manufacturers.

The Café tenant will be provided with dedicated supply through a meter panel located in the Main Switchroom. Refer to the schematic design for power supply arrangement to the Café tenant DB.

5.11 Power Factor Correction and Active Harmonic Filter

As outlined in the CIS electrical standards, a Power Factor Unit will be provided in the new building. A power factor correction unit and active harmonic filter will be installed to maintain the building's electrical power factor at the nominal minimum level of 0.95 lagging at the source.

5.12 Advanced Utility Monitoring System (AUMS)

The monitoring system will be a design and construct package by a specialised contractor. The University of Sydney has a campus-wide Advanced Utility Monitoring System comprising of digital meters located within the main switchboards and selected locations within buildings. These are remotely monitored via a dedicated communications network.

This includes the monitoring of the following as a minimum:-

- Distribution boards and sub-sections;
- Water usage; &
- Gas usage.

Refer the University of Sydney's Advanced Utility Monitoring System Guide and as part of the detailed design in conjunction with the University CIS.

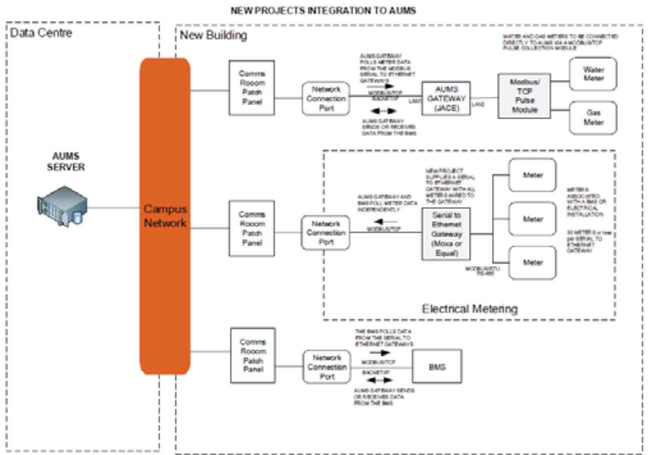


Figure 17 Extract from University's AUMS Standard

Meters will be provided for the following as a minimum:-

- All outgoing submains from the main switchboards, other than those which incorporate their own final integrated metering facility (i.e. Light & Power DBs);
- Mechanical services, with additional metering for the large chiller plant and air handling plant loads greater than 100kVA;

- Hydraulic and fire services;
- General lighting;
- General power;
- Lifts;
- Tenanted or potentially tenanted areas;
- Specialist equipment or high energy use area with a total load > 50Amps; &
- Any other loads greater than 100kVA.

The metering will be Class 0.5 for Power (AS62053-22) and Class 1 (AS62053-21) for Reactive Power. Metering will have Modbus or similar connectivity and provide the following instantaneous information to the BMCS for monitoring and recording purposes:-

- kWh;
- kW;
- kVA;
- kVAr;
- Power Factor;
- Volts (V) line to line and line to neutral;
- Current (A);
- Neutral Current (A); &
- THD%.

As part of the Ecologically Sustainable Development (ESD) recommendations, a Public Information Display will be set up in the foyer and similar prominent public area(s) to educate building occupants and communicate building information such as real-time utility (energy, water, gas) consumption, waste management, transport options etc.

The Monitoring system will be a design and construct package by a specialised contractor.

5.13 Distribution Boards

New distribution boards will be provided for the power distribution. All distribution boards will be Type-2 distribution boards as detailed to the CIS Electrical Services Standard.

Type-2 distribution boards are proposed due to their ability to house lighting control equipment and their ability to supply other distribution boards of adjacent floors in the electrical riser. The electrical distribution boards will be located in separate rooms/cupboards.

Each floor will be provided with one distribution board to supply lighting and power on that floor.

Each distribution board will be provided with separate chassis and metering for lighting and power circuits to comply with the NCC requirements.

5.14 Cabling and Reticulating

Submains and cable trays will be provided for power reticulation within the building. One electrical riser will be provided for the electrical cabling. The riser will be located in the electrical room adjacent the lift shaft.

To minimise the impact of Electromagnetic Interference (EMI) a separation will be maintained between the main submains cabling route and occupied areas i.e. offices.

5.15 Lightning Protection

We have undertaken a lightning protection risk assessment in accordance with the guidelines in AS/NZS 1768. The assessment indicated that lightning protection for the building is not required based on the standard’s acceptable level of risk.

Although the risk assessment, in accordance with the guidelines in AS/NZS 1768, indicates that a lightning protection for the building is not required, lightning protection would be provided as per the request of the University of Sydney.

Based on previous experience, it is common industry practice to install the minimum level of lightning protection for buildings to reduce the risk of lightning effects on personnel, the building and its critical operations and for the purposes of insurance claims.

5.16 Lighting

Functional lighting will be designed and documented by ARUP for all back-of-house areas. Specialist lighting to all front-of-house gallery spaces will be designed and documented by other consultants.

A programmable intelligent electronic lighting control system (such as CBUS DALI) will be provided.

All luminaires will be specified from the Deemed to Comply luminaire schedule form CIS-ENG-F006.

Circulation spaces and end-of-trip facilities will be provided with downlights for general lighting.

Linear LED surface mounted or recessed mounted luminaires will be provided in plantrooms, storage areas, riser cupboards, loading dock etc.

The back-of-house lighting will be coordinated and blended with the specialised lighting for smooth transition in between these two type of areas, and to integrate the lighting control system.

Landscape lighting will be provided in coordination with the landscape consultant and the University of Sydney.

All lighting will comply with the NCC Section J6 for lighting and power density.

5.17 Emergency Lighting

Emergency and exit lighting will be provided where required by the National Construction Code (NCC), AS 2293.1 and the University of Sydney CIS Standards.

All Exit signs will be complete with pictograph to comply with AS2293.1:2005. All Exit signs will be the LED edge-lit type throughout the building. Weather proof exit signs will be installed in all plant rooms and accessible roof areas. All Exit signs will be maintained type.

All fittings will be installed so that they can be easily maintained without the need for scaffolding and major servicing equipment.

The emergency lighting system will be computer monitored system.

The battery system shall be Lithium Ion type (LP or L10 or equivalent Stanilite premium range)

5.18 Small Power

A flexible power system solution will be provided. This would include raised floor power and data distribution with floor boxes or an alternative strategy to suit.

