

JOHN
HOLLAND

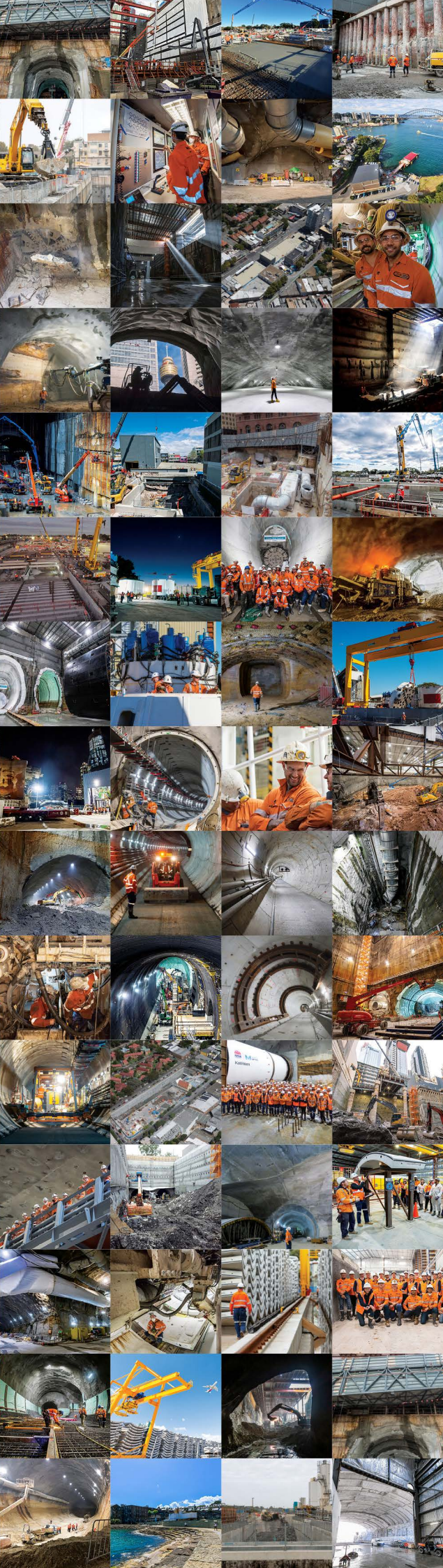
CPB
CONTRACTORS

Ghella

TSE WORKS

2022 Australian Construction Achievement Award
Technical Paper

Sydney Metro City & Southwest Tunnel and Station Excavation Works



EXCELLENCE WAS REFLECTED IN

- Safely operating 17 worksites in constrained CBD & harbourside locations with minimal disruption to traffic and major events
- Safety innovations to meet stringent silica exposure standards, Chain of Responsibility requirements, COVID response, well-being and resilience program
- Producing over 99,000 pre-cast segments with an innovative concrete mix reducing carbon footprint, preserving natural resources without affecting durability
- Designing 9 different segment types for various ground conditions & adjacent structure loadings. Barcoding improved delivery sequencing, quality records for whole of life maintenance
- Achieving the highest ever Infrastructure Sustainability rating from ISC
- Procuring/assembling (each in 6 weeks) 5 TBMs. Mixed-shield TBM excavated safely through harbour marine sediments under 4.0 bar pressure
- Achieving approval from the NSW Environment Protection Authority (EPA) to reuse marine spoil
- Completing 31km of tunnel in 17 months with 16 TBM breakthroughs
- Installing 29km of TBM conveyor belt removing over 4-million-tonnes of spoil – the longest 8.1km drive with a tight S-bend
- Staging excavation near complex underground structures (CBD buildings, heritage structures, major transport tunnels), with minimal disruption, 13 roadheaders excavating 6 caverns, pedestrian, escalator & service tunnels; all waterproofed & permanently lined using tailored formwork
- Constructing Australia’s largest spanning rail cavern at Victoria Cross
- Completing and handing over 20 separable portions on or before contract dates with no significant outstanding issues
- Inducting over 11,000 people with strong local procurement and collaborative relationships with sub-contractors and suppliers
- Leading pre-employment program, training, mentoring and opportunities for young people, indigenous, women, future leaders, long term unemployed



