NSW Health Infrastructure

Paediatric Services Building at The Children's Hospital at Westmead

CHW-ST-RPT-00005 Structural Report

01 | 2 November 2020

Job number 271985-00

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Job title	Paediatric Services Building at The Children's Hospital at Westmead			**Job number** 271985-00
Document title	CHW-ST-RPT-00005 Structural Report			**File reference**
Document ref				

Revision	**Date**	**Filename**	CHW-ST-RPT-00005 Structural Design Report.docx		
Issue 01	2 Nov 2020	**Description**	Issue 01		
			Prepared by	Checked by	Approved by
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		Filename			
		Description			
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		Filename			
		Description			
			Prepared by	Checked by	Approved by
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Contents

Appendices

1 Introduction

1.1 Acronyms

CHW	Children's Hospital Westmead
PSB	Paediatric Services Building
ESG	Health Infrastructure Engineering Services Guidelines
CASB	Central Acute Services Building
WIMR	Westmead Institute Medical Research
KR	Kid's Research
ICU / HDU	Intensive Care Unit / High Dependency Unit
SCHN	Sydney Children's Hospitals Network

1.2 Proposed Development

The proposal seeks consent for the construction of a new Paediatric Services Building (PSB) to be located adjacent to the CASB, and on the site of the decommissioned P17 car park, including development of the Hawkesbury Road forecourt and access links. This includes works associated with CHW forecourt on Hawkesbury Road to provide improved community amenity in the form of a new front entry, improved street frontage and enable a more cohesive main entrance connecting existing CHW, adjoining research facilities, and the PSB.

The scope of proposed works includes:

- Construction of the main PSB: The main PSB may contain the following uses; perioperative and interventional services, neonatal and paediatric intensive care units, cancer centre, acute inpatient beds, back of house and parent facilities.
- Alterations and additions to existing CHW KR and CASB buildings adjoining PSB site area to accommodate floor realignment and movement corridors.
- Construction of a new pedestrian canopy link through KR, connecting the main PSB with the CHW forecourt and existing hospital entrance.
- The canopy link is to be lifted 2 storeys above the CHW forecourt.
- A new ground plane / forecourt landscaped area extending from Hawkesbury Road to the proposed PSB.
- Tree removal to accommodate the construction of the PSB.

1.3 Purpose of Structural Report

This report is written primarily for the support of State Significant Development Application (SSDA), application number SSD-10349252, as part of the project planning requirements. It will also be useful for:

- Engineers or building professionals who are constructing the structure;
- Owners or tenants of the finished building;
- Other members of the design team; and
- Engineers making alterations to the structure in the future.

The report has a number of purposes:

- It contains a description of the project, the site and the structural works;
- It lists the assumptions about structural loadings and the structural performance criteria; and
- It sets out and describes the principle methods of analysis and justifications that will be used in the structural calculations in subsequent design stages.

It should be noted that this document describes works associated with the permanent condition of the structure only. All non-permanent works are considered temporary works and are considered outside Arup's scope of services. All temporary works shall be designed and certified by a registered person and same shall be made known to Arup and the client team prior to undertaking any works on the project.

2 Project Information

2.1 Reference Documents

The following Arup documents have been previously developed as part of the master planning work for the Redevelopment Project. The findings and principles of these documents are carried through to Scheme Design.

- REP-ST-001: Structural Master Planning Report (Dated: 13/12/2019)
- CHW-ST-RPT-00001: Demolition Multi-storey Car Park Structural Report (Dated: 19/03/2020)
- CHW-ST-RPT-00004 Structural Concept Design Report (Dated: 12/08/2020)

A number of external documents have also been provided to Arup through the development of the master planning and scheme design stages, and these inform the direction and structure of this Report:

- CHW-AR-RPT-00001: Children's Hospital at Westmead Stage 2 Master Plan Design Report (Dated: 13/02/2020)
- CHW-AR-DG-PSB-10: BLP Architectural Plans (23/10/2020)

2.2 PSB Site

2.2.1 Existing Site Layout

The site is bounded by Westmead's Central Acute Services Building, the Existing Westmead Children's Hospital, Hawkesbury Road and Redbank Road.

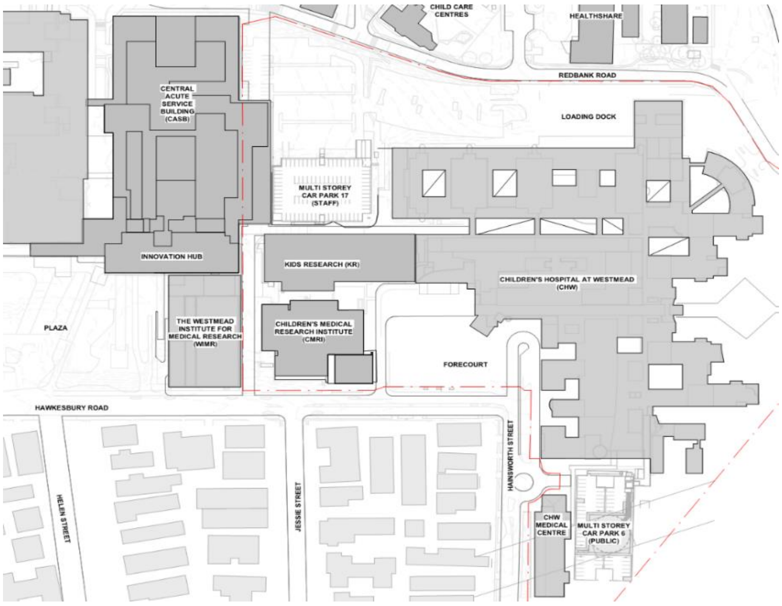

Figure 1: Existing Site Layout

2.2.2 Development Extent

The location of the new Paediatric Services Building (PSB) has been developed from the master planning to interface with the existing Children's Hospital at Westmead (CHW), recently completed Central Acute Service Building (CASB) and Research Buildings. The PSB is partially situated in the location of the existing Multi-Storey Car Park (P17), as shown in Figure 2. The existing structural drawings have been reviewed to determine the construction type, inform the demolition design, as well as the type and location of the existing foundations and the column grid. For the demolition design refer to document CHW-ST-RPT-00001: Demolition Multi-storey Car Park Structural Report, the demolition design does not form part of the scope of this report or SSDA application.

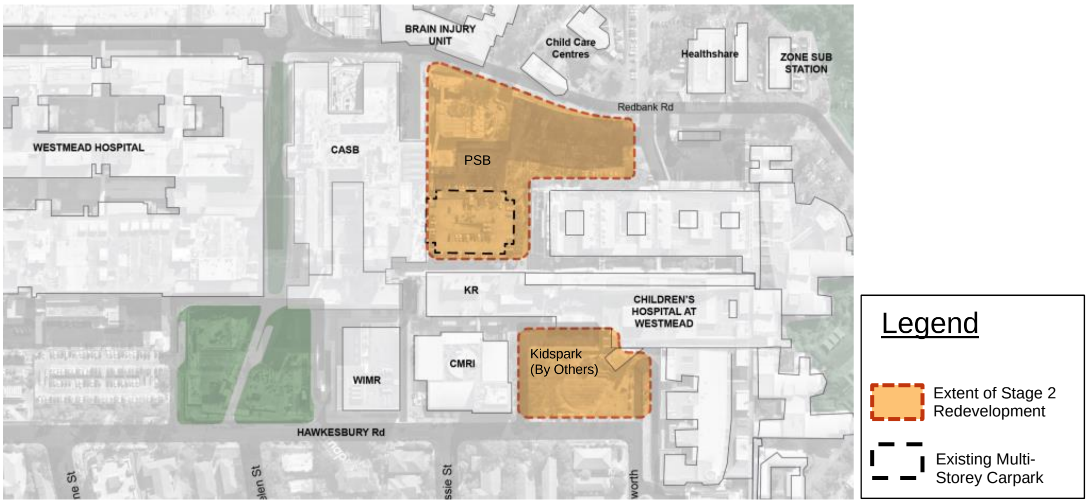

Figure 2: CHW Stage 2 Development Extent

2.2.3 Proposed Location of Key Connection Links

As shown in Figure 3, there will be three major connection links which unite the precinct, including Galleria, Research Street and Kid's Way. Research Street will be a future development and thus doesn't form part of the CHW Stage 2 development. However, in future development stages this bridge link will run parallel to Hawkesbury Road, connecting into Kid's Way allowances for the future connection will be accommodated in the design of Kid's Way.

During CHW Stage 2 redevelopment, the existing Galleria will be extended, connecting into Kid's Way. Kid's Way will be established by connecting the precinct from Hawkesbury Road through to Redbank Road. This will act as the major public access to the new PSB. A portion of the existing Kid's Research (Block 4) will require breakthrough to allow for Kid's Way connection to PSB, as shown in Figure 3.

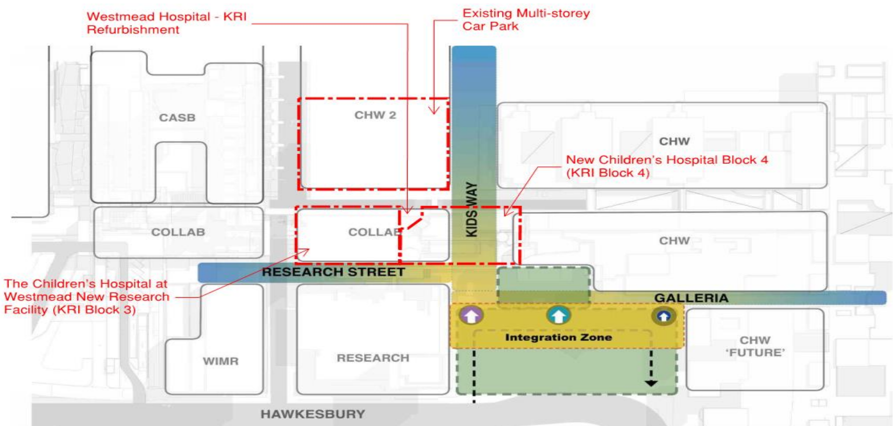

Figure 3: Interface of Proposed Linkages and Existing Buildings

2.2.4 Development Constraints due to Existing Site Layout

- The new PSB will be linked to the adjacent CASB via bridge links at levels 3 and 4, as shown in Figure 4.
- As shown in Figure 2, the new PSB is bounded East, South and West between the existing CHW, KR and CASB, respectively.
- A portion of the existing KR will require breakthrough to allow for Kid's Way connection to PSB, as shown in Figure 3.

