Appendix 12 – Mechanical Report

Cairns Regional Council

Cairns Performing Arts Centre

Mechanical Services Concept Engineering Report

CR001

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Contents

1 Introduction

This report provides a summary of the significant mechanical design considerations for the Cairns Performing Arts Centre. The document outlines key performance requirements, assesses options and makes recommendations for the most appropriate mechanical system. The intent of the report is to provide the client with sufficient information to enable confirmation for the design team to progress to the next design stage.

1.1 Project Description

1.1.1 Site

The Cairns Performing Arts Centre (CPAC) project is proposed on a site adjacent to the Cairns Convention Centre. The site occupies an area bounded by Hartley, Grafton, Wharf and lake Streets.

Figure 1: CPAC proposed site (Image extract from COX Architects)

1.1.2 Proposed Buildings for CPAC

The Cairns Entertainment Precinct is a performing arts facility consisting of:

- Two performance spaces
  - 1100 seater Auditorium (1 balcony), Stage, Orchestra pit (40 people) and Fly Tower
  - 500 seater Studio Theatre – Flexible flat floor retractable seating including stage
- Foyer
  - Front of House (Box office, Foyer, Toilets, Management offices)
- Back of House spaces
  - Admin offices, meeting room and support facilities for up to 20 persons
  - Production and technical offices for up to 10 persons
  - BOH/FOH and building staff rooms and amenities for 30 persons
  - Theatre Dressing rooms (2) for 4 persons
  - Theatre Dressing rooms (3) with en-suites for 10 persons
  - Theatre Dressing rooms (2) with amenities for 40 persons
  - Studio Dressing rooms (2) with en-suites for 10 persons
  - Studio Dressing rooms (2) with amenities for 20 persons
  - Dressing room (1) with amenities for 5 persons
  - Green Room with kitchenette for 100 persons
  - Wardrobe and laundry with good ventilation and fume extraction
  - Food & beverage dock including Garbage facilities
  - Scenery dock storage space
  - Maintenance workshop
  - Storage for staging, sound, lighting and Audio/visual requirement
  - Piano and instrument store with individual climate control
  - Cleaners and chemical storage cupboards with sinks
- A basement car park providing 92 car parking spaces

2 Design Criteria

This concept report outlines the design solutions for the mechanical services that shall serve the Cairns Entertainment Precinct. The following key design objectives have been taken into consideration:

- Acoustic Performance
- Occupant Comfort
- Capital and Operating Costs
- Seamless integration with the architectural design

2.1 Regulations, Standards, Authorities and reference documents

The mechanical services shall be designed in accordance with the following:

- National Construction Code (formerly Building Code of Australia) and
- Building Permit conditions
- AS 1668 Part 1: The use of ventilation and air conditioning in buildings – Fire and smoke control in multi-compartment buildings
- AS 1668 Part 2: The use of ventilation and air conditioning in buildings – Mechanical ventilation in buildings
- AS 3666: Air-handling and water systems in buildings
- AS/NZS 3000:2007: Electrical installations
- Australian Communications Authority
- All other applicable Australian Standards
- Chartered Institute of Building Services Engineers (CIBSE) Guides A, B and C
- Work-cover requirements
- OHS regulations
- Electricity supply authorities
- Fire brigade requirements
- All local council regulations
- Acoustic Studios Design Brief
- Schuler Shook – Theatre Planners – CPAC Brief (08/02/2013)

2.1.1 External Design Conditions

The external design criteria as documented within the Australian Institute of Refrigeration and Air Conditioning and Heating (AIRAH) Application Manual DA-09 for the Cairns region is illustrated in Table 1 below.

	Dry Bulb Temperature (°C)	Relative Humidity (°C)
Summer	32.8	26.8
Winter	15.1	Saturated

Table 1: External Design Conditions

2.1.2 Internal Design Conditions

For the internal design criteria for occupant comfort it is proposed to use international best practice standards as stated within the American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE) design guides as illustrated in Table 2 below.

Room	Summer Dry Bulb Temperature (°C)	Winter Dry Bulb Temperature (°C)	Relative Humidity (%)
Auditorium(s)	24±2	22±2	40-60*
Studio Theatre	24±2	22±2	40-60*
Back of House (Occupied rooms)	24±2	22±2	40-60*
Front of House, Foyer and Public Spaces	24±2	22±2	40-60*
Rehearsal spaces	24±2	22±2	40-60*
Toilets, Washrooms and Cloakrooms	NC**	NC**	NC

Table 2: Internal Design Conditions

* Denotes humidity shall generally fluctuate within the region stated through the normal air conditioning process. However close control is not guarantee

** Space ventilated by make-up from conditioned spaces.

NC denotes "Not controlled"

2.1.3 Ventilation Rates

The outside air rates shall be based on AS1668.2 1991 as tabled below. However where occupancy density figures have been specifically defined as part of the project brief they shall be used in lieu of the figures stated below.

Room Type	Net floor area per person (m^2/person)	Outside airflow rate (Litres/second/person)
Auditorium(s)	0.6	15*
Studio Theatre	1.5	10*
Foyers	0.6	15*
Green Rooms	5	15
Lobbies	1	15*
Stages	1.5	10
Ticket Booths	-	10
Dressing Rooms	2	10

Table 3: Outside Air Rates

* Denotes CO_2 control (outside air able to reduce to 5l/s/p during unoccupied or reduced capacity periods)

Exhaust ventilation rates shall be based on AS1668.2: 1991 as tabled below.