Barangaroo Station – Completed Cavern with Plenum

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Project background

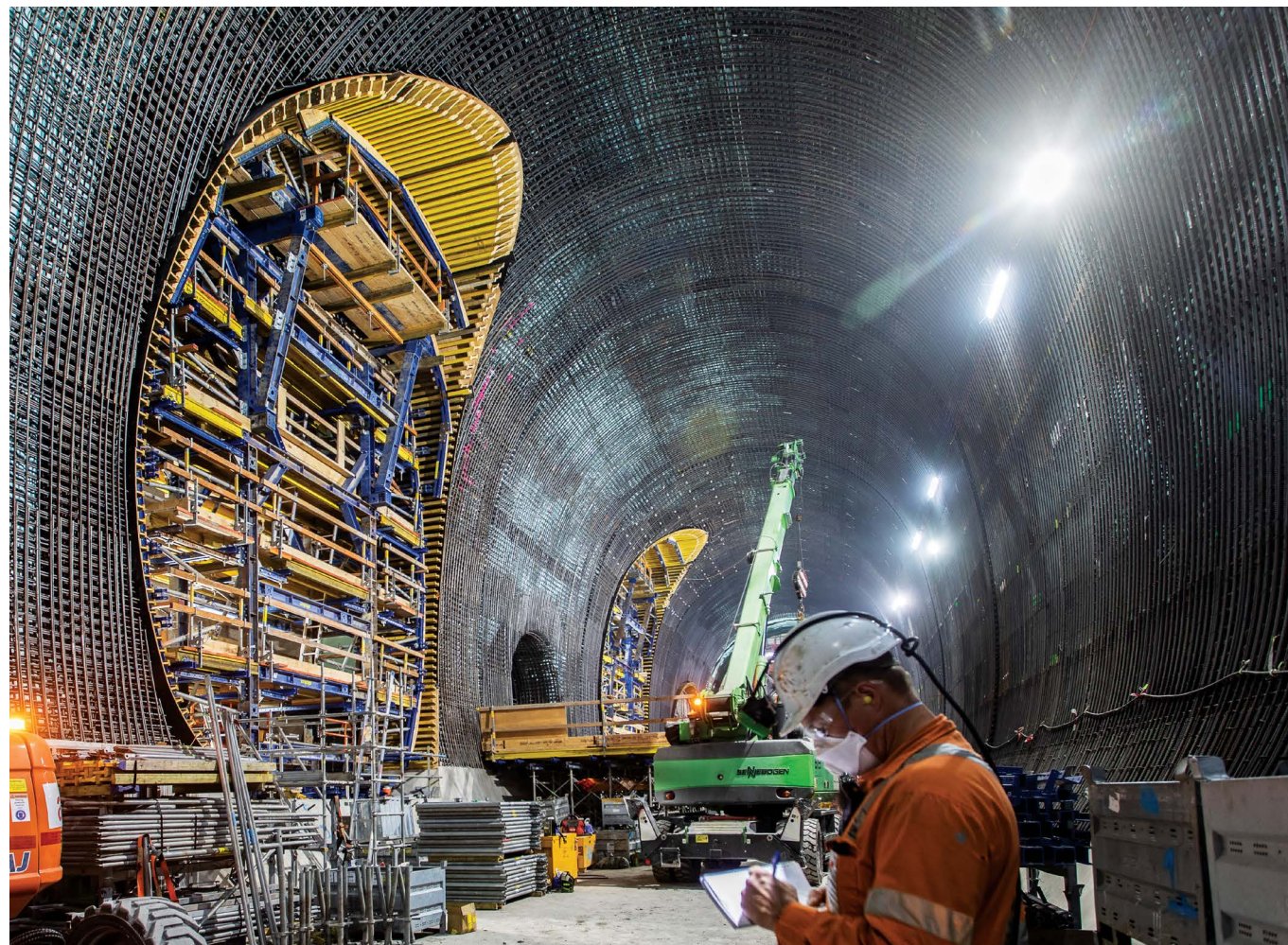
Sydney Metro is Australia's biggest public transport project. The City & Southwest project extends the Metro North West rail line from Chatswood through to the Sydney CBD and beyond to Sydenham and Bankstown.

In 2017, John Holland, CPB Contractors and Ghella (JHCPBG) in joint venture was awarded the \$2.81-billion contract for the Tunnel and Station Excavation (TSE) Works for Sydney Metro City & Southwest - a new Metro line that will deliver a never before seen level of public transport service to Sydney.