All outlet plates will be Clipsal 2000 series or approved equal.

General power outlets quantities will be as per the University of Sydney Electrical Guidelines section 5.9.4 ‘General Power Socket Outlets as a minimum’.

Specialised power outlets will be provided for all required equipment. A number of three phase and single phase outlets will be provided in the terrace area for external portable electrical equipment.

Technical Data sheets for outlets and accessories will be provided to the University for approval.

5.19 Communication Services

The number of communications racks in each Communication Room will be finalised in conjunction with the University ICT team. For our spatial assessment, we have allocated 4 racks in the main communications on Lower Level 02, and two racks in the secondary communication rooms on Plant Level.

The above mentioned communication rooms will house Communications Racks only. All other communications equipment including Lighting control rack, security services rack, MDF, DAS equipment, MATV and other will be installed in a separate MDF room on Lower Level 02.

A communication services riser will be provided in the communications room adjacent the lifts area. For the alternate communication pathway between both communication rooms, a vertical conduit will be utilised.

AV Services power and communication outlet requirements will be obtained from the University’s ICT team.

External underground communication conduits and cabling will be provided by the University’s ICT team and not included in the tender package. The delineation between the works to be done by University and the works to be done as part of the tender package will be coordinated and documented accordingly.

In addition to the incoming copper cabling system, it is proposed to install two diverse fibre cabling systems to the new building. These fibre cables will originate from Macleay Building and Fisher Library Building.

A structured Cat 6A F/UTP class EA cabling system will be provided for the new building.

Communications outlets for the Wireless Access Points will be provided at indicative locations to be agreed with the University of Sydney.

ICT will provide information regarding within-building mobile coverage system which is to be interconnected to the University’s precinct.

Communications outlet quantity and locations will be coordinated with the use of spaces and their requirement.

An MATV system will be designed and documented for the building.

5.20 PV Solar System

A PV system will be provided on the roof of the building and sized to maximise the use of the roof area while maintaining the aesthetics of the building. The system will be designed and coordinated with the architect and client.

The PV system package will be a design and construct (D&C) package by the University’s nominated installer. An initial assessment suggests the PV system will be 86KWP.

5.21 Security Services

Details to be developed with the University’s Security team. The security systems will be Gallagher and will consist of door electronic access control devices and motion sensors.

CCTV cameras will be installed at locations agreed with the University’s Security team. The CCTV system will be Avigilon to match the University’s CCTV system.

Security lighting will be provided to supplement the security system.

6 Hydraulic Services

6.1 Standards and Regulations

The sanitary plumbing / drainage, rainwater collection, stormwater and water supply systems shall be designed to comply with all requirements of the following:-

- National Construction Code 2016 (NCC);
- Australian Standards;
- AS 3500 (all parts) – National plumbing and drainage code;
- AS 5601 – Gas installations;
- NSW Plumbing and Drainage Code of Practice;
- Local authorities requirements;
- Campus Infrastructure & Services (CIS) Hydraulic Services Standard;
- Campus Infrastructure & Services (CIS) Roofing and Guttering Standard;
- Campus Infrastructure & Services (CIS) Advanced Utility Monitoring System Standard;
- Work Cover NSW;
- BCA Building Certifier; &
- Manufacturer's Technical Guidelines.

6.2 Technical Objectives

The hydraulic systems shall demonstrate reliability and performance to achieve an appropriate standard of service, incorporating the following design principles:-

- To provide user friendly systems to suit intermittent building usage;
- To provide energy efficient systems;
- To provide water efficient systems; &
- To provide materials selection based on environmentally sustainable manufacturing practices and durability for building intermittent use.

6.3 Design Criteria

The design criteria will include but will not necessarily be limited to the following:-

Item	Parameter
Rain water drainage	Intensity: minimum 220mm/hr – 5min 1:100 year event, as per CIS Roofing and Guttering Standard Australian Rainfall and Runoff AS3500.3 Local council requirements Gutters to incorporate measures to prevent failure from leaves and silt with minimal maintenance
Domestic Hot Water delivery Temperature	Hot water distribution: 60ºC - 65ºC Male/Female amenities: 43°C Maximum Disabled amenities: 43°C Maximum Kitchen: 60ºC - 65ºC Cleaner's Room: 60ºC - 65ºC
Working velocities in water services pipes	Max 2.4m/s depending on noise sensitivity of area Max 0.8m/s within office (and other noise sensitive) spaces
Maximum operational water pressure	500kPa
Minimum operational water pressure	250kPa
Cold water average supply temperature	10ºC
Velocities within storm-water drainage	Self-cleansing velocities between 0.75m/s and 1.2m/s
Hot water plant	Storage vessels – heat loss is not to exceed values within Table A1 of AS4692.2 (for a 410L vessel max 2.93kWh/24hrs). Primary pipe work between heat source and storage vessels is to have 25mm Rockwool insulation. Heating plant minimum efficiency 80%

The following items will also be met:-

- Acoustic treatment shall be provided to all piped services routed within sound sensitive areas with parameters to be dictated by the acoustic consultant;
- All services passing through fire zones shall be protected against the spread of fire through the use of fire collars and appropriate seals; &
- The reticulation of wet pipework, including sanitary plumbing, trade waste, stormwater and domestic water will be reduced as much as possible above gallery and storage spaces. The intent is to avoid potential damage produced by unexpected leakages.

6.4 Proposed Systems

The scope of the works will include but not necessarily be limited to the following:-

- Sanitary plumbing and drainage;
- Trade waste drainage and treatment (pending building requirements);
- Rainwater roof drainage;
- Rainwater re-use (pending water balance);
- Domestic cold water supply;
- Domestic hot water supply;
- Non-potable water supply (pending water balance);
- Natural gas supply; &
- Sanitary fixtures, tapware and outlets.

6.5 Water Conservation

The hydraulic systems proposed will be robust solutions to achieve a long service life and meet the requirements of the brief. They will be reliable, provide a high Standard of performance and incorporate the following design philosophies:-

- Maximise energy efficiency;
- Maximise water efficiency;
- Maximise water reuse; &
- Utilise material selections based on environmental sustainable manufacturing practices and remain within the project budget.