2.2.5 Site Topography

The existing ground profile varies across the site from RL19.0m to RL20.7m. The extent of the ground plane usage and associated extent of cut and fill has been developed by the design team to maximise the re-use of cut to limit the quantity of material to be removed from the site. The Civil Engineering design report provides further details on the cut and fill extents.

2.2.6 Site Geology

The expected site geology has been based on the interpretation of the JK Geotechnics report 33303Brpt1 *Geotechnical Investigation (Draft)* (3rd November 2020). This report highlighted that the site geology is consistent with the expected regional geology and previous geotechnical reports. The geological profile has been summarised in Table 1.

Table 1: Typical Geotechnical Profile

Component	Depth	Allowable Bearing Pressure	Allowable Shaft Adhesion
Topsoil/Fill	Depth varies across the site from a depth of 0.4m to 6.1m.	N. A	N. A
Class V Bedrock	Depth varies across the site from 0.9m to 9.2m	1000 kPa	100 kPa
Class IV Bedrock	Depth varies across the site from 3.5m to 10.5m	1200 kPa	120 kPa
Class III Bedrock	Depth varies across the site from 4.2m to 11.5m	4000 kPa	400 kPa
Class II Bedrock	Depth varies across the site from 6m to 12.2m	8000 kPa	800 kPa

2.2.7 Contamination

In April 2019, a detailed site inspection was conducted by JBS&G to delineate the extent of asbestos impacted fill, as well as characterise non-asbestos contaminates across the site. The investigation found that soils were impacted by anthropogenic contamination including asbestos, plastic, metal fragments, bricks, concrete fragments, traces of bitumen and glass. Asbestos-containing materials (ACMs) was detected in fill up to 4.3m below ground surface. Based on the investigation findings of bonded and friable asbestos within fill, which is consistent with previous investigations conducted within the Westmead precinct, JBS&G state that all fill material at the site is considered to be impacted with asbestos to varying extents.

2.2.8 Groundwater

Investigations performed during the design of the adjacent Central Acute Services Building outline the absence of groundwater in the augered sections of the boreholes (soil and extremely weathered rock). Available information from previous ground investigation in the area revealed that a perched groundwater table at the interface of residual soil and weathered rock could be present and varies between RL 12.5m AHD and RL 20.5m AHD.

It was noted that there is the possibility of seasonal variation of groundwater levels with infiltration through fissured soils into fractured rock mass.

2.2.9 Construction Constraints

Zero patient impact during construction phase is one of the main objectives in delivering the project. Early consideration to construction phasing will improve the chance of successfully meeting the ‘business as usual’ approach with minimal disruption to patient care. Forethought about the construction process, access, material handling, crane location, concreting facilities, site constraints and safety during construction will be required at an early stage.

Additionally, some buildings within the Westmead Health and Education precinct may house vibration sensitive assets, which may require strict peak particle velocity (PPV) limits during construction, including but not limited to KR, CMRI, WIMR and the Westmead Adults Hospital. It is important that these locations are identified before the commencement of construction.

3 Design Criteria

3.1 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
AS3600: 2018	Concrete structures
AS3700: 2018	Masonry structures
AS4100: 1998	Steel structures
AS/NZS 2243: 2010	Safety in Laboratories
AS/NZS 2982:2010	Laboratory Design and Construction
NCC (BCA): 2019	National Construction Code (Building Code of Australia)

3.2 Design Life

The design life for all structures is to be 50 years.

3.3 Building Importance Level

The PSB is categorised under the Building Code of Australia as Importance Level 4. As a health facility that provides surgery and emergency treatment. The structure is yet to be confirmed a post-disaster recovery facility.

The importance level is used for calculation of design recurrence intervals for wind and seismic events, these design events for safety are summarised in Table 2.

Table 2: Lateral Loading Probability of Exceedance References for PSB

Component	Annual Probability of Exceedance*
Wind loading	1:2500
Earthquake loading	1:2500
* Annual probability of exceedance has been taken from AS1170.0:2002 Appendix F, Table F2	

3.4 Design Floor Loadings

The proposed design loadings in accordance with and/ or in excess of Section 3 of AS/ NZS 1170.1:2002 are listed in the table below. Where values exceed AS1170 this is to allow for future flexibility of the structure.

Table 3: Structural Design Floor Loading Allowances

Floor Usage	Superimposed Dead Loads (kPa)	Live Loads (kPa)
All general areas (to allow for future proofing and changes in floor use)	1.8 kPa (ceiling and services, finishes)	4.0 kPa
Hospital Ward Areas	1.8 kPa (ceiling and services, finishes)	3.0 kPa
Operating Theatres	2.5 kPa	4.0 kPa
Designated storage, filing, stacking areas	2.5 kPa	7.5 kPa
Plant rooms (including machinery)	2.5 kPa	7.5 kPa

3.4.1 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; and
- Loads in light and medium car parks.

3.5 Serviceability

3.5.1 Deflection Limits

The Post Tensioned (PT) and reinforced concrete elements have been sized to limit deflections to acceptable limits defined in AS3600:2018 Table 2.3.2. These are summarised in Table 4. Where not explicitly described in Table 4 below, deflection limits for reinforced concrete and structural steelwork have been designed generally in accordance with AS3600 and AS4100 respectively. The deflection limits summarised in Table 4 have been adopted in the design of the structural elements.

Table 4: Deflection limits

Element	**Deflection limit under Total Load**	
	Spans	**Cantilevers**
Beams and Slabs		
Generally- floor plate within the building (not on the perimeter)	L/250 or 25mm max.	L/250 or 20mm max.
Live load only	L/360	L/180
Supporting articulated masonry	L/500 (incremental)	L/250 (incremental)
Supporting un-jointed masonry	L/1000 (incremental)	L/500 (incremental)
Beams and Slab Supporting Cladding Elements		
Transfer structures (cumulative at location of element transferred) (Live Load only)	L/1000 or 12mm max.	L/500 or 12mm max.
Heavy Façade (Brick)	L/1000 or 10mm max.	L/500 or ±10mm max.
Light Façade (Glazing)	L/750 or 13mm max.	L/750 or ±13mm max.
Interstorey drift under wind	H/500	
Interstorey drift under seismic (PSB only)	10mm	
Pile Settlement	1% of pile diameter	
Differential Pile Settlement	Grid spacing/1000 or 10mm whichever is least.	
Horizontal Pile Movement	H/500	

The deflection limits described in the above table are calculated under the following load combinations:

Deflection Type	**Combination**	**Time**
Initial Deflection (ID)	$G + SDL_1$	Before loading
Short Term Deflection (ST)	$G + SDL_1 + 0.7Q$	At first loading
Long Term Deflection (LT)	$G + SDL_1 + SDL_{extra} + 0.4Q +$ Creep + Shrinkage	30 years
Incremental Deflection (Inc)	LT - ID	

G : Self weight.
SDL_1 : Superimposed dead load on floor including hobs and upstands
SDL_{extra} : Facade, and services area load

3.5.2 Vibration Criteria

Floor structures have been designed for footfall vibration in accordance with Australian Health Facilities Guidelines, AS2670, "Assessing Vibration: a technical guide" Department of Environment and Climate Change (DECC) NSW, 2006 and international best practice.

A response factor is defined as the calculated weighted root mean square acceleration divided by the appropriate base value. This root mean square is a measure of vibration energy averaged over a period of time (1s). This is then frequency weighted to better represent human perception, as people are more sensitive to vibration at some frequencies than others. The acceptance levels represent 'low levels of adverse comment' on the vibrations. Acceptance levels are expressed this way because the perception of vibration is not constant from person to person. The intention is that the levels of acceleration will be acceptable to most people. Table 5 summarises the maximum response factors for the various typical spaces within the hospital:

Table 5: Maximum Response Factors

Area	Maximum Response Factor
Imaging # ^	R = 1
Operating Theatres ^	R = 1
Clinical wards and common areas	R = 2

Design Guidance Note No. 1 indicates that imaging areas need only comply with a response factor of 1. However, specific imaging requirements are to be confirmed in the following stages of design to determine if more stringent criteria are required.

^ Areas nominated to support operating theatres, imaging and other sensitive areas also require the immediate floor above to achieve the target response factor of 1.

It is important to note that some specialist medical equipment is particularly sensitive to vibration. Meeting the vibration criteria above does not guarantee that such equipment will not be affected by vibration. It is recommended that the location of sensitive medical equipment is coordinated at an early stage, as floor vibration due to footfall excitation may need to be more strictly controlled in these areas. Discussion with the laboratory consultant may be required.

As a general rule, placing sensitive equipment at the lowest possible floor and as close to a column or wall can minimise the extra structural cost to achieve the required vibration criterion.

3.6 Durability

Concrete covers are to be in accordance with AS 3600. The durability requirements of AS 3600 has been applied to all reinforced and PT concrete. It is proposed that the minimum concrete strength f'_c shall be 40MPa and concrete cover shall be a minimum of 30mm. However, structural requirements for certain elements may increase concrete strengths above the minimum required for durability.

3.7 Structural Fire Resistance

Fire resistance levels for structural elements shall be determined in accordance with the Building Code of Australia (BCA). Various parts of the building fall into classes 5 and 9A of the BCA, with the design FRL (Fire Resistance Level) for these classes being 120/120/120. FRLs of 180/180/180 may be required for selected areas such as substations, and 240/240/240 for areas such as loading docks.