Room Type	Airflow Requirement
Toilets	The greater of 10l/s/m^2 and 25l/s per listed fixture
Plant rooms	5 l/s/m2
Car Park	Deemed to Satisfy Design
Auditorium Control Room	5 l/s/m2

Table 4: Exhaust Ventilation requirements

2.1.4 Acoustics Requirements

Room Type	NR Level
Auditorium(s)	20
Studio Theatre	20
Foyers	40*
Green Rooms	35*
Lobbies	40*
Stages	20
Ticket Booths	40*
Dressing Rooms	35*

Table 5: Acoustic Performance

* From CIBSE Guide A

2.2 General & Site Wide Issues

2.2.1 Proposed Utility Services

New connections shall be required to provide electricity, water and condensate drain points for the mechanical systems.

2.3 Construction Issues

No construction issues have been identified at this stage that will impact the installation and implementation of mechanical plant to serve the project.

2.4 Environmental & Sustainability Issues

The design shall follow the environmental strategy as set out within the Ecologically Sustainable Design (ESD) consultants brief (Cundall) which address the requirements of Cairns Regional Council.

3 Mechanical Services

3.1 Overview

It is intended that the internal spaces shall be air conditioned through dedicated individual systems for each discrete area. These air conditioning systems shall be connected to centralised base building heating and cooling plant to offer an energy efficient solution that is energy efficient

3.2 Proposed systems

The following systems are proposed for CPAC:

- Outdoor air supply system
- Chilled water reticulation system
- Base building air-conditioning system
- Toilet exhaust system
- General exhaust system
- Condensate drains
- Electrical power and control systems for mechanical plant
- Automatic controls and building management system (BMS)
- Testing and commissioning of all systems

3.2.1 Auditorium

For the main auditorium, conditioned air shall be supplied from an underfloor plenum beneath the seats through side-wall diffusers. Supplying air at low level reduces any draft issues and has the added advantage in using the heat generated from each seated occupant in driving heated air out of the auditorium. These buoyancy effects help reduce the return air fan load. The stage in the auditorium shall have conditioned air supplied via displacement terminals that extend from the ducted network.

The system shall be suitable to provide a level of comfort for audience, artists and production staff.

Benefits of an underfloor system:

- Low energy system
- Enhanced level of occupant comfort through increased % of outside air
- Buoyancy driven system means internal heat gains, CO_2 and other pollutants move naturally away from occupied space.
- All air system reduces maintaince and removed water or refrigerant based system from the being located in the occupied space
- Low noise from mechanical services due to attenuation and low supply air velocities

Stage areas shall be have supply and exhaust air which can be isolated separately to allow the use of stage smoke and haze effects.

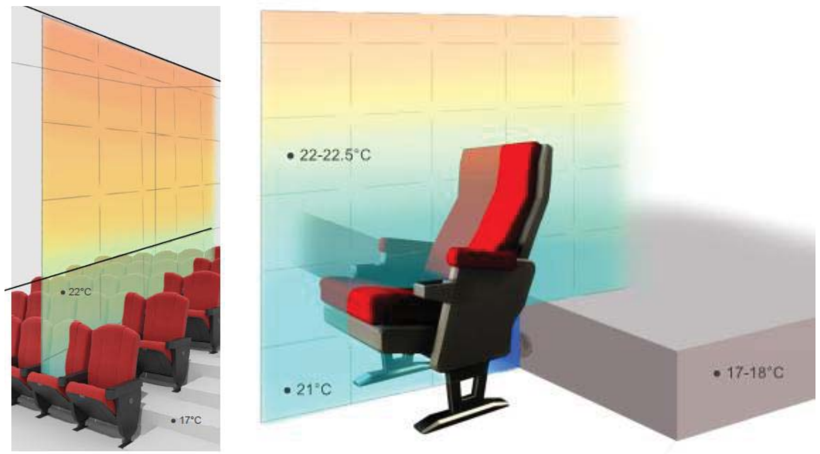


Figure 2: Displacement system

The smoke exhaust ventilation system shall be capable of user activation to clear theatrical smoke or pyrotechnical effects to quickly clear the stage of smoke/fumes.

3.2.2 Performing Arts Spaces

All performing arts spaces, side stages, orchestra pit and instrument storage shall require humidity control to protect musical instruments.

The piano and instrument store room shall be installed with individual climate control.

3.2.3 Basement Car Park

The basement car park shall be mechanically ventilated using supply and exhaust air fans connected to ductwork.

3.2.4 Front and Back of House, Rehearsal Rooms

Front and back of house areas, as well as rehearsal areas are to be conditioned using treated, ducted air supplied from ceiling mounted swirl diffusers.

All dressing rooms shall include individual user adjustable temperature control.

3.2.5 Kitchen and Toilet Areas

Kitchens and toilet areas shall have their own dedicated exhaust ventilation system to expel pungent air from the space. The exhaust air shall be expelled from the building through the roof using roof-mounted exhaust fans. Exhaust points shall be separated from air intake points by a minimum distance of six (6) metres.

3.2.6 Communication Rooms

Communication rooms shall be air conditioned using DX-split refrigerant units. Door grilles shall be utilised to provide make-up air to ventilate the space. A wall mounted fan coil unit shall be positioned in each communication room. The final location of the fan coil unit is to be co-ordinated with the rack/equipment layout.

3.2.7 Stairs

Stair Pressurisation systems shall be provided on each egress stair complete with variable speed drives and in-line fans.

4 System Descriptions

4.1 Variable Air Volume (VAV) System

A VAV system delivers conditioned air (from a primary air handling plant) to a space. The VAV system will modulate the amount of air delivered to the space (between a minimum and maximum level) depending on the amount of heat is generated within the space to be air conditioned. The primary plant (AHUs) located in dedicated plant rooms shall supply conditioned air to the VAV boxes by virtue of cooling and heating coils located within the primary plant.