6.6 Sewer and Sanitary System

The sanitary drainage system will collect the soil and waste water from all building points, discharging through gravity systems into the existing university campus network. Pumped discharge systems will be used where the gravity drainage cannot be achieved. The drainage system shall comply with statutory codes, CIS requirements and Sydney Water requirements.

All systems will be sound attenuated within sensitive areas as aforementioned.

6.7 Trade Waste System

Kitchen waste will be collected via a gravity trade waste drainage system, via a series of branch drains and fully vented modified stacks (minimum of 100mm diameter). The drainage system will be vented in accordance with the Plumbing Code of Australia and AS3500.2.

The grease wastes will be discharged to the sewer system via a grease arrestor located in the basement and pump out.

The grease arrestor's capacity will be subject to the final catering requirements.

6.8 Stormwater and Roof Drainage Systems

Roof drainage design will comprise of rainwater outlets connected to a conventional gravity downpipe system where possible, discharging into the civil stormwater system.

A conventional downpipe system is regarded as most appropriate (rather than siphonic) as they have a higher degree of spare capacity which is not the case for siphonic system. The downpipes will be sound attenuated within sound sensitive areas throughout the building.

Sub-soil and cavity wall drainage will be collected and pumped into the stormwater systems.

6.9 Domestic Cold Water System

The domestic cold water (DCW) service will be supplied from an existing university water main, except location is to be identified. This main will potentially be used as mains supply to the fire systems. The incoming cold water will pass through a water meter assembly and the backflow prevention device.

A DCW pump-set is currently proposed. At present this will be reviewed as flow and pressure become available.

The domestic cold water shall serve all building fixtures, fire hose reels, kitchen/toilet amenities and mechanical plant as required. Control valves will be installed where practicable so that the entire building or specific fixture groups or wet areas may be isolated without affecting adjacent areas.

6.10 Domestic Hot Water System

Domestic hot water (DHW) will be supplied to the building to service toilet blocks, kitchens and cleaners rooms.

A centralised gas-fired DHW system with flow and return loops will be provided for bulk delivery. Local point-of-use hot water units will be considered for remote locations where appropriate.

Thermostatic mixing valves will be provided at fixtures to reduce point of use temperature in accordance with the statutory codes to prevent scalding. All point of use thermostatic valves to building amenities shall be located where they are accessible for service and maintenance purposes.

Minimum Hot water storage temperature shall be 60 - 65°C. Hot water delivery at each outlet will be controlled by point of use temperature control devices. The pipe work will be insulated against heat loss and allowances will be made for adequate thermal expansion in pipe work.

6.11 Natural Gas Service

The natural gas service will be supplied from the university campus network. Further investigations are required to identify the connection point. One new gas meter and regulator set will be installed.

All the gas fittings and natural gas installations will be carried out to AS5601, Gas Supply Authority Recommendations and AGA approvals.

The gas meter room will be located at loading dock level and will contain the meter assembly and pressure reduction regulator sets. The gas pressure will be reduced to 5-7kPa prior to distributing to the base build mechanical boilers and domestic hot water plant.

Natural gas shall be reticulated to all gas fired appliances including the hot water plant and mechanical plant as required. All gas services will be designed to meet statutory codes and authority requirements.

An automatic shut-off valve will be provided and linked with the FIP to isolate gas supply in the event of fire alarm activation. All gas appliances shall be fitted with flame failure safety devices as standard.

6.12 Sanitary Fixtures and Tapware

The proposal is to implement water saving initiatives including low flow tapware to lower the overall water usage within the building.

All fixtures and tapware selected for use on the project will be high quality commercial WELS ★ rated to minimise water use at outlets.

All fixtures and tapware specification will form part of the architectural documentation package.

6.13 Further Investigation

The following items require further investigation before the commencement of works:-

- The economic benefit of installing a rainwater collection and reuse system.

7 Fire Services

7.1 Standards and Regulations

The sanitary plumbing / drainage, rainwater collection, stormwater and water supply systems shall be designed to comply with all requirements of the following:-

- National Construction Code 2016 (NCC);
- AS 2419.1-2005;
- AS 2118.1-1999;
- AS 1670-2004;
- AS 1668.1-1998;
- AS 2441-2005;
- AS 2444-2001;
- Sydney Water (and all other local authorities);
- Campus Infrastructure & Services (CIS) Essential Fire Safety Measures Standard;
- Campus Infrastructure & Services (CIS) Hydraulic Services Standard;
- Campus Infrastructure & Services (CIS) Advanced Utility Monitoring System Standard;
- Work Cover NSW;
- BCA Building Certifier;
- Fire Rescue NSW (FRNSW) requirements; &
- Manufacturer's Technical Guidelines.

7.2 General

The objectives of the provisions of the NCC for firefighting equipment and services are to:-

- Safeguard occupants from illness or injury while evacuating during a fire;
- Provide facilities for occupants and the fire brigade to undertake fire-fighting operations; &
- Prevent the spread of fire between buildings.

The firefighting equipment and services shall be provided to meet the minimum deemed-to-satisfy provisions for this proposed type of building as classified by the BCA and to meet the requirements of any alternate solution determined by the project Fire Engineer.

The fire detection, emergency warning and fire protection systems for the building will be designed and installed in accordance with the NCC 2016 and all relevant codes and standards.

The design will be co-ordinated with the Fire Engineering brief.

7.3 Design Criteria

Item	Parameter
Fire Hose Reels	0.3l/s @ 250kpa minimum
Fire hydrants	Boosted 700kpa (minimum) – at the most disadvantaged hydrant outlet Number of operational hydrants as per code requirements depending on fire compartment sizes (assumed as 2, to be confirmed)
Fire Sprinkler spray densities	Gallery- Light Hazard Loading Dock- Ordinary Hazard 2 Density of discharge 5mm/min; area of operation 144 m2 Stores - Ordinary Hazard 2 (client to advice artefacts in storage) Density of discharge 5mm/min; area of operation 144 m2 Café/Restaurants- Ordinary Hazard 1 Density of discharge 5mm/min; area of operation 72 m2 Plant rooms- Ordinary Hazard 1 Density of discharge 5mm/min; area of operation 72 m2
Maximum operational water pressure hydrants	1200kPa
Fire alarm and detection systems	AS1670.1 inclusive of clause 3.26(f) AS1670.4-2004

7.4 Water Supply

A new water connection will be made to the university's water main which will extend to the fire hydrant & sprinkler booster valve assemblies.