3.8 Structural Robustness

The structure will be designed to 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: 2002. The key minimum actions are discussed in the proceeding sections.

3.8.1 Minimum Resistance

The structure will be designed to have a minimum lateral resistance equivalent to 1.0% of $(G + \Psi cQ)$ for each level, applied simultaneously at each level for a given direction.

3.8.2 Minimum Lateral Resistance of Connections and Ties

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

3.9 Tolerances and Movements

Tolerances for concrete and structural steel will be considered in accordance with the relevant Australian Standard, unless noted otherwise in the structural, services or architectural specifications.

The movements of the structure will be calculated in accordance with the relevant Australian Standard(s) based on the design loadings. The structural movements expected to act on the structure include the items described in Table 6 below.

Table 6: Structural Movements

Movement	
Settlement:	1% of footing width at allowable bearing pressure for spread footings.
Heave	either absolute or differential
Temperature range:	Exposed structure +65°C and -10°C from mean temp 20°.
Shrinkage:	Floor slabs - design shrinkage <500 microstrain. (Final values to be agreed with concrete suppliers)
Vertical structure:	Design shrinkage <500 microstrain.
Creep:	Floor slabs and vertical structure.
Elastic shortening:	Vertical structure and elements under prestressing.

Loading arising from restrained or partially restrained creep and shrinkage will be designed for in accordance with joint locations.

Additionally, the effect of column shortening due to axial loads and construction methodology will affect the heights between floors and will be considered in the design and construction of the columns and walls.

4 Structural Design of PSB

4.1 General Principles

The following section describes the key structural principles and requirements that has been applied to the structural design as well as the preferred outcomes to be achieved considering long term value, future proofing and adaptability.

The key structural design initiatives are:

- *Adaptability* – the structure will focus on flexibility through floor plate design, standard column grids and generous sacrificial top cover zones to maximise future flexibility. The structural design will be developed to accommodate future flexibility of the location of the medical imaging. The structural design will allow for future penetration zones in order to maximise future flexibility.
- *Sustainability* – most effectively achieved by not needing to replace obsolete or deteriorating infrastructure. Hence, we will focus on designing durable, low maintenance building structure.
- *Expansion* – the structural design will provide necessary provisions in columns and foundations for a helipad in the future. Structural strategies for future proofing are discussed in Section 4.16 of the report.

4.2 Building Configuration & Key Connections

The configuration of the new Paediatric Service Building has been summarised in Table 7. Furthermore, key logistics and connections between the CASB, existing CHW and new Paediatric Service Building has been delineated in Figure 4.

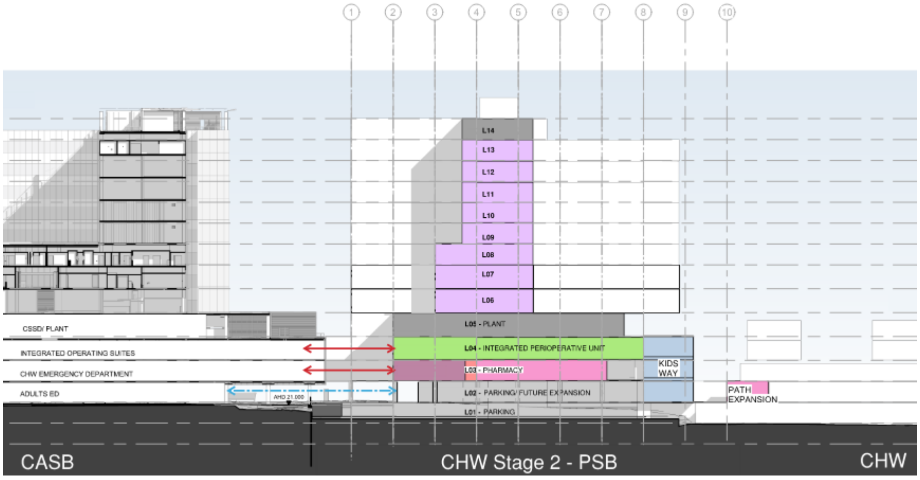

Figure 4: Key Links to CASB

Table 7: Summary of New Paediatric Service Building Configuration

Paediatric Service Building	Description	
Floors:	Level 1 – 2	Carpark / Loading Dock (L2)
	Level 3-4	Typical Hospital
	Level 5	Plant
	Level 6 - 13	Typical Hospital
	Level 14	Plant
	Level 15	Future Helipad
CASB Links to PSB	• Level 3 • Level 4	
Typical Grid	8.4m x 8.4m	
Floor to Floor:	4200 and 4500mm 5000mm for L05 & L14 subject to final mechanical design	

4.3 Existing Location of Multi-Storey Carpark Foundations

The structural grid for the existing multi-storey car park, P17, is 7.7mx7.7m. The structure is supported on reinforced concrete columns that are concentrically founded on bored pier foundations, which are socketed a minimum of 400mm into Unit C sandstone with a permissible bearing capacity of 3500kPa. The pile caps are typically 900x1100 reinforced concrete.

A desktop study of the existing structure has identified the approximate location of the existing foundations. However, further investigation will be required upon the demolition of the MSCP, this will help minimise the onsite complexity and cost of encountering the existing foundations and pile caps. Refer to Appendix A for the location of existing foundations.

The locations of the identified foundations are considered and where possible avoided or detailed as such that the new structure will bridge the foundations.

4.4 Foundations

A review of the JK Geotechnics report 33303Brpt1 *Geotechnical Investigation (Draft)* (3rd November 2020) found that the geological profile of the site typically comprises of the bedrock overlain by natural clayey soils, overlain by loose fill. The upper layers of clayey soils and loose fill tend to increase towards Redbank Road. Based on this assessment, the most suitable foundation type used for this building will be reinforced concrete bored piles.

The advantage of using single piles at the column locations is that they will be suitably sized so that no pile cap will be required. There will be sufficient tolerance between the pile and column over, thus eliminating timely and costly construction of the pile cap element. Figure 5 shows typical plan and section of proposed bored piles. To achieve the required load capacity the bored piles need to be socketed into at least medium strength rock.

The area under the stability lift cores will have a denser number of piles and a pile cap will be required to transfer the line loads from the wall elements into the individual pile elements of the foundation zone.

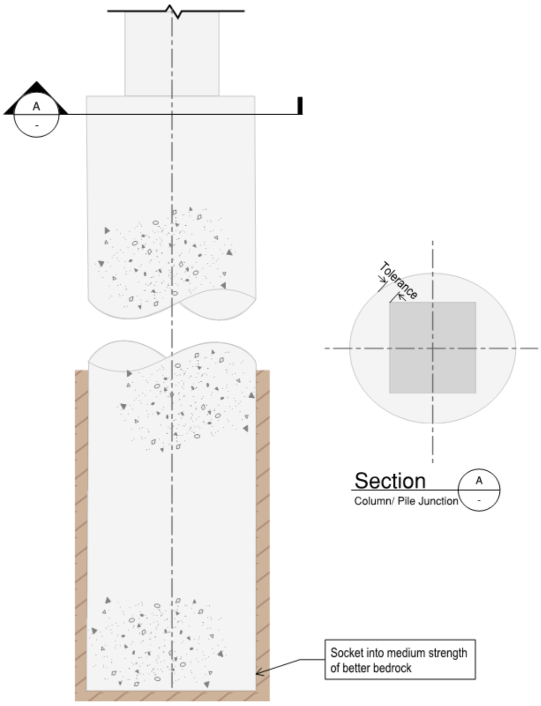

Figure 5: Typical Bored Pile Section & Plan

Table 8: PSB Foundation Options

Element	Pile Diameter	Founded in	Allowable pressure
Bored Pile	1.05-1.2m Ø of varying length	Class II Rock	800kPa shaft adhesion; 8000kPa end bearing

4.5 Base Slab

The location of a carpark and loading dock is currently proposed beneath the PSB. The configuration and the extent of cut and fill to achieve the required spatial planning and meet the cost plan has been reviewed by the design team. The resolution of the levels has guided the most appropriate structural solution for the retention and base slab design. The options are; a slab on grade where the excavation profile has extended into natural ground (not fill). This will be in the order of 150RC + 200mm build up. This will allow appropriate compaction to achieve the required load bearing capacity. Where the base level is founded on uncontrolled fill, a suspended slab would be appropriate, in the order of 300RC +100mm base course founded on piles. Where required band beams can be introduced to support higher loaded areas, for example the loading dock. This will mitigate the need for additional piles. Consideration to be made for the requirements for the piling.

It is assumed, based on previous experience, a minimum piling mat of 300mm will be required to support the loading from the piling rigs. This 300mm piling mat build up can be achieved by either a 200mm base course used as a piling mat with an additional 100mm layer on top which is scrapped back down to the final 200mm, as shown in Figure 6, or by a 300mm piling mat build-up below the structure, as shown in Figure 7. Once piling is complete the piling mat / base course material is to be capped and marked to contain ACM.

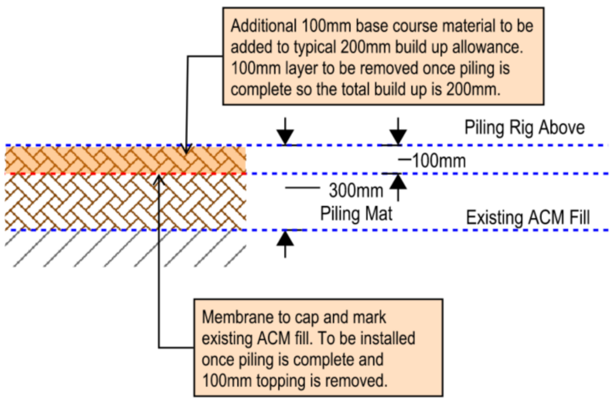

Figure 6: Option 1 - Allowance for Piling Mat - 200mm Total Build Up

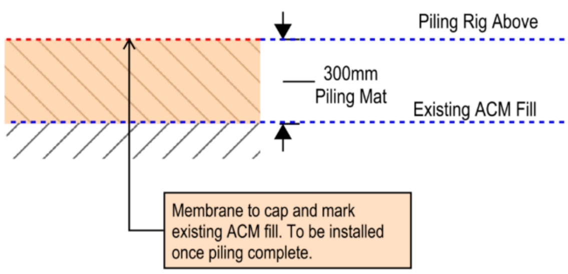

Figure 7: Option 2 - Allowance for Piling Mat - 300mm Total Build Up

4.6 Retention Design

Significant volumes of bulk earthworks are required to achieve the desired ground plane level of the PSB. In order to aid the balance of cut and fill by redistributing the cut from the north-western building corner to the remaining building extents, significant retention around the Eastern and Southern portion of the site is required. The required retaining walls range from 1 - 3.6m in height. A ground beam has been utilised where the required retention is less than 1.9m, once the required retention is greater than 1.9m a piled retaining wall is required.