The TSE Works were highly complex delivering the first rail tunnels under Sydney Harbour, new stations at Crows Nest, Victoria Cross, Barangaroo,

Martin Place, Pitt Street, and Waterloo and more direct connections to high-capacity Sydney CBD stations.

It was Australia's first project to have five tunnel boring machines (TBMs) building tunnels simultaneously including under iconic Sydney Harbour and through the congested underground CBD environment, while roadheaders created some of the largest caverns in the country.



Scope of work

TSE scope of works included:

- Designing and constructing twin 15.5km fully lined tunnels between Chatswood and Marrickville, including 57 cross passages
- Excavating, waterproofing and lining underground mined stations at Victoria Cross, Martin Place and Pitt Street
- Excavating open station boxes at Crows Nest, Barangaroo and Waterloo
- Constructing dives and permanent portal structures at Chatswood and Marrickville
- Excavating, waterproofing and lining a 230m long rail crossover cavern at Barangaroo
- Constructing a substation shaft at Artarmon and a temporary TBM retrieval shaft at Blues Point.
- Constructing a tanked station box structure at Barangaroo
- Widening works in the Northern Railway Corridor.
- Undertaking drainage and earthworks for the future train maintenance and stabling facility at Marrickville.

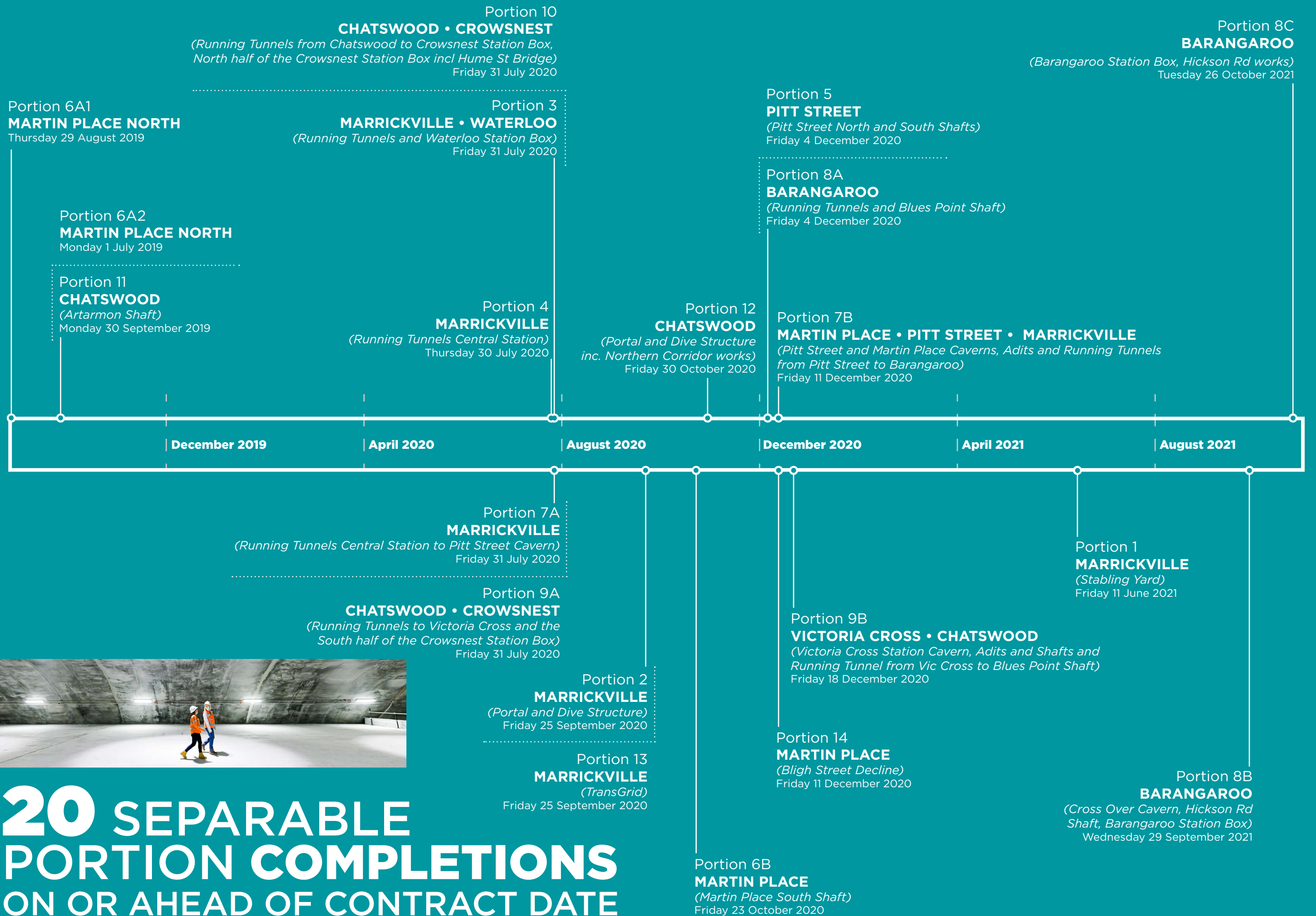
This complex project was subject to stringent planning approval conditions, an environment protection license and interface agreements with