Pumps will be provided to meet the system demand.

7.5 Fire Hydrant System

A fire hydrant system will be installed in accordance with the requirements of NCC 2016, AS2419.1-2005, the FER and FRNSW. Fire hydrants will be installed internally to provide coverage.

The building configuration requires on floor hydrants to be provided to afford coverage.

Fire hydrant booster connections will be installed compliance with AS2419.1-2005, AS2118.1-1999 and FRNSW requirements.

7.6 Fire Hose Reels

Fire hose reels shall be installed to comply with the deemed to satisfy provisions of Clause E1.4 of the NCC, AS2441-2005 and the requirements of the project fire engineer.

Fire hose reels shall be located within four (4) meters of exits and provide full floor plate coverage to AS2441-2005 requirements. Fire hose reels shall be supplied from the domestic cold water system. Where necessary, on floor reels will be provided.

7.7 Fire Sprinkler System

As per the CIS Essential Fire Safety Measures Standard, the building will be protected by an automatic fire sprinkler system. The sprinkler system will be designed to comply with the requirements of the NCC 2016 and AS2118.1-1999.

Hazard Classifications will be afforded as follows:-

- Gallery- Light Hazard;
- Loading Dock- OH2;
- Stores - OH2 (client to advice artefacts in storage);
- Café/Restaurants- OH1; &
- Plant rooms- OH1.

It is assumed that no gallery spaces will have high combustibility loads. It is proposed that the floors will be provided with pre-action sprinklers with a double knock VESDA detection system separate to the buildings fire alarm system.

Although a dry sprinkler protection system is proposed to protect sensitive areas, non-sensitive areas (i.e. kitchen, plant room, etc.) will be protected with a wet sprinkler system. The aim of the pre-action system is to avoid to discharge water in case a false alarm.

The fire sprinkler system will be fed from a Grade 3 water supply, consisting of a single connection to the campus water main.

Fire sprinkler booster connections and alarm valves will be installed and located within sight of the main entrance in compliance with AS2419.1-2005, AS2118.1-1999 and FRNSW requirements.

The design flow rate for the sprinkler system will be matched to the sum of the most onerous sprinkler demand.

Each sprinkler protected zone of the building will be fitted with an isolation valve, flow switch and remote flow switch test facility on the branch from the riser.

All devices will be monitored by the fire indicator panel (FIP).

7.8 Fire Attendance Point

A fire hardstand will be provided as per FRNSW requirements. An FIP will be provided within the main foyer of the building entry in accordance with NCC 2016, AS.1670. The fire attendance point within the foyer will contain only essential firefighting control equipment including the FIP and SSISEP panel.

7.9 Fire Detection and Alarm System

A fire detection system will be installed throughout the building as per the requirements of the NCC 2016, AS1670.1-2004, AS1670.4-2004, AS1668.1-1998 and FRNSW.

The detection system will monitor all devices connected to the fire hydrant and fire sprinkler systems.

The fire indicator panel (FIP) will be an addressable type, with non-proprietary software.

The fire alarm control panel will be located in the FIP. The system will be a programmable analogue addressable type. All devices will be compatible with the fire alarm control panel.

7.10 Sound Systems and Intercom Systems for Emergency Purposes

A sound system and intercom system for emergency purposes (SSISEP) will be installed throughout the building. The SSISEP will be designed and installed in compliance with the requirements of the NCC, AS1670.1-2004, AS1670.4-2004 and the NSW Fire Brigade.

The SSISEP control panel will be located adjacent to the FIP.

A manually activated voice announcement facility will be provided at the panel.

The EWIS panel will be located within the main entrance adjacent to the fire indicator panel.

Speakers will be provided throughout the floor plate in accordance to AS1670.4 requirements, with additional visual warning devices provided throughout the building in accordance with NCC. Break glass alarms and warden intercom phones will be provided on each level

7.11 Portable Fire Extinguishers

Portable fire extinguishers will be provided to satisfy clause E1.6 of the Building Code of Australia, AS.2444-2001 and local government requirements.

Generally fire extinguishers will be distributed throughout the building in areas of specific hazards such as electrical distribution boards and plant rooms.

Fire extinguishers in public areas will be located within the FHR/FH cabinets to minimise the potential risk of vandalism.

7.12 Distribution Piping and Wiring Systems

The fire services and life safety distribution piping and wiring systems will be coordinated with the architectural design and all other services. They will follow set services routes throughout the building, and will be concealed wherever possible, whilst allowing for ease-of-access for maintenance and servicing.

7.13 Further Investigations

The following items require further investigation before the commencement of works:-

- Confirmation of available water pressure and flow in the university operated water main at the point of connection for the site (including size of water main); &

8 Vertical Transportation

The intent of this document is to serve as a Schematic Design report providing design assumptions, performance requirements and performance outcomes that have been reviewed and developed during the design process.

The vertical transport schematic design report has been prepared to articulate:

- Design targets;
- Design methodology and assumptions;
- Preliminary lift spatial details.

It is intended that discussion and agreement on these items would provide the basis for progressing the documentation into the future design and documentation phases.

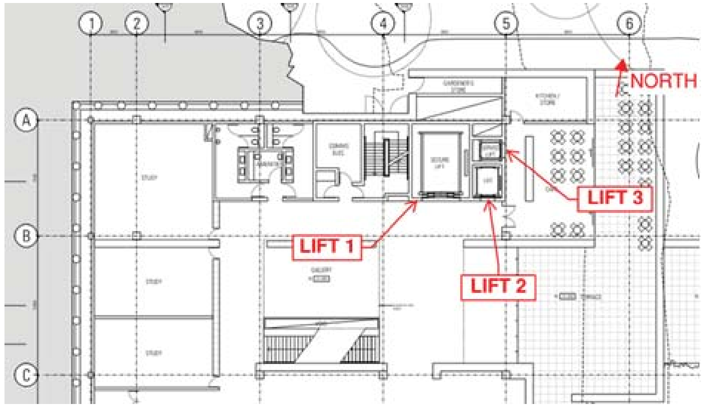
Generally the lifts provided in the CCW Museum are intended for practical use of material, goods and DDA movement. The main passenger lift (lift 2) is not provided to move the full building population as the stairs are provided for this purpose.