4.7 Floor Framing Design

HI guidance and preference is to adopt an 8.4m x 8.4m grid for the majority of the building, to suit the standard HI fitouts for a range of Hospital Departments. Two structural floor options have been investigated on this typical grid in a general area, refer to Table 3 for loading allowance.

- Option 1: post-tensioned band beam and slab system,
- Option 2: post-tensioned flat plate.

The structural configuration of each option is illustrated in Figure 8 and Figure 9. Adopting constant column grids throughout the structure will result in an economic structural solution and can provide opportunity for construction process optimisation.

Preliminary vibration analysis has been conducted on each floor framing option to achieve a target response value, RF, of 1 and 2, respectively. Further discussion on this criterion is available in Section 3.5.2. A merit comparison and preliminary structural depths of each option with respect to the response value is discussed in the following sections of this report.

An allowance has also been made for a 40mm integral screed topping which is included in the slab thickness, to allow for adaptability and future flexibility of wet area set down locations.

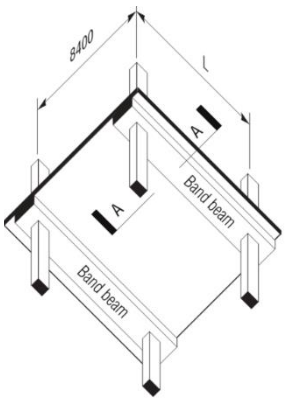

Figure 8: Option 1

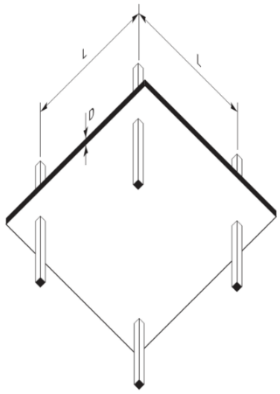

Figure 9: Option 2

It is important to note that heavier loaded zones such as plant rooms, areas with vibration sensitive equipment or any non-typical bays may require increased structural depths. Consequently, the structural depths indicated in Section 4.8 should be taken as a guide and will be reviewed once the design develops.

To avoid increased structural depths, irregular column grids, long spans, cantilevers, unrestrained tall columns and transfer structures should be avoided where possible to avoid imposing a significant construction cost to the structure. It is recommended that the project team minimise the use of these elements where possible.

Continuing close collaboration with the architect and other members of the design team in the proceeding stages will ensure the end result optimises the project objectives.

4.8 Typical Structural Beam & Slab Depths

Table 9: Recommended Structural Depths for Floor Option 1 and 2

Response Factor (RF)	**Structural Floor Options**		
		(1) PT Band Beam & Slab	(2) PT Flat Plate
RF = 1	Slab Thickness (mm)	230	300
	Beam Size (mm)	400Dx2400W	-
RF = 2	Slab Thickness (mm)	210	300
	Beam Size (mm)	400Dx2400W	-

4.9 Structural Options – Latest Architectural Plans

Refer to Appendix B and Appendix C for two options, band beam and flat plate, for the structural framing of the latest architectural plans for the PSB. These options have been developed based on the principles described in this report and in conjunction with the latest architectural layouts. These layouts and benefits of each system will develop as the multidisciplinary design resolution progresses.

4.10 Benefits of Post Tensioning

A PT floor system is considered the most appropriate construction for the following reasons:

- PT construction technique reduces the volume of construction materials – concrete and reinforcement.
- This skilled construction method is common in the local market and is therefore a good, cost-effective solution.
- Short lead time, fast slab turn-around time.
- Wider column grids, good for flexibility in floor space.
- Reduced depth of beams and slabs – good for services distribution and reduced overall storey height and thus column and foundation requirements.
- Concrete construction requires no additional fire and corrosion protection compared with steel construction. Concrete has inherent fire resistance and does not need continuing maintenance.
- Provision for future coreholes can be integrated in the design by ensuring the coreholes avoid the PT cables. This can be aided by marking the location of tendons on the slab soffit after formwork is removed.
- Less susceptible to vibration.

4.11 Vibration Assessment

A finite element model was assembled utilising OASYS GSA software to evaluate the dynamic response of the slab option when it is subjected to normal walking activities. The 40mm screed topping was included in slab and beam thickness for the vibration analysis.

4.11.1 Restraints

Continuous cladding provided around perimeter of the floor has been assumed to provide full vertical restraint to perimeter beams. This will be verified as the design and façade design develops. Rotational restraint to the slab is provided by columns, this action is considered by modelling columns having pin supports at half length.

4.11.2 Mass

It is important that the distributed mass used in vibration analysis is representative of the mass that will be present during service, as a higher mass will reduce the response of the floor at a given frequency. Consequently, for this analysis the mass per unit area is taken as un-factored self-weight of the structure including superimposed dead loads (1.8kPa) and 1kPa of live load. This is deemed appropriate as hospitals have extensive fit-out. Typically, in dynamic analysis only 10% of live load is considered in the analysis.

4.11.3 Slab Properties

As beams and slabs are post-tensioned, it is considered that under dynamic loads, beams and slabs have 90% Ixx values due to minimal levels of cracking which would be expected within post-tensioning slab under dynamic loads.

38GPA is used for the dynamic modulus of elasticity of concrete. The level of damping assumed in the analysis is 3.5%.

4.11.4 Footfall

The following parameters have been used in the analysis to determine the response of the floor plate under footfall loading.

- Walking frequency: 1-2.2Hz
- Number of steps: 100
- Average mass of person walking: 76kg

The output of the analysis is the natural modes of vibration and their corresponding properties; frequencies and mode shapes. All modes up to 15Hz are considered in the analysis.

4.12 Merit Comparison

Table 10: Merit Comparison for Each Option

Criteria for comparison	**Structural Floor Options**		
	(A) PT Band Beam & Slab	**(B) PT Flat Slab with Drop Panels**	**(C) PT Flat Plate**
Construction	Ease of construction as it is commonly employed in the local market. Fast slab turn-around time. PT ducts can be easily laid as they do not weave through each other.	Laying of PT ducts is labour intensive. The two-way ducts need to be weaved through each other. High risk of getting the duct profiles wrong.	Laying of PT ducts is labour intensive. The two-way ducts need to be weaved through each other. Higher risk of incorrectly placing the duct profiles.
	Can use metal decking (e.g. Bondek, Condeck) as permanent formwork for the slabs as the PT is one-way and can fit within the metal decking ribs. Use of metal decking as formwork is cheaper than conventional timber formwork, which is labour intensive to construct and requires the use of more props and stripping afterwards.	Use of metal decking is restricted as the ribs of metal decking prevent the PT ducts being placed as low as possible at the low points, resulting in inefficient slab design (thicker) if used. Conventional formwork would be more typical.	Use of metal decking is restricted as the ribs of metal decking prevent the PT ducts being placed as low as possible at the low points, resulting in inefficient slab design (thicker) if used. Conventional formwork would be more typical.
Flexibility of Penetrations	Poor in beam zone. See table below for comments on penetration allowance for future flexibility.	Poor in drop panel zone. Difficult due to two-way PT ducts concentrated around column strip. See table below for comments on penetration allowance for future flexibility.	To be coordinated with the PT ducts.
	May require trimmer beams around opening depending on size of opening.	May require trimmer beams around opening depending on size of opening.	May require trimmer beams around opening depending on size of opening.
Material Use	Efficient structural system.	Thicker slab than Option A	Thicker slab than Options A and B
Services Issues – Flexibility & Installation of Services	Continuous beams may obstruct services.	No beams – simplifying services reticulation outside the drops. Services must be routed away from drop panels around columns.	No beams – simplifying services reticulation.

4.13 Service Penetrations

Health Guidance Note No. 1 specifies the requirement to accommodate a service penetration adjacent to the column, as shown in Figure 10. Punching shear becomes critical in Option 2, the PT Flat Plate. This is because the penetration reduces the punching shear perimeter, resulting in the need for shear links or shear rails. In Option 1 punching shear is relieved by localised thickening of the concrete with perimeter thickenings.

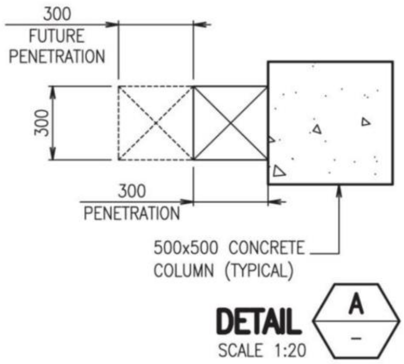

Figure 10: HI Requirements for Future Penetrations

4.14 Columns

It is proposed that the PSB will adopt square reinforced concrete (RC) columns. The size of the column is a function of the amount of load it is required to resist, the floor to floor height and the tributary area it supports.

Table 11 summarises the preliminary column sizes required for each floor framing option with RF=2. Since RF=1 is required in operating theatres and imaging rooms, columns sizes will accommodate the increased thickness once the design develops and the extent of these areas and the impact on the load take down is determined.