47 landowners and key stakeholders, including Sydney Trains and Transport for NSW, to protect their assets located in proximity to the project.

Some of the unique challenges of this scope of works included:

- Intricate works around the CBD, high volumes of pedestrians and sensitive receivers
- Working near/under high-rise buildings requiring thorough checks of designs and records with designed mitigation and monitoring regime
- Numerous heritage-listed buildings and structures nearby
- Over 200,000 truck movements, avoiding queuing and putting pedestrian safety first
- Implementing stringent transport safety laws, onboarding 662 spoil truck drivers and inspecting 647 trucks which collectively travelled over 21-million kilometres.
- The project was delivered in 20 separable portions allowing the client and follow on contractors to begin operational fit out and overstation developments.







JHCPBG tunnel alignment map

Design solutions



Historical photo of former brick pit which was later filled in with municipal waste

Building the twin tunnel infrastructure required for the new Sydney Metro rail line involved design challenges given the alignment through some of Sydney's most densely populated urban areas.

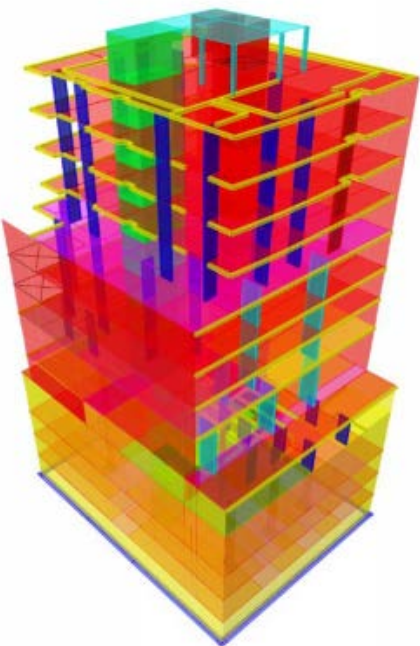
The tunnelling route and cavern locations required a detailed interrogation of anthropogenic change including for buildings and basements, Sydney Park built on former brick pits, a historic tunnel at Sydenham and numerous operating transport and utility assets above and below ground.