The secure lift (lift 1) is very large (7500kg) and will require a machine room. We have provided an option for a machine-roomless lift (MRL) that does not require a machine room and would have a reduced capacity of 5000kg and a smaller cabin.

8.1 Project Information

Project Information	
Building Name	Chau Chak Wing Museum
Building Type	Arts and cultural

8.1.1 Building Layout and Lift Numbering



8.2 Design Methodology

For the purpose of our analysis we have referenced the Chartered Institute of Building Services Engineer's – Transportation Systems in Buildings (CIBSE) Guide D. CIBSE Guide D is an internationally recognised document for defining the parameters of lift equipment and performance outcomes when designing vertical transportation systems.

We also reference the CIS Vertical Transport Standard version 002 dated 18 September 2015.

8.2.1 Forecasted Passenger and Materials Movement

To determine the appropriate vertical transportation solution, various assumptions have been used in terms of how staff, students and visitors access the building and engage with the vertical transportation services.

The following is a summary of anticipated passenger flows which are being used in the preparation of performance simulations, traffic calculations and the proposed Vertical Transportation design solution.

- The primary access for staff, students and visitors to all floors of the development will be via the ground floor entrance.
- The centrally located stairs would provide the main vertical access for the general public.
- The single passenger lift (Lift 2) will provide access to all floors for staff, elderly persons, families with prams and persons with limited mobility.
- Delivery and dispatch of materials (including rubbish) for the gallery and the café will be via the loading dock on lower level 2.
- The primary purpose of lift 1 (secure lift) is for gallery use.
- The primary purpose of lift 3 is to service the café on lower level G.
- Lift 1 will be designed with a car and door openings to accommodate large items of gallery equipment, displays and the like.
- It is anticipated that loading and unloading of lift 1 may be done with the assistance of a powered hand truck (walkie stacker).
- There is the possibility that lift 2 may serve the plant room and be available for plant maintenance and replacements as required.

8.3 Vertical Transportation System Design

8.3.1 Lift Performance Traffic Analysis

The traffic review will be further refined and finalised in future stages as the design progresses and after the client has reviewed our assumptions. The preliminary traffic studies have been based on the following methodology and design considerations.

- Stairs are the primary vertical access method for students and visitors;
- Floor levels and number of floors served are based on the current drawing set as provided by JPW;

- Targeted lift departure interval (round trip times).

8.3.2 Performance Targets

Following is a summary of performance targets as provided by the Chartered Institute of Building Services Engineer's – Transportation Systems in Buildings (CIBSE) Guide D.

Target Performance Levels		
Item	Performance Level	Reference
Interval (seconds)	<60	CIBSE Guide D
Balanced 2 – Way Handling Capacity (%))	15 %	CIBSE Guide D
Stair Utilisation	>90%	CIBSE Guide D
Lobby widths	Minimum 3.0 m	CIBSE Guide D

Note – lift number 2 is the main passenger lift for the building and the only lift that requires a traffic study.

8.3.3 Proposed Vertical Transportation Design

8.3.3.1 Lift 1

CERC has provided a list of requirements that include the lift car and door sizes for lift 1. Based on this information lift 1 will be a custom designed lift with a machine room. We have also sourced information for a smaller lift (option) without machine room (MRL) should smaller lift car and door sizes be accepted.

We propose that the lift machine room is located in the plant space and that lift 2 is extended into the plant room to provide access for maintenance etc.

	Custom Goods Lift	**Option for MRL**
Number of lifts	One (1)	
Capacity	7500 kg	5000 kg
Passenger rating	100 Passengers	67 Passengers
Type of lift	With machine room	Machine-roomless
Power / drive system	Variable Voltage, Variable Frequency	Variable Voltage, Variable Frequency
Speed	0.5 mps	0.5 mps
Levels served	LL2, LL1, G, LG, UL	LL2, LL1, G, LG, UL and Plant
Clear internal car size	3000 mm wide x 4000mm deep	3000 mm wide x 2800mm deep
Entrance details	3000 mm wide x 3000 mm high (centre opening)	3000 mm wide x 3000 mm high (centre opening)
Shaft size (width and depth)	4500 mm wide x 5000 mm deep	4500 mm wide x 3800 mm deep
Shaft overrun	5600	5000
Shaft pit	2250	2250
Machine room	Above the shaft at Plant room level – approximately 25 - 35m²	None

8.3.3.2 Lift 2

Number of lifts	One (1)
Capacity	1600 kg
Passenger rating	21 Passengers
Type of lift	Machine-Room-Less (MRL)
Speed	1.0 mps
Levels served	LL2, LL1, G, LG, UL (option to serve plant room)
Clear internal car size	1600 mm wide x 2100 mm deep
Entrance details	1000 mm wide x 2100 mm high (centre opening)
Shaft size (width and depth)	2300 mm wide x 2600 mm deep
Shaft overrun	4200
Shaft pit	1600

8.3.3.3 Lift 3

Lift three is provided for the café as service lift.

Number of lifts	One (1)
Capacity	1000 kg
Passenger rating	13 Passengers
Type of lift	Machine-Room-Less (MRL)
Speed	1.0 mps
Levels served	LL2 and G
Clear internal car size	1100 mm wide x 1900 mm deep x 2200 mm high
Entrance details	900 mm wide x 2100 mm high (side opening)
Shaft size (width and depth)	1650 mm wide x 2300 mm deep
Shaft overrun	4000
Shaft pit	1300

8.3.4 Design Consideration and Criteria

To determine the appropriate vertical transportation solution, various assumptions regarding building criteria and lift performance have been used and summarised below.

8.3.4.1 Population

The theoretical building population is not relevant as the lift (Lift 2) would be used for staff, elderly persons, families with prams and persons with limited mobility only.

8.3.4.2 Handling Capacity

Handling capacity is defined as the total number of passengers (expressed as a percentage of the total assumed building population) that a lift system can transport from the main lobby level in a period of 5 minutes during the peak period. Handling capacity is considered a measure of the "quantity" of lifting that the lift system provides.

8.3.4.3 Two Way Traffic Profile

Certain performance calculations have been prepared using a two-way traffic profile whereby passengers are simultaneously entering and exiting the building, generally during a lunch or dinner time sitting at a restaurant or eatery.