Each VAV box shall be linked to both a pressure differential sensor and a room temperature sensor. In connection to the Building Management System (BMS) the primary AHU shall modulate its total volume of conditioned air supplied to the VAVs based on how much air is required by the VAV's. In doing so each AHU can be run efficiently to produce only the amount of conditioned air required depending on the room conditions. The impact of this efficient process will be to reduce the overall cooling demanded from the base building cooling plant (chillers, cooling towers, pumps etc).

4.2 Base building Air Handing Units

Dedicated air handling units shall be installed for each space.

Each unit shall be capable of supplying conditioned air to the space. Each shall be fitted with the following key components:

- VSD to the fans
- CO_2 control to modulate the amount of the outside air between a set minimum and full outside air to promote the use of economy cycle. An economy cycle shall be utilised when the external conditions are sufficient to provide supply air without the need to use mechanical cooling or heating whilst meeting the required room conditions
- Cooling coil
- Low Temperature Hot Water Coil
- Deep bed filters
- Primary and secondary attenuators (fitted either as part of the unit or duct mounted locally)

Figure 3 Example of an Air Handling Unit (AHU)

4.3 Chilled Water System

A base building centralised chilled water system shall be used to serve the cooling requirements of CPAC. The cooling plant shall:

- Provide chilled water to the cooling coils of the air handling units (as required)
- Be connected to cooling towers via a condenser water loop to enable heat rejection in an highly efficient manner. Each cooling tower shall be installed with VSD's to modulate the speed of the fans.

The chilled water system shall consist of the following components:

- High efficiency water-cooled chillers
- Primary and Secondary chilled water pumps
- High efficiency draft induced cooling towers
- Chemical water treatment equipment to serve the cooling towers
- Condenser water pumps
- Chilled water and condensate water distribution pipework

The water-cooled chillers shall be located in an internally sealed plant room. The plant room is to be ventilated through the installation of weather proof louvers to the external façade.

Figure 4: Example of a water cooled chiller

4.4 Cold Water Storage

The chilled water system is proposed to be reticulated through the buildings sprinkler tank. In doing so the chiller plant will charge the tank with chilled water therefore the sprinkler tank will behave as a thermal energy storage system. The sprinkler tank will be used as a heat exchanger and no water will be removed from the sprinkler tank. The use of a storage system will benefit the system in a number of ways:

- Provide a buffer of chilled water – Daily cooling demand fluctuations from the building can be smoothed out through the buffer tank allowing the chiller to operate more effectively.
- Reduce chiller wear n tear – Reduces frequency chiller compressors start/stop to meet the buildings varying cooling load throughout the day.
- Thermal load lopping – The production of chilled water during the night will allow the chillers to run more efficiently when external ambient conditions are generally cooler. This will result in a likely reduction in electricity bills due to the shift in proportion of chiller energy consumption during peak to off peak hours.

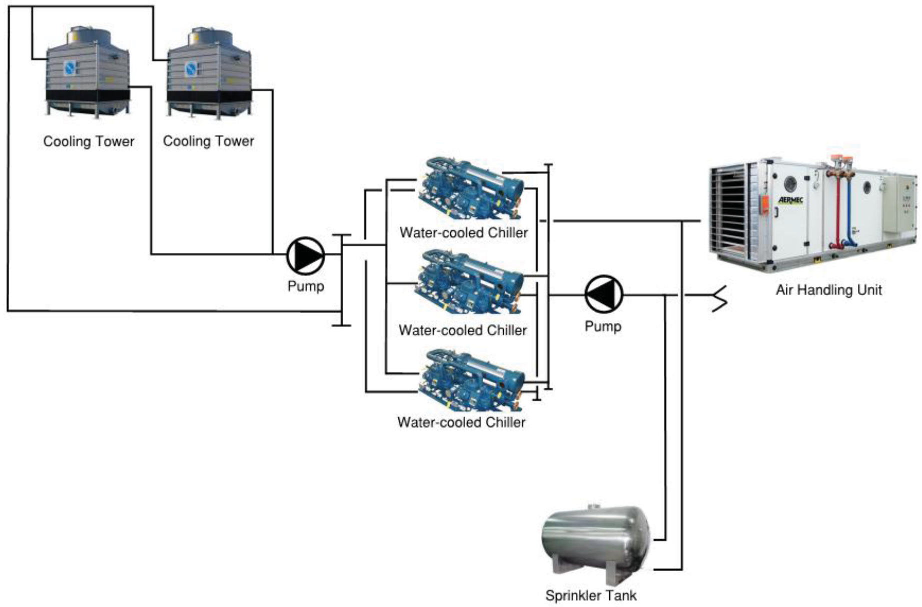


Figure 5: Illustration of cooling plant schematic

4.5 Low Temperature Hot Water (LTHW)

Low temperature hot water shall be produced through the use of a dedicated water-to-water heat pump. The heat pump shall be connected to the condenser water system shall extract heat which would otherwise be rejected through the use of cooling towers. LTHW from the heat pump will be delivered to both the AHU heating coils and to a dedicated hydraulic circuit to provide a heat source for the generation of domestic hot water.

4.6 Ventilation Systems

Dedicated mechanical ventilation shall be installed to serve the car park, life safety systems and all other supply and exhaust systems as required by AS1668.

The selection of each fan shall aim to minimise noise and vibration at the source; thus the choice of quiet fans shall be considered for acoustically-critical systems. Centrifugal fans with backward-inclined aerofoil blades are generally acceptable. Axial and forward-curved centrifugal fans are sometimes acceptable. Vane-axial units may produce less noise at low frequencies than centrifugal fans, but they should be avoided because they are tonal and typically 10dB noisier than other fans.