High rise buildings, skyscrapers and basements

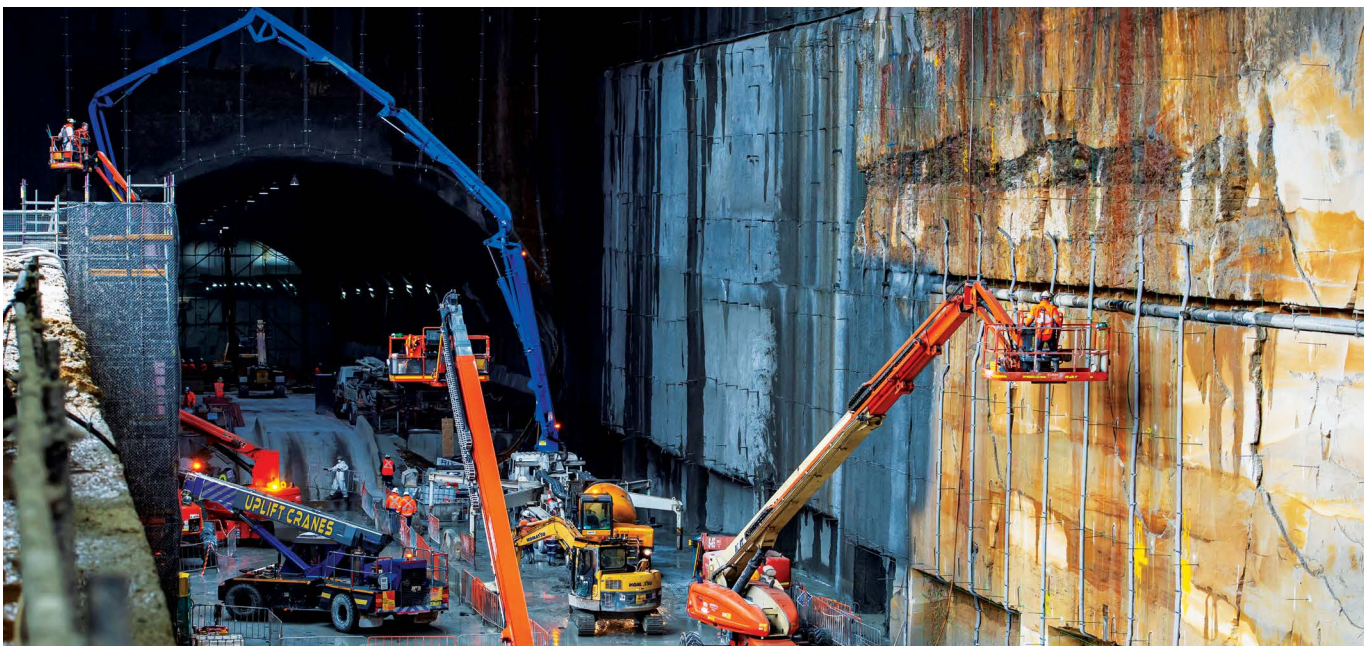
High existing building loads, eccentrically loaded pad foundations and concentrated lift core loads in the CBD required an intensive investigation of their respective load impacts on the tunnel lining and excavation. The exercise involved a specialist group of structural engineers and façade specialists, who often had to interpret and develop drawings for updates, additions, and alterations to existing, and in some instances, non-existent building plans or representative documentation.

JHCPBG therefore undertook a detailed predicted

effects assessment of high-rise buildings in locations where tunnelling was 6 metres or less from the basements to determine maximum allowable settlement and assess a building's reaction to the risk during construction.



3D building model to determine predicted effects of the tunnelling



Sydney sandstone disappears behind a wall of shotcrete as the station box takes shape

Barangaroo Station

The largest influence on the design of the Barangaroo station box was its location which is only 10 metres away from Sydney Harbour.

The design needed to be for a Grade A watertight structure which would cater for the station being submerged below the water table, at depths of up to 28 metres.

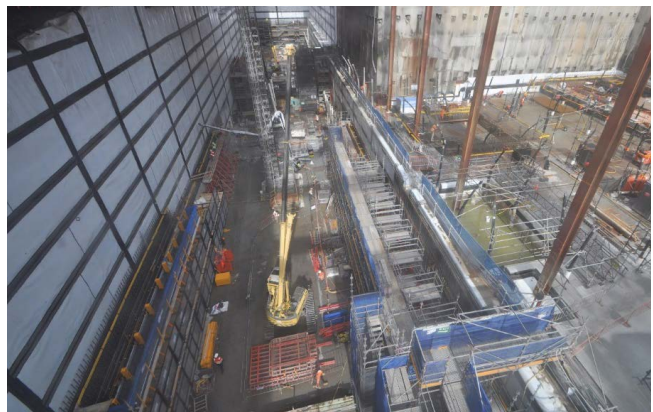


Image shows location of Barangaroo Station (pink) and adjoining rail crossover cavern (yellow) and the proximity to Sydney Harbour

To resist the massive buoyancy loads acting on the station, two key features were introduced to the design.

1. A large-scale shear key was cut into the Sydney sandstone under the adjoining Hickson Rd / High St heritage wall to lock the station into the rock mass.
2. Large permanent strand anchors (normally used in large-scale dam construction) were installed to lock the station box down to the rock mass – a first use of their kind for this type of infrastructure project.

In addition, 63,287 square metres of waterproofing membrane was installed in two layers to cover the entire structure from floor to roof.