8.3.4.4 Average Waiting Interval (AWI)

Average Waiting Interval (AWI) is the average time between lift car arrivals at the main lobby during the peak period. AWI is considered a measure of the "quality" of the lift service when a conventional dispatching system is used.

8.3.5 Goods and Materials Movement.

Lift 1 would be designed to accommodate gallery equipment and materials of the following sizes:

Gallery displays and furniture – 2800 w x 3800 d x 2800 h

It is anticipated that a forklift or walkie stacker would be used for loading and unloading lift. The forklift mass is allowed at 1500kg). The design of lift 1 would be as described in AS1735.2 – Class C loading.

Lift 3 would be designed to accommodate café equipment, supplies and waste that may include food and beverages in boxes. These would be handled with manual / hand trollies. Waste would be moved in bins of up to 205 litres.

8.4 Vertical Transportation Features

The vertical transportation services will be designed with the following features.

8.4.1 Lift Equipment Design

8.4.1.1 Machine Room-less Lifts (MRLs)

All equipment would be of latest technology. The type of lift equipment specified shall have been in continuous operation for a minimum of five (5) years prior to being tendered and have a substantiated record of reliability and serviceability under comparable traffic loads and environment.

With speeds between of 1.0 mps and 2.5 mps and a duty range from 630kg up to 5000kg, machine-roomless lifts are ideally suited to medium rise university applications.

We anticipate machine-roomless lifts being used for lifts 2 and 3.

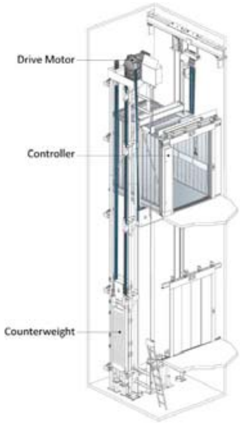


Figure 18 Typical Machine-roomless (MRL) Lift

8.4.1.2 Traction Lifts with Machine Room

Lifts are required to be of the machine room type when load or speed exceeds the limits of a MRL. For the base option - Lift 1 would require a machine room to locate the large lift machine and drive. This machine room would be located above the shaft in the plant room.

8.4.2 Sustainability

The lift installation will be designed to deliver to performance targets with a minimal environmental impact.

All lifts shall include Variable Voltage Variable Frequency (VVVF) motor drives and where beneficial, Regenerative Drive feature's.

Lifts with a regenerative drive feature allow the lift to generate power back into the building's internal electrical system when the out of balance load is assisting the direction of travel, i.e. when the lift is travelling in the up direction with limited load and the counterweight is heavier than the car.

Additional equipment features that will be specified to reduce the power consumption of the lift system include:-

- High efficiency permanent magnet gearless motors;
- LED lights;

- Motion sensing / timing devices to turn off lift car lighting and ventilation fans when the lift is not in use.

8.4.3 Lift Security

- All lifts would be fully integrated with the building access security control system and include the following provisions where required:-
- Electronic data key or swipe card readers in each lift which allows for individual floors to be secured and released; &
- Have allowance for CCTV cabling within the lift car trailing cables.

8.4.4 Emergency Back Up Drive

Should a failure of the lifts power supply occur (either permanent or generator) this feature will move the lift to either the next floor served or drives the lift to a designated floor.

Next Floor – this option uses a battery bank to energize the lifts brake solenoid and uses the lifts natural balance to move the lift car up or down to the next floor served.

Designated Floor – This option uses a battery bank to energize the drive and motor to run the lift to a designated floor regardless of the lifts balance.

These features are not required for code compliance but are recommended as good design practice to aid with the release passengers in the event of a power failure.

8.4.5 Car Interior Design

All lift car interior finishes would be as described in the latest version of the CIS Vertical Transport Standard.

8.4.6 Floor Naming

Most lift manufactures use a maximum of 2 digits for floor names. Car buttons with tactile and braille are manufactured to suite the floor naming. Generally 3 digits or more are not possible.

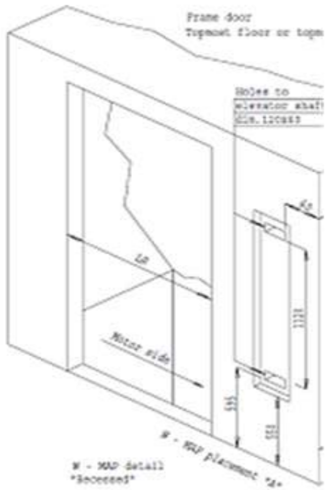
The architect may choose to introduce 2-digit floor naming during the early design phases of the project so that confusion is reduced and signage produced by other contractors is not conflicting.

8.4.7 Maintenance Requirements

All equipment would be of latest technology with a proven reliability and serviceability under the anticipated traffic loads and environment.

Machine-roomless lifts typically have a control panel located adjacent to the landing entrance of the top floor served, for each lift. The panel can be concealed behind foyer finishes however the maintaining lift contractor will require free and easy access to this panel at all times to conduct maintenance routines and interrogating the control systems in the event of an equipment failure.

Where machine room lifts are adopted the majority of repair and maintenance routines will be conducted in the lift motor room (LMR).



8.5 Standards, Codes and Regulations

The vertical transportation services will be designed to comply with all requirements of the following codes and standards:

- Australian Standards;
- NCC 2016;
- Workcover NSW; &
- CIBSE Guide D.

8.5.1 Building Code of Australia

The following areas of the NCC are relevant to the vertical transportation design solution and will be captured within specification documentation.