4.7 Pumps

Selection and balancing of centrifugal pumps for maximum efficiency is essential. Low pump efficiency can cause high pump noise and energy transmission to the fluid and piping.

Variable frequency drive systems shall be given careful consideration as will noise and vibration from the control unit. Where multiple pumps are joined to a common piping system special attention shall be paid so as not to create 'beat frequency' vibration.

Figure 6: Multiple pumps

4.8 Ductwork

Ductwork shall be thermally insulated to meet code requirements under Section J of NCC. Airflow in ductwork shall be maintained to low velocities that render it inaudible to human hearing. Ductwork shall be fitted with internally lined insulation to provide acoustic attenuation.

4.8.1 Air Velocities

The airflow velocities in ductwork systems that serve acoustically-critical spaces must be very low throughout the ductwork (except where the ductwork is distant from the space, for example in the plant room), and even lower as the ductwork approaches the terminal units within the acoustically-critical spaces.

The building services design criteria as documented by the project Acoustic Engineer (Acoustic Studio) is NR 20.

Duct velocities shall be limited to the following values:

- Main Ducts – 4.5 m/s
- Branch Ducts – 3.5m/s
- Run outs - < 2m/s
- Between splitters in primary attenuator – 5m/s

4.8.2 Duct materials and geometry

Rectangular galvanised sheet metal ductwork shall be used for most applications because it provides the most cost effective attenuation of low frequency fan noise along the duct. Ducts with an aspect ratio > 3:1 should be avoided. If high aspect ratio ducts are unavoidable, external duct stiffeners may be required to control vibration. Internal stiffeners create noise and should not be used.

If exposed ductwork is required inside an acoustically-critical or noisy space, internally lined circular duct shall be considered, since this shape allows less noise to break into or out of the duct. Circular ducts are not to be used for general purposes in acoustically-critical systems, since they do not adequately attenuate low frequency noise.

Transitions in duct geometry should be ≤ 10º.

Figure 7 Poor Duct Elbow Geometry

4.8.3 Routing of Ducts and Pipes

The routing of ducts and pipes shall be considered carefully by the design team early in the design. Sound isolation can be severely reduced by chases or penetrations in walls for ductwork. Non-essential service penetrations are to be avoided through sound isolating constructions. Ducts are not to enter performance spaces, control rooms or rehearsal spaces directly from another occupied space. Instead, they are to enter from an enclosed and quiet duct space. In some areas, surface mounted fittings will be required in order to avoid penetration of isolating walls or ceilings.

4.8.4 Services In or Near Acoustically-Critical Spaces

Services for acoustically-critical spaces are not be routed through noisy spaces or through other acoustically-critical spaces. Also, services serving other areas (only) are not be routed through acoustically-critical spaces. Noise can enter the duct in one space and be transmitted down the duct to another. Hot water and steam pipes generate noise as the pipes expand and contract in the pipe clamps and as valves constrict the flow. Flow noise can be a problem in all pipes, including domestic hot and cold water. Pipes connected to pumps will vibrate and radiate low frequency pump noise as well as flow noise. This vibration can be efficiently transmitted through the building structure.

Where sprinkler pipes penetrate the envelope of any acoustically-critical space they must be sealed airtight with a resilient surround seal. Where sprinkler systems include an intermittently operating ‘jockey’ pump, the pipes should be treated as plumbing pipes.

Rainwater pipes transmit noise from outside and radiate flow noise in storms. They should be located outside acoustically-critical spaces. Rainwater pipes should not run through the roof void above the auditoria, as rain noise would be audible during a storm. Instead, run the water to the edges where drains can descend outside the room envelope. Similar care must be taken in routing of drainage pipes from showers, washbasins and toilets.

4.8.5 Services Crossing Acoustic Isolation Joints

Pipes and conduit routing should be planned to minimise the crossing of acoustic isolation joints. Specify isolators and flexible connectors where pipes or conduits cross an acoustic isolation joint. Ducts crossing acoustical joints should be supported on isolators for the first five hangers each side of the joint.

Figure 8 Flexible duct connection and sealed penetration at an isolation joint

4.8.6 Acoustic Crosstalk Control

Crosstalk control will be needed between spaces served by a common air system but requiring acoustic separation, such as dressing rooms. This control is typically achieved by using acoustically lined ductwork or small attenuators, combined with external ductwork lagging.

4.8.7 Atmospheric Side Noise Control

Attenuators, including acoustic louvers if appropriate, may be necessary to limit noise emission from the building and to control noise ingress within naturally-ventilated areas of the building.

4.9 Thermal Modelling

Building heat loads (including fabric and solar loads) shall be determined using steady state calculation software. Input variables such as environment conditions, façade orientation, shading elements, building fabric, lighting and equipment loads, occupancy variations and temperature of adjacent spaces shall be considered to build an accurate thermal load profile for each space in the building.

Design checks using hand calculations and reference material shall be made to ensure that the results of the steady state calculation software are in alignment with expected heat load values.

Following calculation of the building heat loads, the mechanical plant equipment can be sized accordingly.

4.10 Building Management System

A BMS is proposed to control and monitor the mechanical services. The BMS will be configured in close coordination with the facility management of Cairns Entertainment Precinct.