Works to create the watertight concrete structure of Barangaroo Station

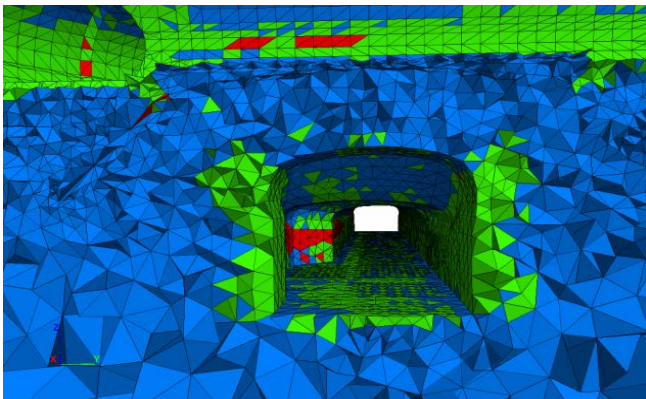


A protection slab was installed for the safe traverse of the TBM over the top of the Cross City Tunnel

Designing for optimal station depth

Cross functional innovation and excellence in design for the underground CBD stations was needed to meet the requirements of minimal land-take footprints, not being too deep for fire and life safety requirements and avoiding clashes with other CBD basements and infrastructure.

A notable example was the design and construction of the Pitt Street underground station. The geometry of this station was influenced by the geology of the area, with poor quality rock in the crown of the tunnel, adjoining basements and the abandoned historic Sydney Monorail foundations.



3D modelling of interface between Cross City Tunnel and Pitt Street station

Pitt Street station is also located above the Cross City Tunnel (multi-lane road tunnel), with only 4.6m between the two structures. The permanent support bolts of the Cross City Tunnel are 3.5m long, leaving only a 1.1m beam of sandstone between the two structures.

The design team used innovative 3-D modelling of the existing tunnels together with an extensive program of 'live' real-time monitoring instrumentation to design and facilitate safe excavation of the station and tunnels required at Pitt Street.

3-D survey and imagery in rail tunnels

JHCPBG and their designers conducted an asset condition survey for several existing rail and cable tunnels using 3D survey and imagery techniques. This included the use of proprietary systems and custom-built camera equipment to improve timeliness of data capture. This was necessary given the constraints of conducting condition surveys during short duration night-time track possessions.



Automated systems installed in adjacent operational rail tunnels

Construction highlights

Martin Place Station

Hidden away beneath the heart of Sydney CBD, cathedral-like caverns were forged out of the sandstone for the future Metro station under Martin Place. Each phase of work needed to be intricately planned due to the space constraints of the site and the complex logistics of major construction in a heavily populated area surrounded by businesses, tourists, high volumes of commuters, pedestrians and vehicle traffic.

The team also addressed a significant scope change stemming from an unsolicited proposal to government for the integrated station development. JHCPBG prepared two designs in parallel while the station development proposal was evaluated.

Dome shaped caverns

The design change at Martin Place not only increased the volume of excavation but also the geometry and amount of concrete and steel reinforcement required. The team identified an opportunity to use prefabricated cages for wall and crown reinforcement. This innovation eliminated significant work at heights and decreased the amount of scaffolding and man-hours needed.

The complexity of the huge caverns beneath Martin Place meant a one size fits all approach would not work. Each prefabricated cage was significantly different in size and shape, meaning each section of installation had to be intricately planned and executed.