Item	BCA Requirement	Design Outcome and Comment
Lift car emergency lighting (Clause E3.1)	A lift car must have an emergency lighting system designed— (a) to come on automatically upon failure of the normal lighting supply; and (b) to provide at least 20 lux of lighting for 2 hours on the alarm initiation button.	All lifts and hoists must comply
Cooling of lift	While a lift in a lift shaft is in service, the	All lifts must comply

Item	BCA Requirement	Design Outcome and Comment
shaft (Clause E3.1)	cooling of the lift shaft must— (a) ensure that the dry bulb air temperature in the lift shaft does not exceed 40°C; and (b) if the cooling is by a ventilation system, be provided with an air change rate determined using a temperature rise of no more than 5 K.	
Facilities for Persons with Disabilities (Clause E3.6b)	Lifts to be provided with: Handrail complying with the provisions for a mandatory handrail in AS 1735.12 Lift floor dimension of not less than 1100 mm x 1400 mm for lifts with a travel less than 12m. Minimum clear door opening complying with AS 1735.12. Passenger protection system complying with AS 1735.12. Lift car and landing control buttons complying with AS 1735.12. Lighting in accordance with AS 1735.12. For all lifts serving more than 2 levels: (a) Automatic audible information within the lift car to identify the level each time the car stops; and (b) audible and visual indication at each lift landing to indicate the arrival of the lift car; and (c) audible information and audible indication required by (a) and (b) is to be provided in a range of between 20–80 dB(A) at a maximum frequency of 1 500 Hz. Emergency hands-free communication, including a button that alerts a call centre of a problem and a light to signal that the call has been received.	All passenger lifts to be specified to meet the requirements of AS1735.12.

8.5.2 Lift Standards

The following Australian Standards are relevant to the vertical transportation design within WBAP.

Item	Requirement	Design Outcome and Comment
Automatic fire sprinkler systems AS 2118.1 (Clause 5.7.2)	Sprinkler heads in lift shafts Sprinklers shall be installed in all lift shafts that are inside or in communication with buildings. Sprinklers shall be located in the top and base of each lift shaft. Sprinklers installed in lift shafts and sheave rooms shall be protected by stout metal guards and shall have a temperature rating of not less than 100°C in accordance with the appropriate part of AS 1735. Pipe work in hoist and lift shafts shall be galvanized.	To be confirmed by the fire consultant
Design for access and mobility AS 1428.2 (Clause 12)	Lift car size Lifts installed for public use should have audio, visual and tactile information. Lifts shall comply with AS 1735.12, except that the floor area in lifts shall be increased 300 mm in each direction, from the minimum size specified in AS 1735.12. i.e. 1400mm wide X 1700mm deep.	Lifts 1 and 2 will comply

The lift installation will be developed in accordance with the following standards;-

- AS 1735 - Lifts, Escalators and Moving Walks
- AS 1735.1 - General Requirements
- AS 1735.2 - Passenger and goods lift - Electric (For reference in the event of silence or ambiguity within AS1735.1 and code referenced within)
- AS 1735.4 - Service lifts – Power Operated
- AS 1735.11 - Fire-rated landing doors
- AS 1735.12 - Facilities for persons with disabilities
- AS 1735.14 - Low-rise platforms for passengers
- AS 1735.15 - Low-rise passenger lifts – Non-automatic controlled
- AS 1735.16 - Lifts for persons with limited mobility – Restricted use – Automatically controlled
- AS 4431 - Guidelines for Safe Working on New Lift Installations in New Constructions
- Building Code of Australia
- AS 1428.2 - Design for Access and Mobility; Part Two: Enhanced and Additional Requirements – Buildings and Facilities
- AS1428.4 - Design for access and mobility - Means to assist the orientation of people with vision impairment - Tactile ground surface indicators
- AS 1668.1 - Ventilation and Air-conditioning in Buildings – Fire and Smoke Control
- AS1668.2 - Acceptable Ventilation Guidelines
- AS1530 - Methods for fire tests on building materials, components and structures
- AS1657 - Fixed platforms, walkways, stairways and ladders - Design, construction and installation
- AS1670.4 - Fire detection, warning, control and intercom systems - System design, installation and commissioning - Sound systems and intercom systems for emergency purposes
- AS1170.4 - Earthquake actions in Australia
- AS1418.8 - Cranes, hoists and winches – special purpose appliances
- AS 2118.1 - Automatic Fire Sprinkler Systems
- AS/NZ 3000: Electrical Installations (known as the Australian/New Zealand Wiring Rules). Wiring requirements for lift installations
- AS/NZ 3008 - Electrical Installations – Selection of Cables – Cable sizes for lift installations
- ISO 7465 - Passenger lifts and service lifts -- Guide rails for lift cars and counterweights
- ISO 9001 - Quality Systems

8.5.3 CIBSE Guide D

CIBSE guide D provides advice in relation to the width of lift lobbies. Lobby widths should be 1.5 to 2 times the depth of the deepest lift car that faces the lobby.

9 Fire Engineering

This report describes the schematic fire safety design for the proposed Chau Chak Wing Museum at the University of Sydney. The schematic t design has been developed using a combination of performance based fire engineering and Deemed-to-Satisfy (DtS) Provisions as set out in the Building Code Australia (BCA) 2016.

Note that this report does not aim to address the specific DtS non-compliances associated with the design. These will be addressed and documented in the subsequent Fire Engineering Brief (FEB) and Fire Engineering Assessment Report (FER) as part of the formal fire strategy approvals process in NSW.

This report outlines the fire life safety concepts in order for the architect and design team to progress the design.

9.1 Building Characterisation

The building is a Class 9b museum and Class 7 storage. The proposed design is to include a number of open voids and open stairs connecting 4 levels. The building is located on a sloping site and therefore has access to road or open space on three separate levels (Ground floor, Lower Ground Level and Lower Level 1).