The BMS will:

- Control and monitor all mechanical equipment inside the building
- Control the internal and external lighting
- Monitor all other services within the building for faults (lifts, security, electrical, hydraulic, fire)
- Monitor electricity and water meters
- Incorporate its own UPS

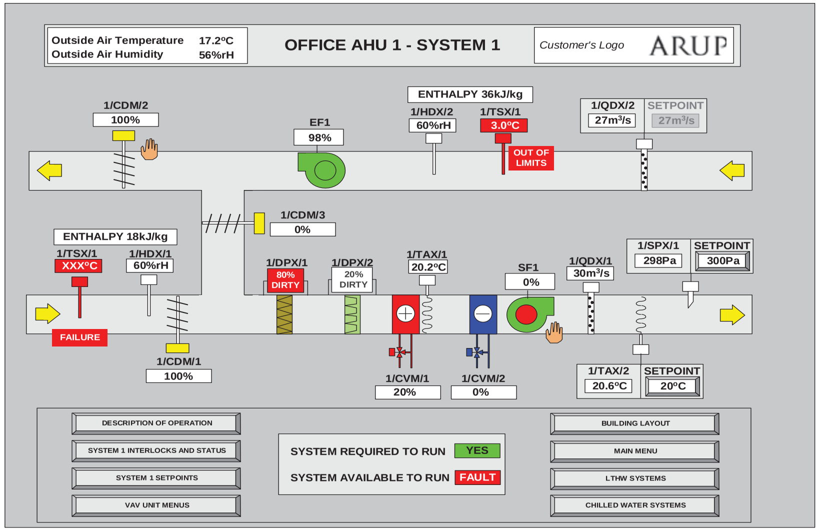
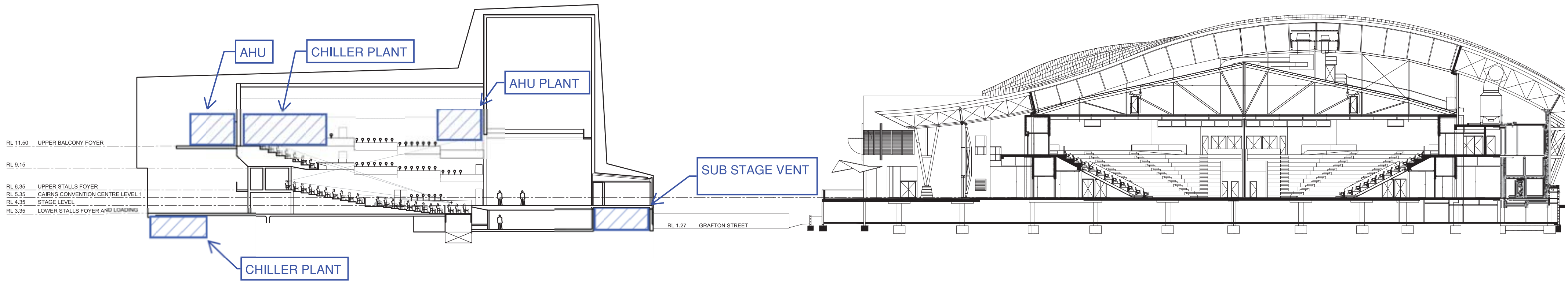


Figure 9: Example of a BMS interface screen of an air handling unit

Appendix A

Mechanical Plant Spatial's



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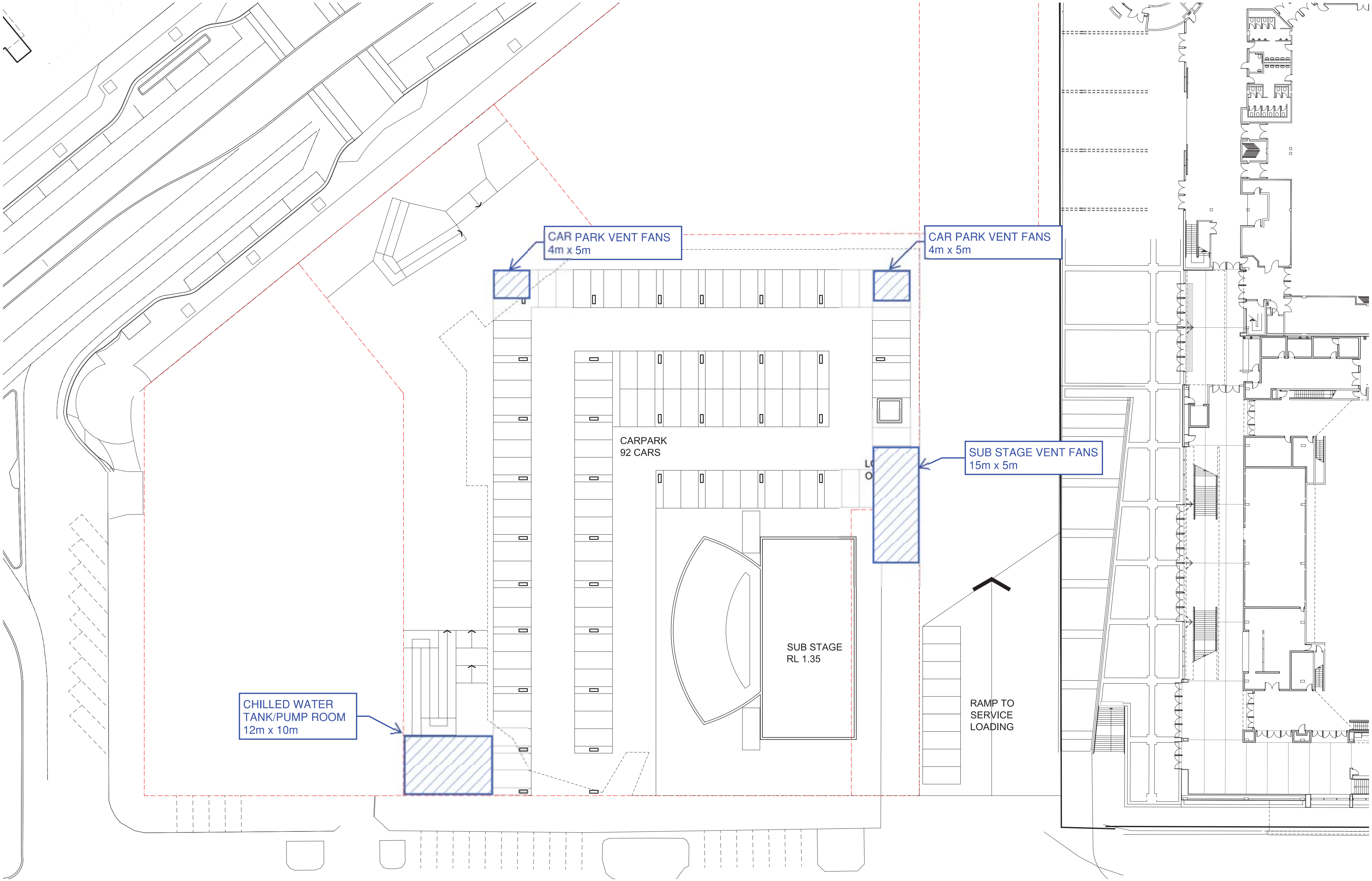
ARUP - MECHANICAL PLANT SPATIAL REQUIREMENTS
22/1/13