Table 11: Recommended Column Sizes

Floor	**Column Size / Concrete Grade**
Roof to L12	800x500 40MPa
L11 to L10	800x500 50MPa
L9 to L8	800x500 65MPa
L7 to L6 (Slender Columns for Future Infill)	1500x500 65MPa
L5 to L4	800x800 65MPa
L3 to L2	800x800 80MPa

4.15 Lateral Stability Analysis

The lateral stability system will be formed by a combination of lift and stair cores and bracing. Centrally placed lift cores are preferred as this will align closely with the centre of stiffness of the structure and therefore minimises the torsional component of the lateral loading, resulting in a more efficient structural design. The central core is to be supplemented with additional core walls forming the stair cores and/or other shear walls. It is assumed that the core walls will be jump formed, this is a typical construction methodology that will be economical for this building type and height.

The importance level discussed in Section 3.3, will be used for the calculation of design recurrence intervals for wind and earthquake events. The following table summarises the relevant loading codes that will be used in the design:

Structural Robustness	In accordance with AS 1170.0
Wind loading	In accordance with AS 1170.2
Earthquake loading	In accordance with AS 1170.4

For this form of structure, the stability design is driven by:

- The notional loading requirement of AS 1170.0:2002 Section 6.2.2. This requires 1.0% of the gravity service load applied horizontally at each level.
- The seismic design requirement of AS 1170.4: 2007.
- The wind loading requirements of AS 1170.2.

4.15.1 Wind Loading

In the absence of wind tunnel testing, wind loading applied to the structural elements will be assessed through AS1170.2. The design parameters used for the PSB will be discussed in the proceeding section.

4.15.1.1 Design Parameters

The following design parameters will be utilised in the design:

- Region = A2
- Importance Level (BCA Table B1.2a): = 4
- Annual probability of exceedance: = 1:2500

Regional wind speeds:

- Ultimate- V_{2500} = 48m/s
- Serviceability- V_{25} = 37m/s
- Terrain category = Category 3
- Maximum Structure Height – Z = 63m

4.15.2 Seismic Loading

Earthquake loading applied to the structural elements will be designed in accordance with BCA 2019 and thus AS3600:2018, which requires seismic loading to be calculated in accordance with AS 1170.4: 2007.

The ductility factor and structural performance factors have been determined based on the structural system and the requirements of AS1170.4.

The annual exceedance probability recommendations in AS1170.0 Appendix F, which takes into consideration the design life of the structure, will be adopted in the design of the building in place of those recommended in the BCA. The annual exceedance probability recommendations in AS1170.0 are lower (i.e. longer return periods), resulting in a larger earthquake event, compared to those recommended in the BCA. The ground motions are based on the Ce site class given in AS 1170.4. This is to be verified by the geotechnical investigation for the project.

Seismic design parameters utilised in the design of each structure will be discussed in the following sections.

4.15.2.1 PSB

Seismic design parameters are shown in Table 12 indicating an earthquake design category of EDC-III. As such, a dynamic analysis will be undertaken to assess earthquake loading on structures in accordance with AS1170.4 Section 7.

Table 12: Seismic Design parameters for PSB

Seismic Parameter	Value	Reference	Comment
Importance Level	4	BCA – Table B1.2a	Medical emergency and surgery facility which is essential to post-disaster recovery.
Hazard Factor (Z)	0.08	AS 1170.4 Table 3.2	
ULS Annual probability of exceedance	1/2500	AS1170.0 Appendix F. Table F2	Return period for a 50-year design life of an importance level 4 structure.
Probability Factor (kp)	1.8	AS 1170.4 Table 3.1	For annual probability of exceedance of 1/2500
μ/Sp	1.3	AS 3600 Table 14.3	Non- ductile Structural Walls
Site Class	Ce	AS1170.4 Clause 4.2.2	Based on available ground investigation data
Earthquake design category	EDC-III	AS1170.4 Table 2.1	Height of importance level 4 structure is >25m

4.16 Future Helipad

It has been proposed that a helipad will form part of future developments for the PSB. This has been considered in the spatial planning and design requirements of the helipad landing and transportation times to departments within the PSB. Foundations, columns and structural walls have been designed to accommodate additional load imposed by the helipad.

4.17 Future Medical Imaging - Shelled Area

The current architectural plans indicate that Level 2 carpark, accounting for 2958m^2 of the southern portion of the PSB, will provide a shell for the future relocation of medical imaging, as shown in Figure 11. The following future proofing strategies will be incorporated in the design of the PSB to ensure the floor plate has adequate adaptability for the future provisions:

- The floor plate and level above (for ceiling supported equipment) will be designed to achieve a response factor of 1, as specified by Health Infrastructure Design Guidance Note No. 1. However, specific imaging requirements are to be confirmed in the following stages of design to determine if more stringent criteria are required.
- As specified by Health Infrastructure Design Guidance Note No. 1, areas nominated to support operating theatres, imaging and other sensitive areas also require the immediate floor above to achieve the target response factor of 1. Therefore, the portion of Level 3 which will sit directly above the future imaging department, will also be designed to achieve a response factor of 1.
- An allowance for a 40mm integral screed topping, included in the slab thickness, will be provided to allow for adaptability and future flexibility of wet area set down locations.
- Since carparks have no floor finishes, co-ordination of the future finished surface levels with the interface of door openings, including lifts and stair cores, will be required in the following design stage. Future finish floor levels can be achieved with ramping from the base build level, alternatively an allowance for the finishes could be accounted for in additional concrete cover, which could be removed in future stages and replaced with floor finishes, to ensure the floor level remains unchanged.

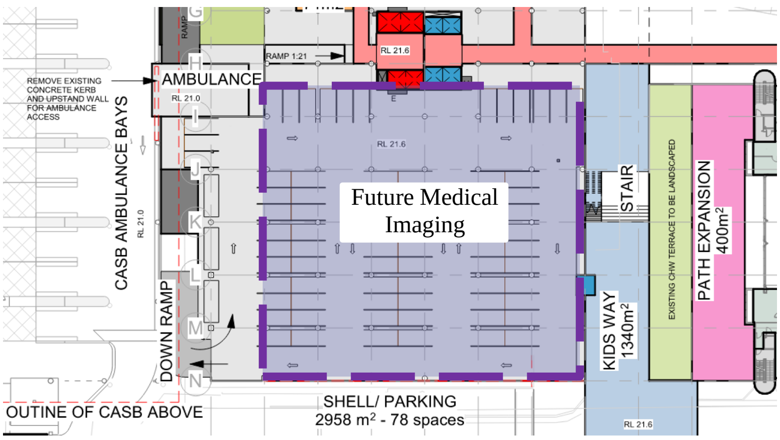

Figure 11: Shelled Area

4.18 Additional Initiatives

Other future proofing measures that are to be incorporated into the structural design and coordinated with the architects and services engineers are:

- Sacrificial topping slabs or additional concrete cover zones that allow the relocation of wet area set down for future room layout changes.
- Incorporate additional services penetrations adjacent to columns to allow for future services. The current concept is to allow for a 300mmx300mm blockout, as discussed in Section 4.13.

Structural documentation will specify that PT tendon as-built locations are to be marked on the soffit of the slab on site or are to be recorded accurately on as-built PT shop drawings. This can then act as a guide together with X-ray scanning for forming future penetrations without seriously impacting on the capacity of the slab. PT tendons in the slab will typically be at 1 m to 1.4 m centres in each direction, therefore this provides a good level of flexibility for future small penetrations. Future penetrations in the slab would need to be reviewed in detail. If necessary, certain areas can be designated as future knock out panels, and the slab designed to suit to allow for future large penetrations.

5 Buildability

Constructability considerations are an inherent part of the design. Health and safety implications are formally reviewed periodically through safety in design workshops, which are documented in the Project Safety Hazard. Constructability is also addressed collaboratively through CiDDs. This workshop is a consolidation of safety and quality issues the Principal Contractor has had in the past, control measures which could be implemented to prevent reoccurrence, as well as the Risks and Opportunities at Design (ROAD) workshops.

Buildability issues have been covered throughout each sub-section of the reported structural elements. Buildability is an inherent feature of good design and the following key points display good design highlighted by buildability constraints:

- Foundations – Consider location of existing piles and design around them to minimise construction complexity and associated costs. Eliminate pile caps where possible to save time and cost on unnecessary construction.
- Floor framing – Provide the lightest and most robust solution in the form of a bonded post-tensioned concrete banded slab. This is very common in the Sydney construction industry and is very well suited to healthcare projects. This framing system minimises the depth of both slabs and beams, allows for flexibility in the placement of heavy loads. Furthermore, flexibility for future penetrations can be integrated into the design.
- Loading - Construction loading allowances have been considered in the design of the permanent structural works.
- Provide a 40mm topping tolerance in the PSB slab depth to allow for future placement of set downs for wet areas.

6 Ecologically Sustainable Development Considerations

Sustainability in structural engineering context is most effectively achieved by not replacing obsolete or deteriorating infrastructure. Hence, the fundamental aim of structural design is to focus on designing a durable, low maintenance building through efficient use of construction materials and post tensioned (PT) design techniques.

Transfer structures where possible should be avoided and floor space flexibility has been achieved by implementing an appropriate 8.4x8.4m grid.

Cantilever beams and their span should also be minimised, as deep beams are usually required to control deflection at the tip of a cantilever. Additionally, the load carried by a column supporting a cantilever span will be higher due to the lever arm effect. Consequently, increasing the supporting column size.

The building is also to be designed with adaptability and future provisions as explained under the sub-heading of Future Proofing. This fits in with the ESD principles.