View from Martin Place escalator adit

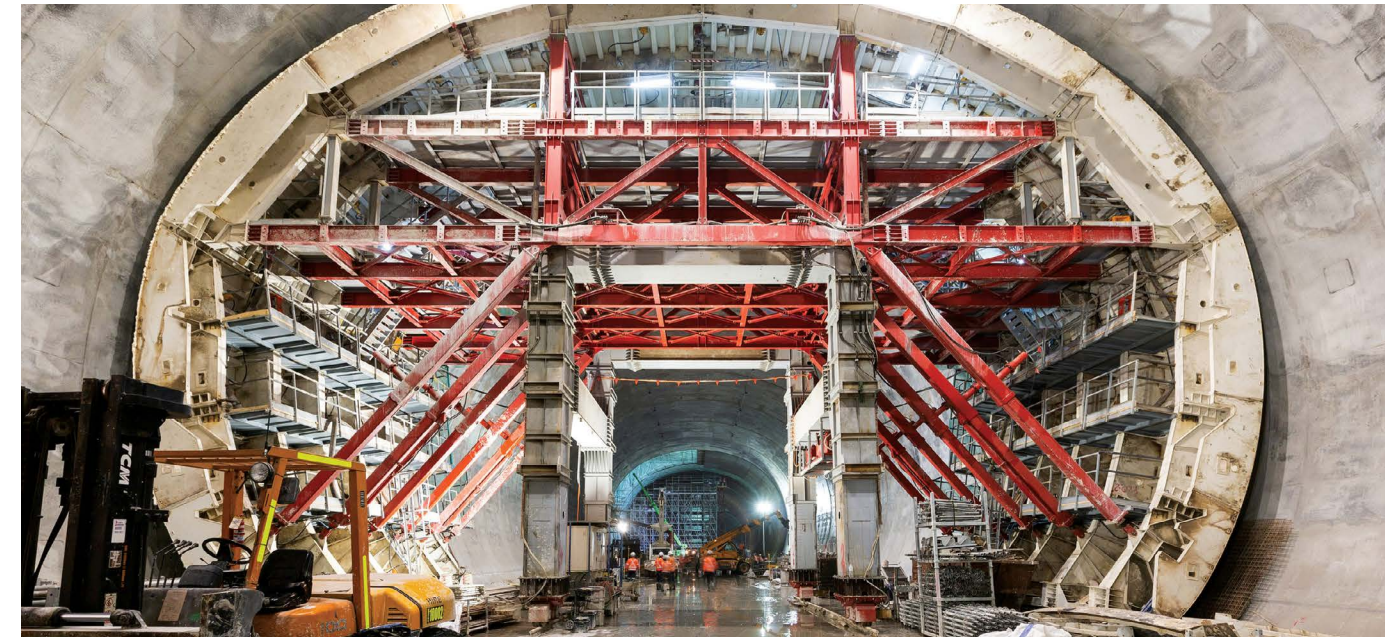
Marrickville pre-cast facility

In just four months the pre-cast facility at Marrickville was built and operating. The bespoke factory had a batch plant and two carousel production lines, with each carousel designed to churn out a segment every five to six minutes. Feeding five TBMs demanded a steady supply of segments and drove the team's momentum. It took only 20 months for the team to finish the massive job of producing over 99,000 concrete segments, averaging 252 a day.

With recycling embraced across the project, the Marrickville pre-cast facility was also able to refurbish and reuse plant and equipment from the Metro North West factory in Kellyville, including 108 segment moulds and other carousel parts.



Complex cavern shapes and constrained working areas led to an innovative reinforcement solution



Victoria Cross cavern

History-making under harbour tunnels

Precision planning and operations were needed to get the under harbour TBM Kathleen, into the cavern at Barangaroo and ready for departure. The slurry TBM's shields and cutterhead were moved across the Barangaroo site and Hickson Road on self propelled modular transporters (SPMTs) over two nights in mid-2019.



TBM Kathleen navigating across Hickson Road

A 240 tonne gantry crane lowered the shields delicately down the narrow shaft onto the SPMT waiting 30 metres below.

Finally, the cutterhead was loaded and then slotted onto the middle shield so the assembled machine could be carried to the launch position within the cavern.

Pedestrian adits

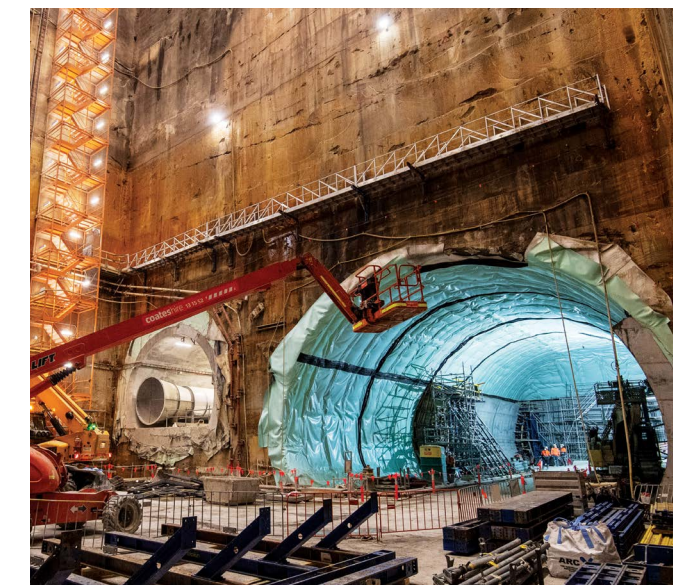
An engineering challenge at the Pitt Street site was the pedestrian tunnel junctions due to the intersecting tunnel angles. The design required perfection in pouring concrete and installation

and alignment of the formwork required for the arch lining. The steel reinforcement required bars to be radially bent and bent twice again in two different directions.