CAIRNS PERFORMING ARTS CENTRE 04/12/2012

COX RAYNER ARCHITECTURE



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22/1/13

CAIRNS PERFORMING ARTS CENTRE 12/11/2012

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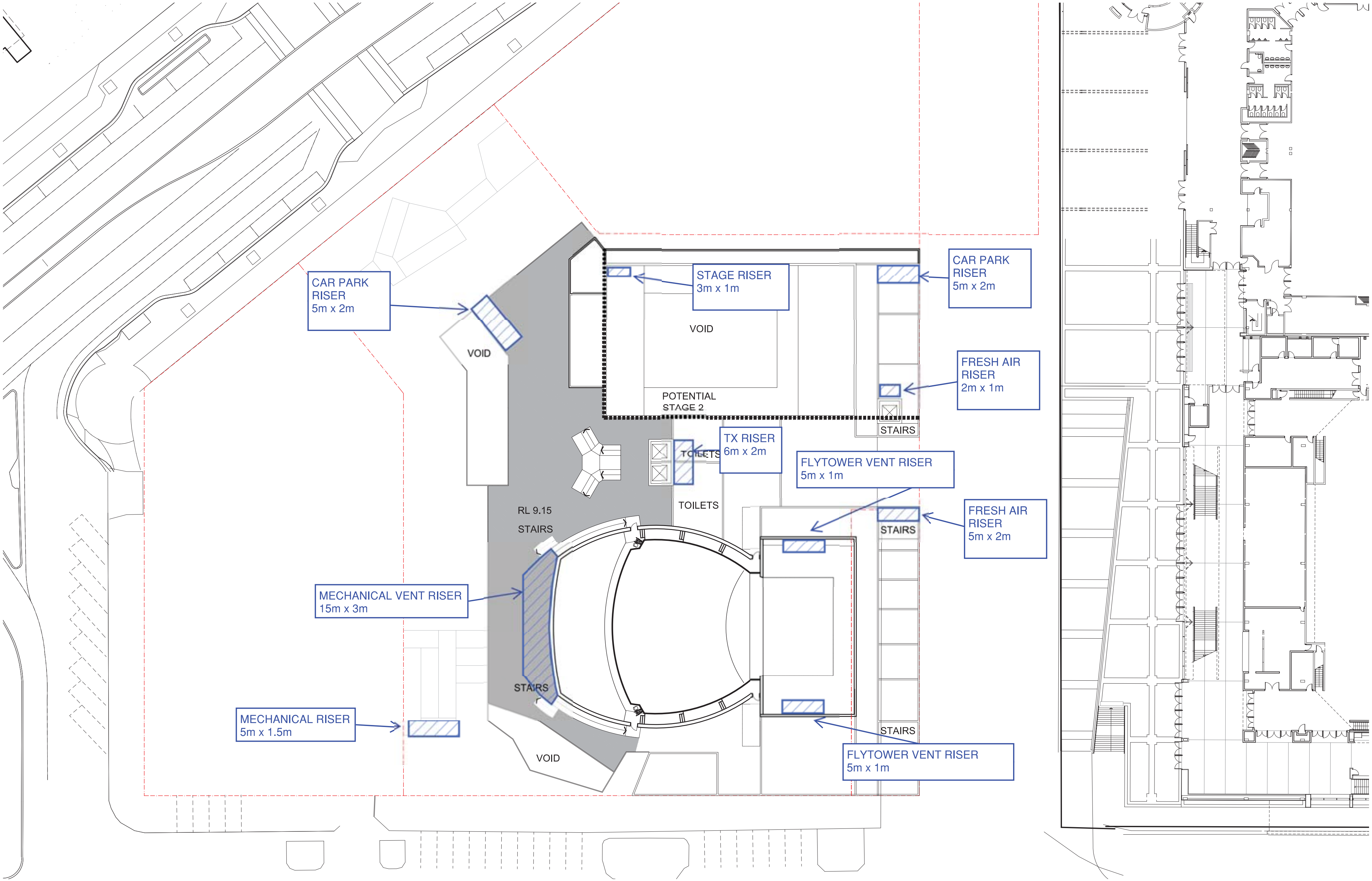