The use of “green” cement will be specified in the concrete performance specification by stipulating the minimum amount of recycled material. The recycled material which will be specified is Ground Granulated Blast Furnace Slag (GGBFS) which will be used in conjunction with Portland cement. GGBFS is a by-product of the iron manufacturing process. The benefits to the environmental by replacing a portion of the Portland cement with GGBFS are:

- Reduced CO2 emissions
- Use of an industrial by product to eliminate landfill
- Reduced demand for virgin natural resources
- Lower embodied energy

Appendix A

Existing Foundations Located On Site

Legend:

- Proposed RC Columns
- Indicative Location of Existing Bored Piles

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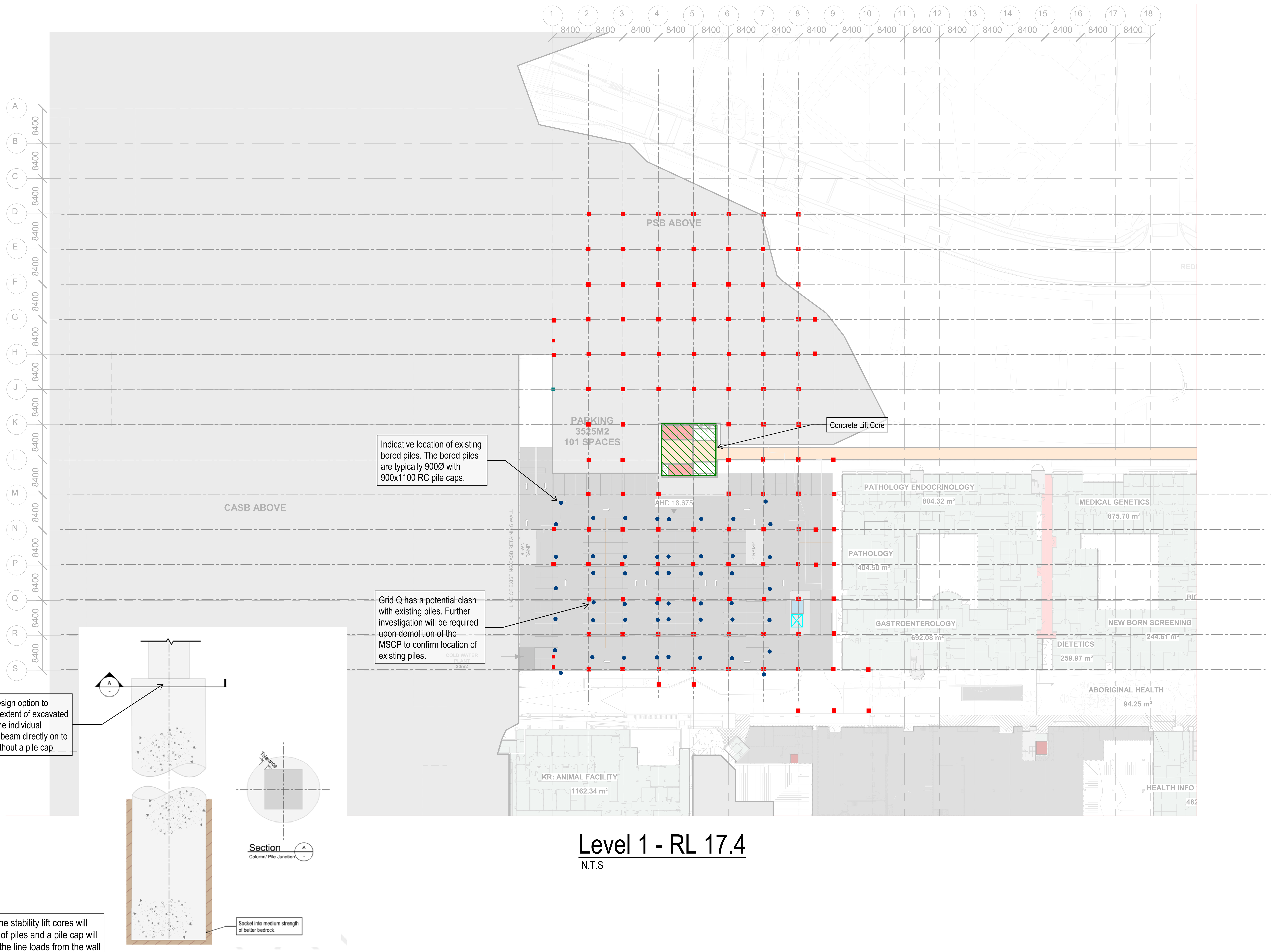

Level 1 - RL 17.4

N.T.S

Typical Bored Pile Section

N.T.S

Note: The area under the stability lift cores will have a denser number of piles and a pile cap will be required to transfer the line loads from the wall elements into the individual pile elements of the foundation zone.

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Client
Health Infrastructure NSW

Project Title
The Children's Hospital at Westmead Redevelopment

Drawing Title
Preliminary Framing Plan for Paediatric Service Building (PSB)

Scale at A1
N.T.S

Role

Suitability
S2

Arup Job No
271985

Rev

Name

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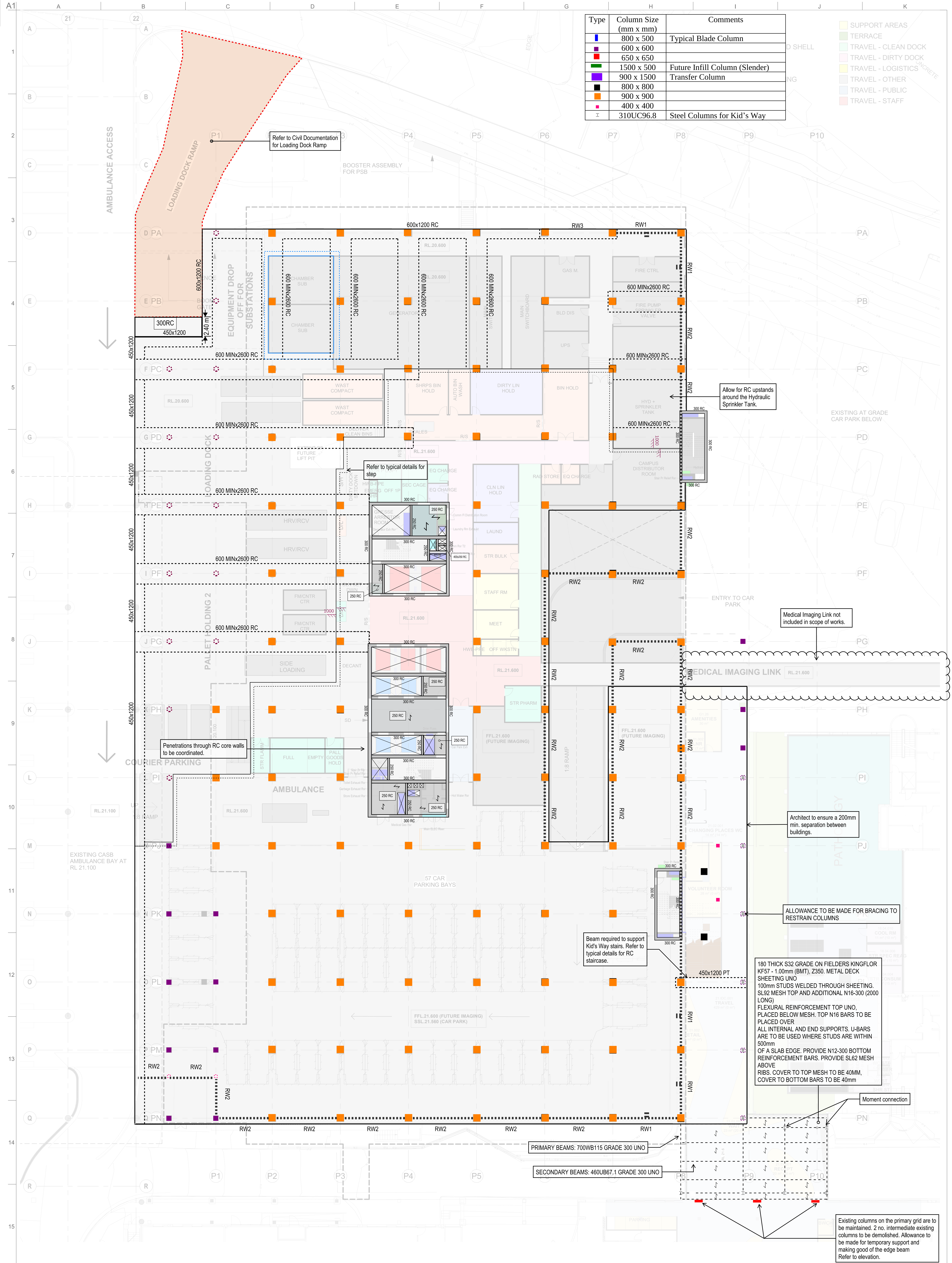
Appendix B

PSB Framing PT Band Beams

Type	Column Size (mm x mm)	Comments
Blue	800 x 500	Typical Blade Column
Purple	600 x 600	
Red	650 x 650	
Green	1500 x 500	Future Infill Column (Slender)
Violet	900 x 1500	Transfer Column
Black	800 x 800	
Orange	900 x 900	
Pink	400 x 400	
I	310UC96.8	Steel Columns for Kid's Way



NOTES:

Level 02

300RC Suspended Slab Cast on Ground
300RC Ramp Slab Cast on Ground

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PROJECT: The Children's Hospital at Westmead Stage 2 Redevelopment

Drawing Title: LEVEL 2 GENERAL ARRANGEMENT - OPTION 1

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Revision
Status: For Information
Role: Structural