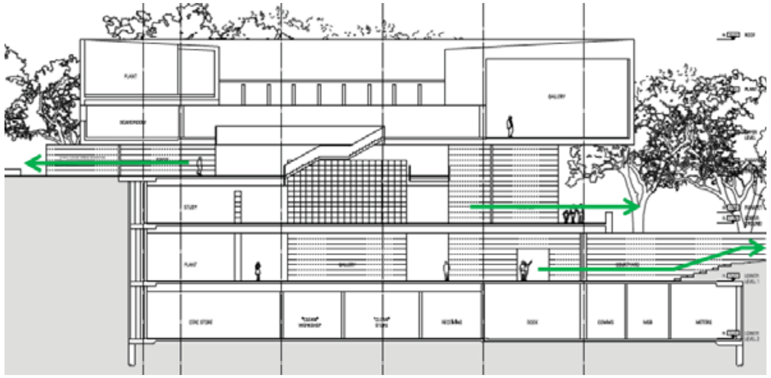


Figure 19 Building Section and exit locations

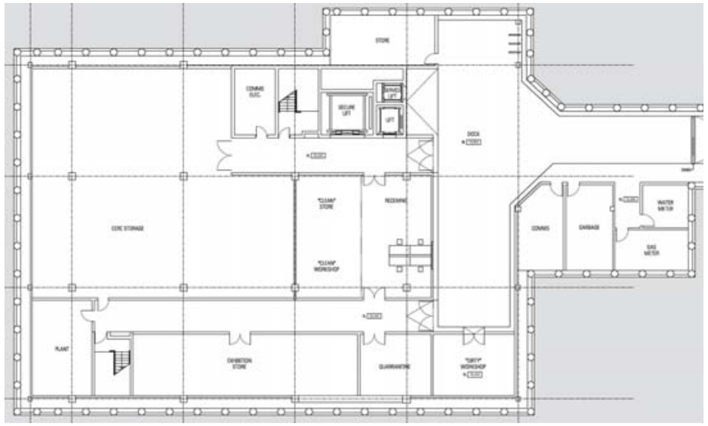


Figure 20 Lower Level 02 plan

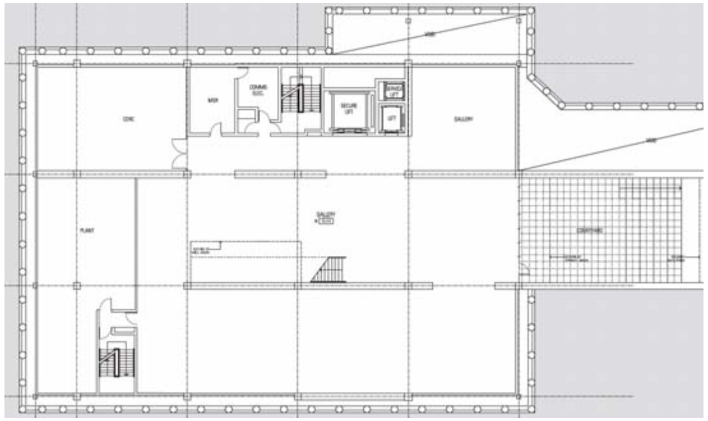


Figure 21 Lower Level 01 plan

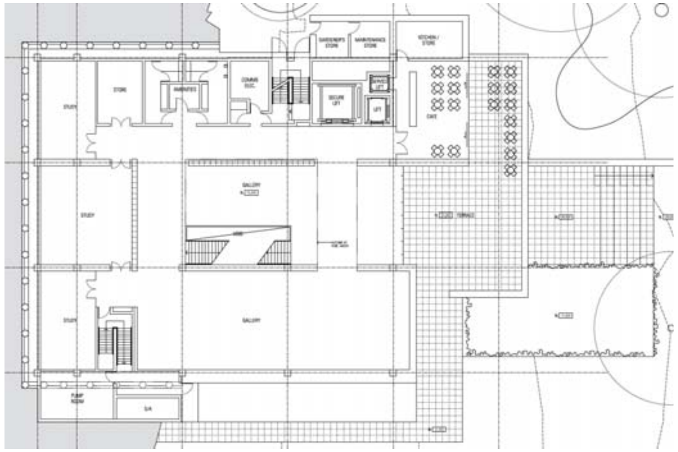


Figure 22 Lower Ground Level plan

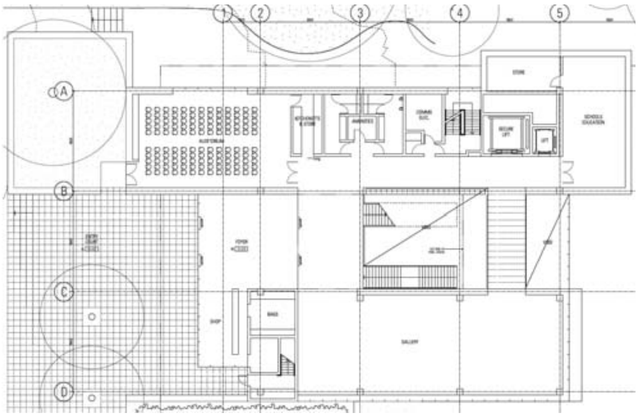


Figure 23 Ground Level plan

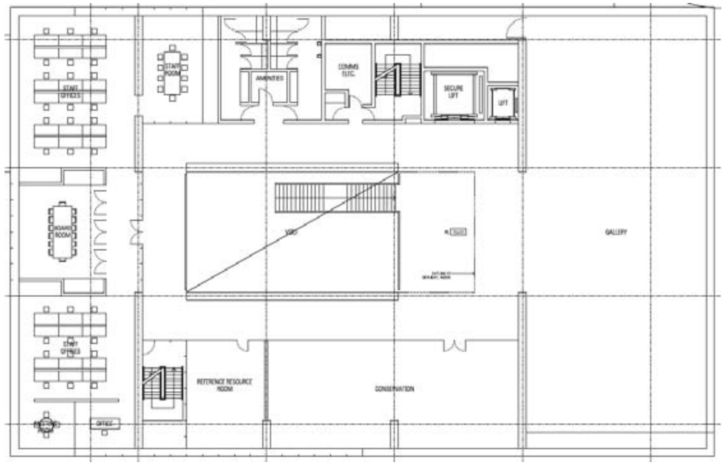


Figure 24 Upper Level plan

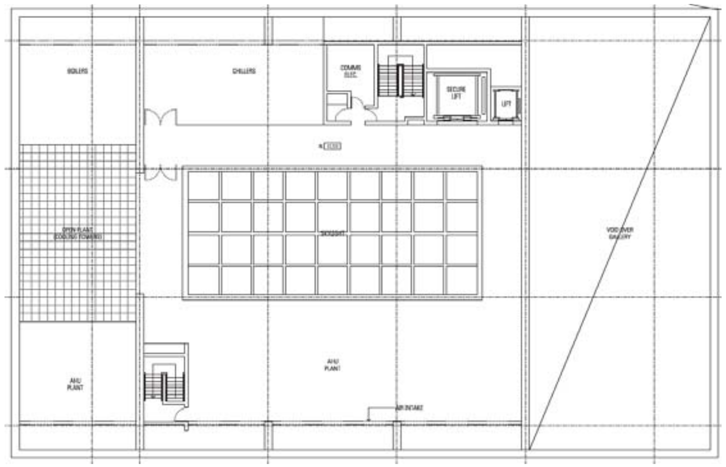


Figure 25 Plant Level plan