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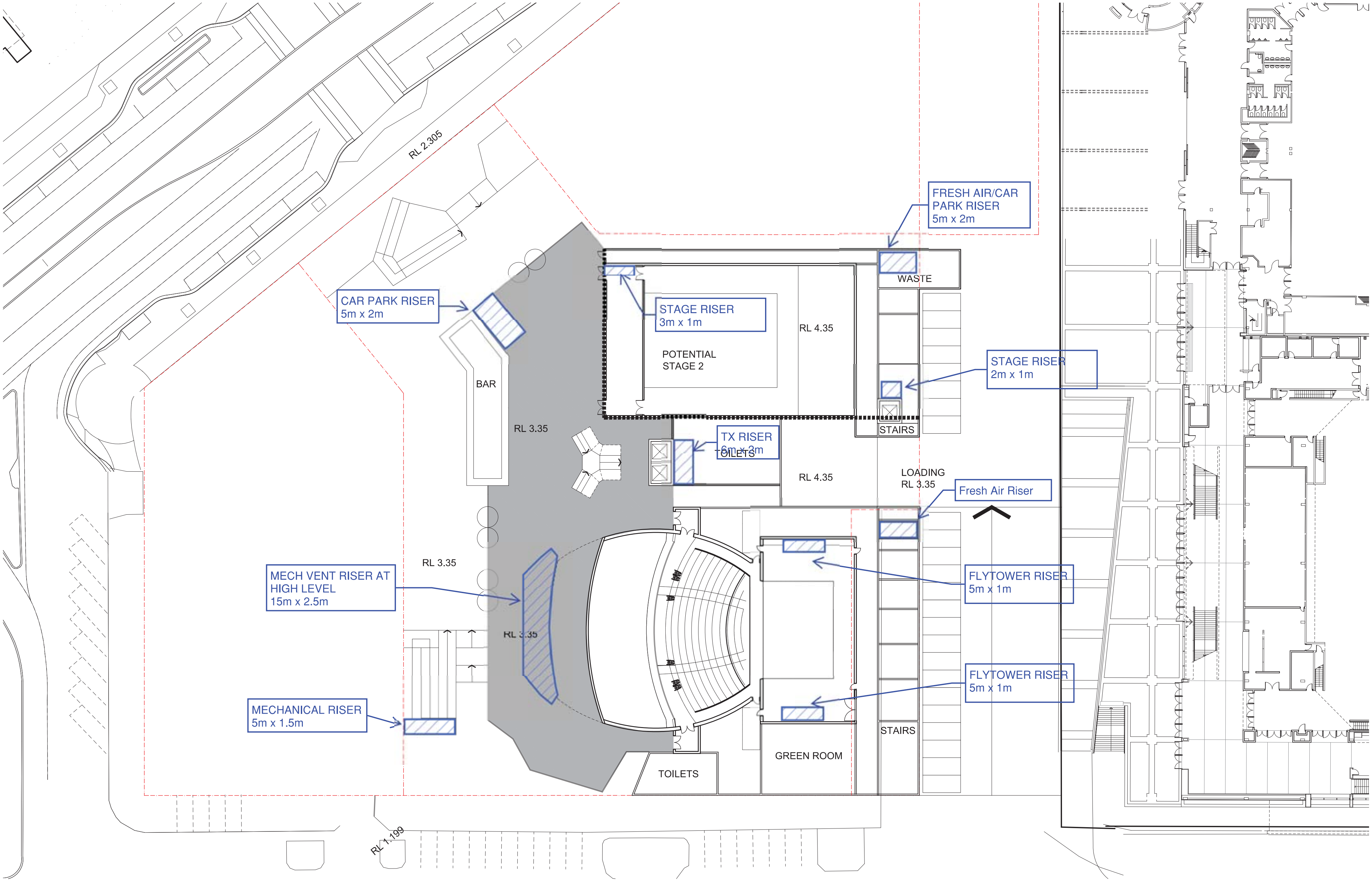

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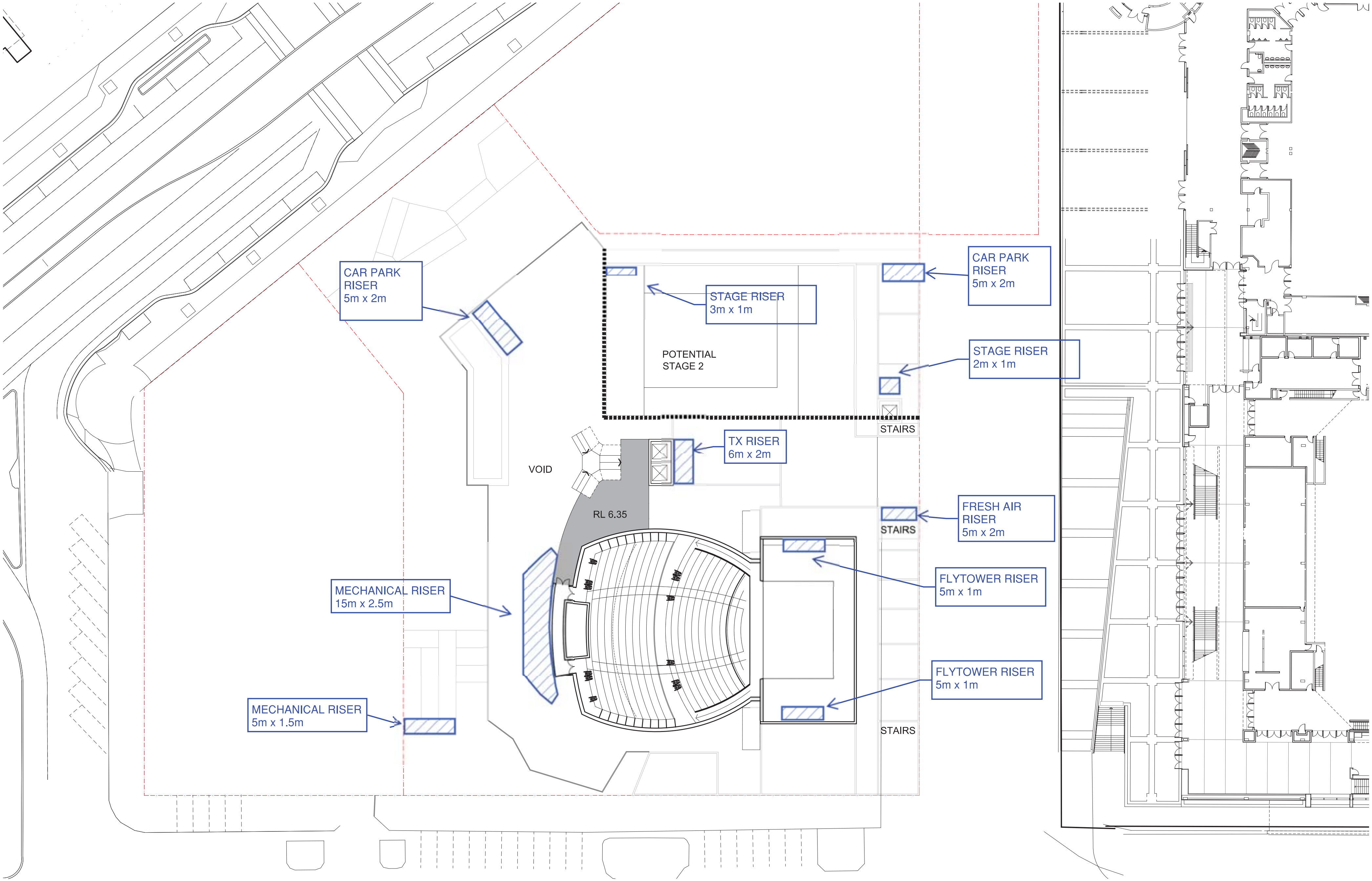