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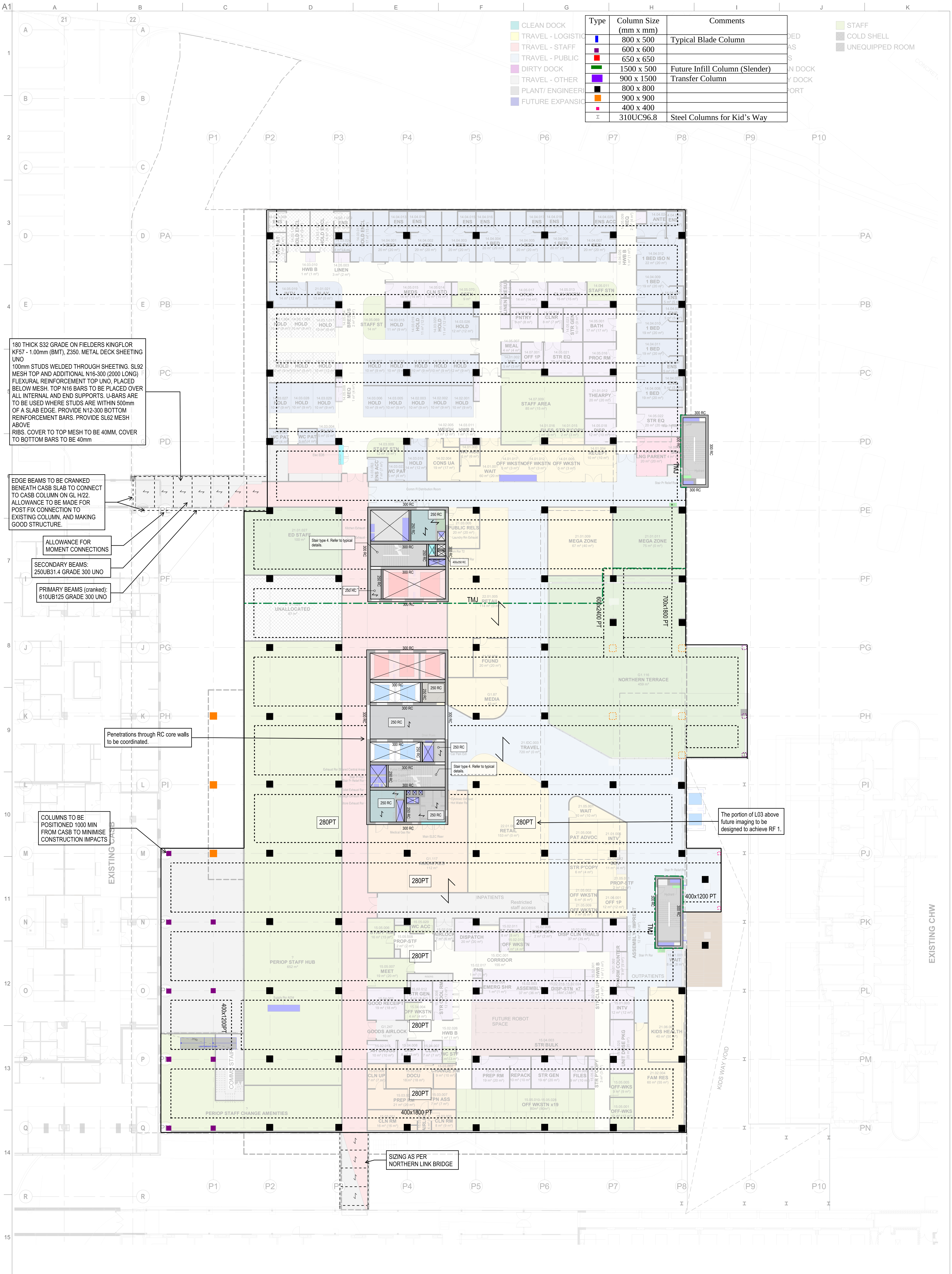
■ (red)	650 x 650	
▬ (green)	1500 x 500	Future Infill Column (Slender)
▬ (violet)	900 x 1500	Transfer Column
■ (black)	800 x 800	
■ (orange)	900 x 900	
▪ (pink)	400 x 400	
I	310UC96.8	Steel Columns for Kid's Way



NOTES:

Typical Podium

210mm PT Slab U.N.O

400x2400 PT One Way Spanning Primary Band Beams U.N.O

400x1200 PT Edge Beams U.N.O

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PROJECT
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LEVEL 3 GENERAL ARRANGEMENT - OPTION 1

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Violet	900 x 1500	Transfer Column
Black	800 x 800	
Orange	900 x 900	
Pink	400 x 400	
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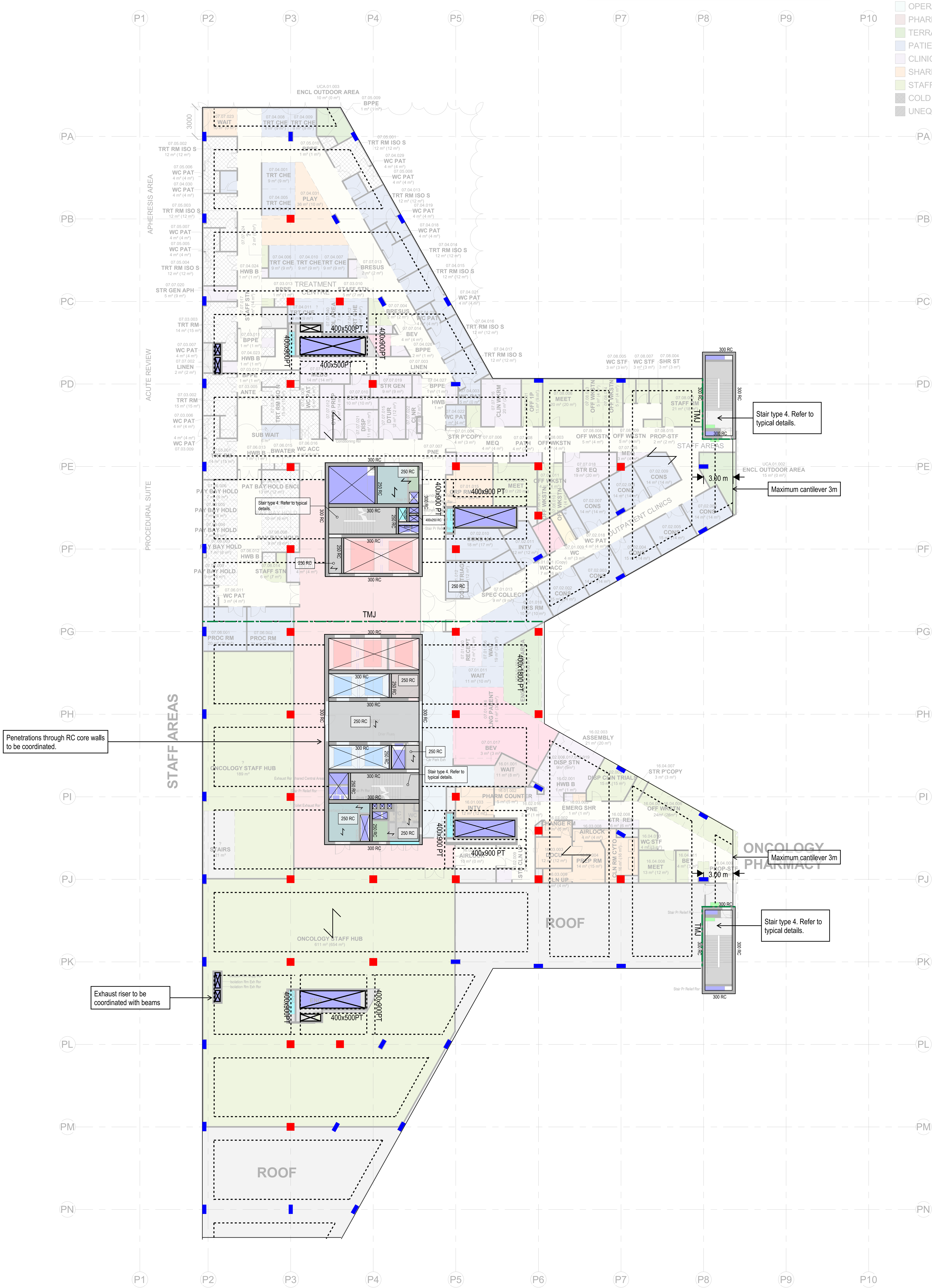
- TRAVEL - LOGISTICS
- TRAVEL - STAFF
- TRAVEL - PUBLIC
- TRAVEL - OTHER
- PLANT/ ENGINEERING
- LANDSCAPE
- DEPARTMENT CIRCULATION
- FAMILY
- FOH
- OPERATING
- PHARMACY
- TERRACE
- PATIENT AREAS
- CLINICAL SUPPORT
- SHARED
- STAFF
- COLD SHELL
- UNEQUIPPED ROOM



NOTES:

Typical IPU

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400x1200 PT Edge Beams U.N.O