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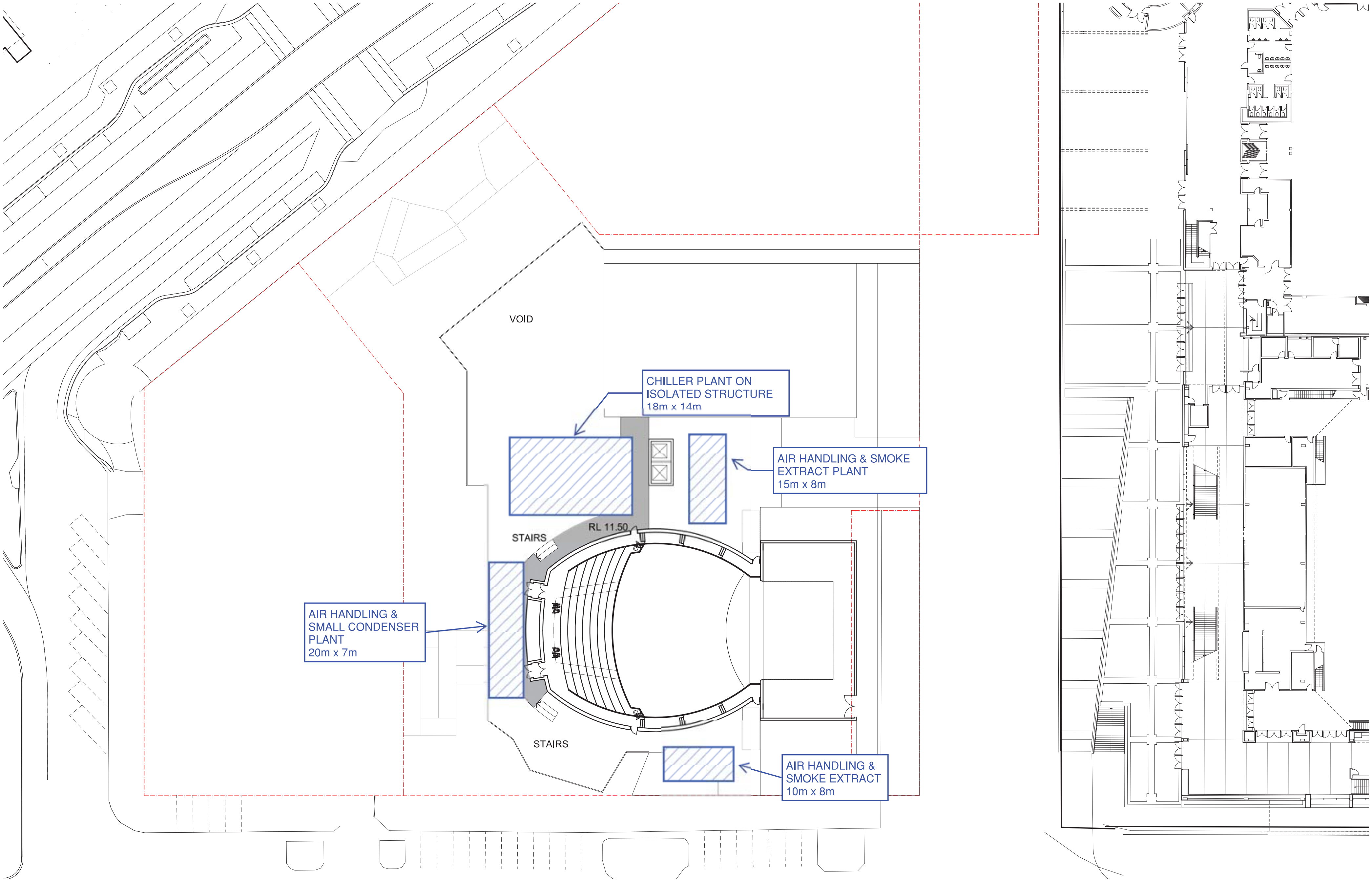

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