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Appendix C

PSB Framing PT Flat Plate

Type	Column Size (mm x mm)	Comments
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	1500 x 500	Future Infill Column (Slender)
	900 x 1500	Transfer Column
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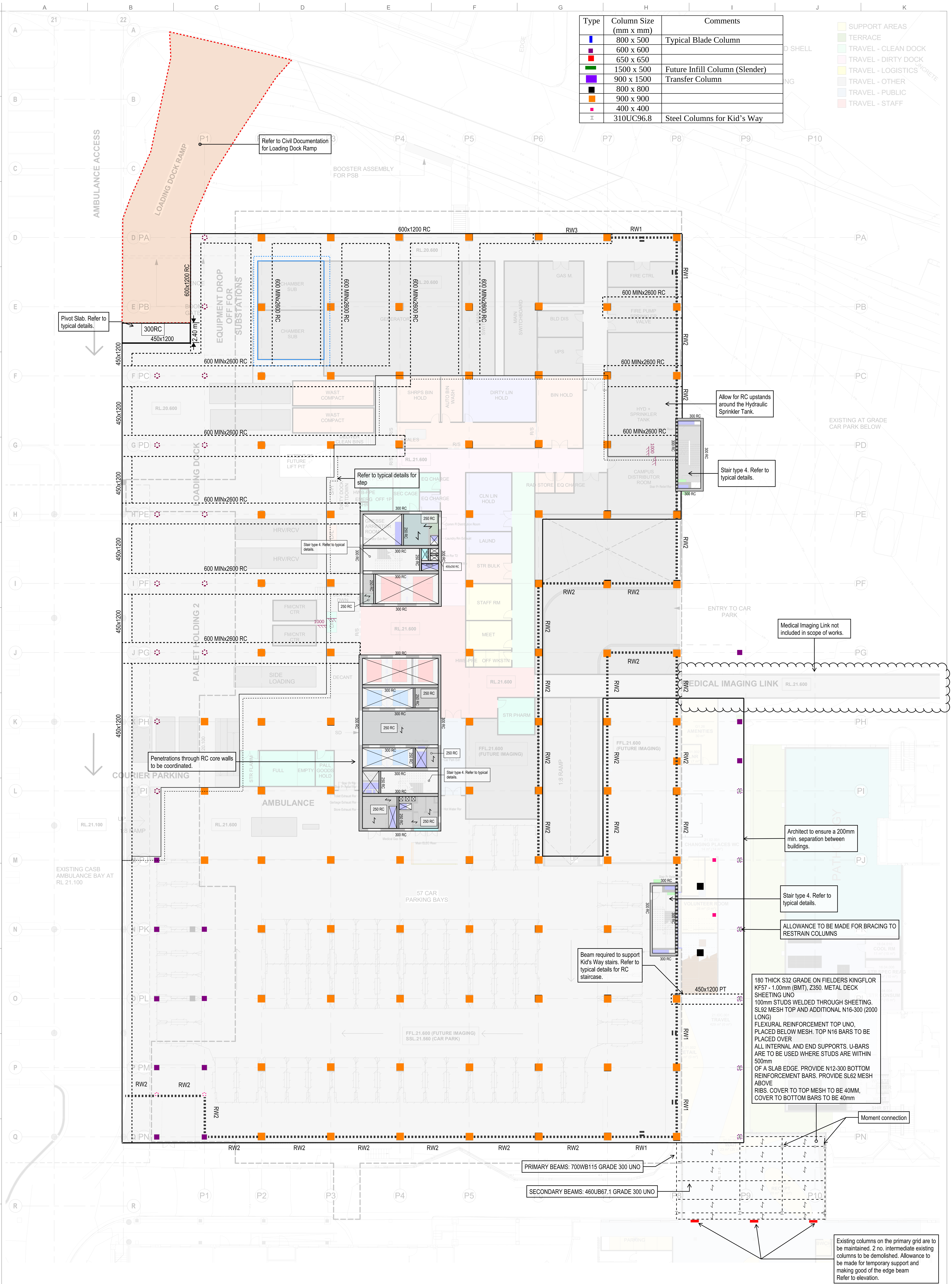

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NOTES:

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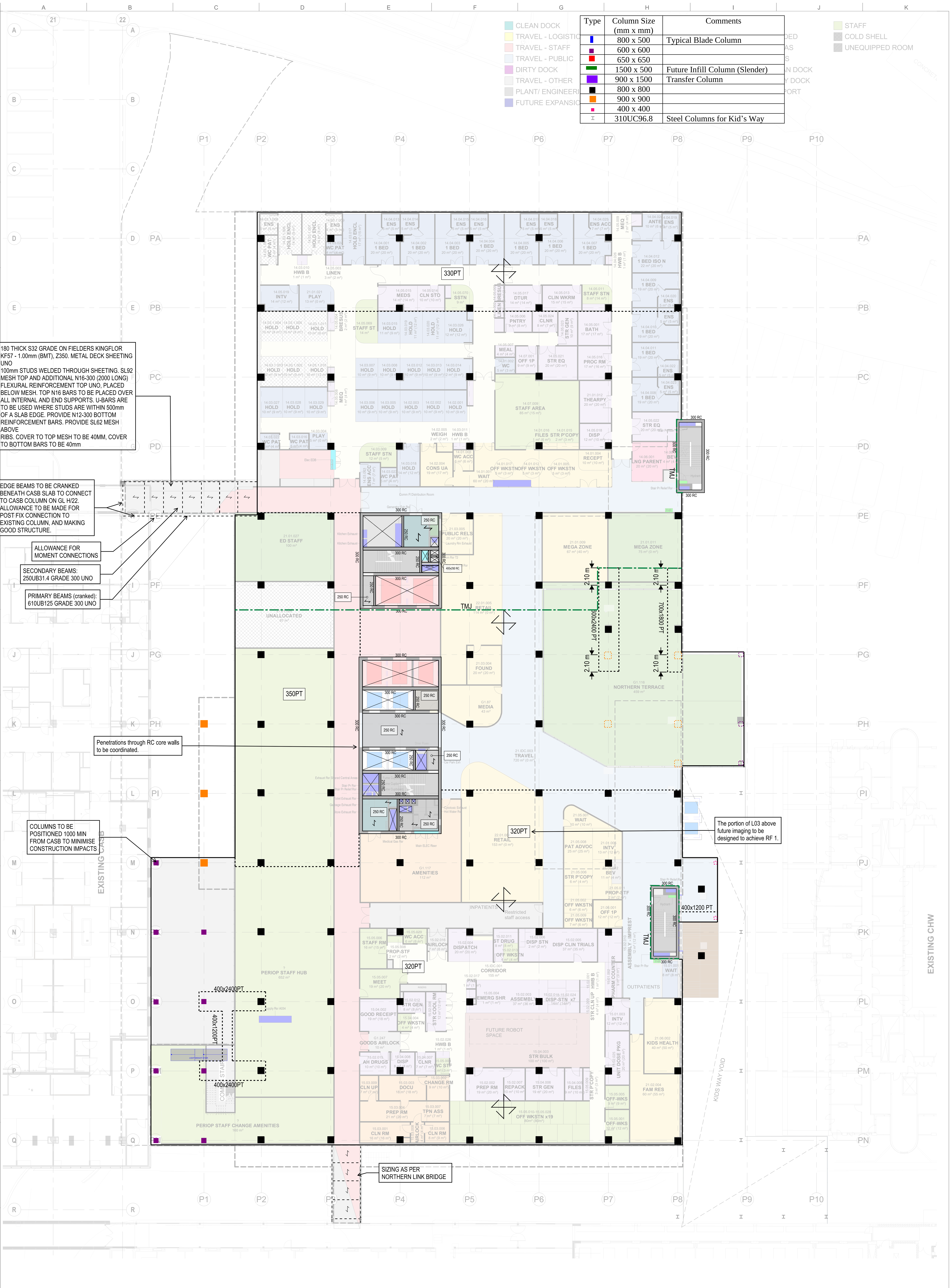

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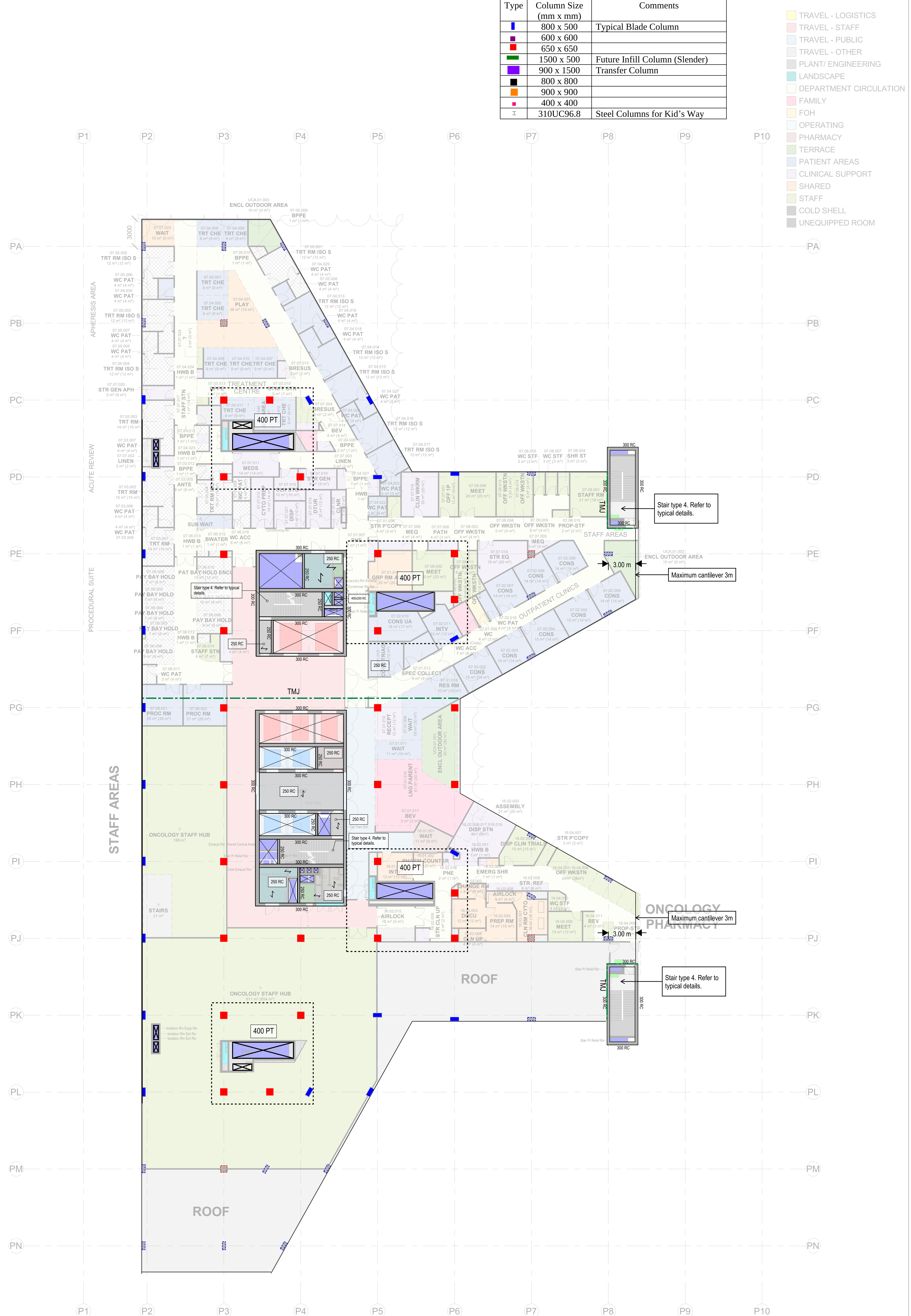

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