Victoria Cross Station cavern

The Victoria Cross Station team were tasked with building the largest rail cavern in Australia. Five roadheaders worked solidly to carve out about 360,000 tonnes of rock to build the gigantic structure which stretches beneath North Sydney CBD.

A lift shaft 45 metres deep was also excavated for the northern entrance to the future station.



Victoria Cross Station northern shaft adit

Developing capacity and skills

The continual focus on skills and mentoring leaders was recognised in JHCPBG winning the NSW State Training, Large Employer of the Year 2019 award.

Over 100 people in critical roles or with leadership potential were given one-on-one coaching and set their own personal leadership commitments/goals to implement.



One of the pre-employment cohorts celebrates completion of the pre-employment program

Partnering with Global Skills, Sydney Metro and TAFE NSW, JHCPBG provided long-term unemployed with skills to kickstart civil construction careers. We hosted 32 potentials through this program and indentured 31 apprentices on a Certificate III in Civil Construction. Over 50% of the candidates gained long term work opportunities and skills supporting new careers.



Students undertook initial training in basic skills at TAFE

JHCPBG engaged with local high schools identifying students interested in school-based traineeships during their final two years to complete a Certificate II Civil Construction or

Certificate II Business Services. Customised to meet student, school, and project needs, the unique program provided long-term employment and career opportunities with 15 of 17 students successfully completing their traineeship.

Site-based training upskilled over 150 trainees to a new level for major projects providing qualifications (Certificates) in Leadership/Management, Business Services, Civil Construction, Civil Supervision, Contracts Administration, Accounting and Electrotechnology.



The Marrickville pre-cast team surrounded by completed segments

Marrickville pre-cast facility's safety, culture and behaviour-based programs enabled inexperienced workers to become multi-skilled in pre-cast processes. The high-performing workforce safely produced high quality segments at the optimal rate of one every five minutes.

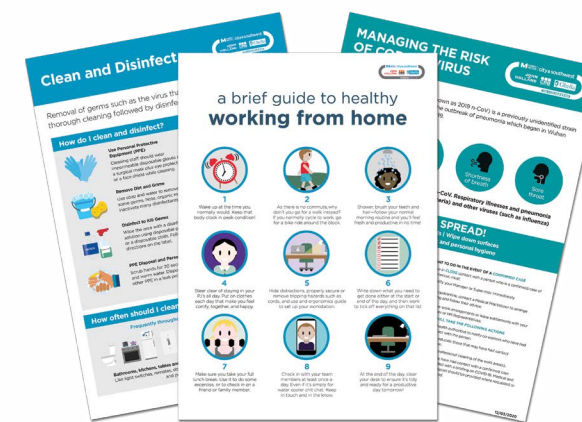
Worker qualifications were captured and tracked in the on-boarding digital system ensuring up-to-date training and appropriate qualifications. WHS training and assessments for all worker reduced incidents to plant and property and increased productivity.

JHCPBG established and maintained a constructive and harmonious working relationship with union(s), external regulators and tribunal (ABCC, CCU and Fair Work Commission). This was achieved through effective stakeholder strategies, ongoing engagement, collaboration and consultation, resulting in zero lost time to industrial dispute.

Managing COVID-19

Just as TBM tunnelling wrapped up but with extensive civil work remaining in early 2020, the world was facing the reality of the COVID-19 pandemic. Highly contagious and potentially fatal, the Australian and NSW governments acted swiftly to impose public health restrictions. These restrictions included physical distancing, limits on movement, and increased hygiene measures which put much of the nation into lockdown.

Fortunately, the importance of major construction projects to the economy was recognised and work



Posters were put up at sites and in the project office to remind staff and workforce how to protect themselves from COVID-19

on our sites continued. But we had to change the way we worked to ensure that we continued to put safety first and keep our people and our workplaces as safe as possible. Movement between



Safety initiatives implemented on site included limiting regular touch-points when accessing areas and regular sanitation points

sites and project offices was restricted and no visitors were allowed. Wherever possible, audits and inspections were conducted virtually using mobile devices so that inspection images/footage could be shared with stakeholders in real time.

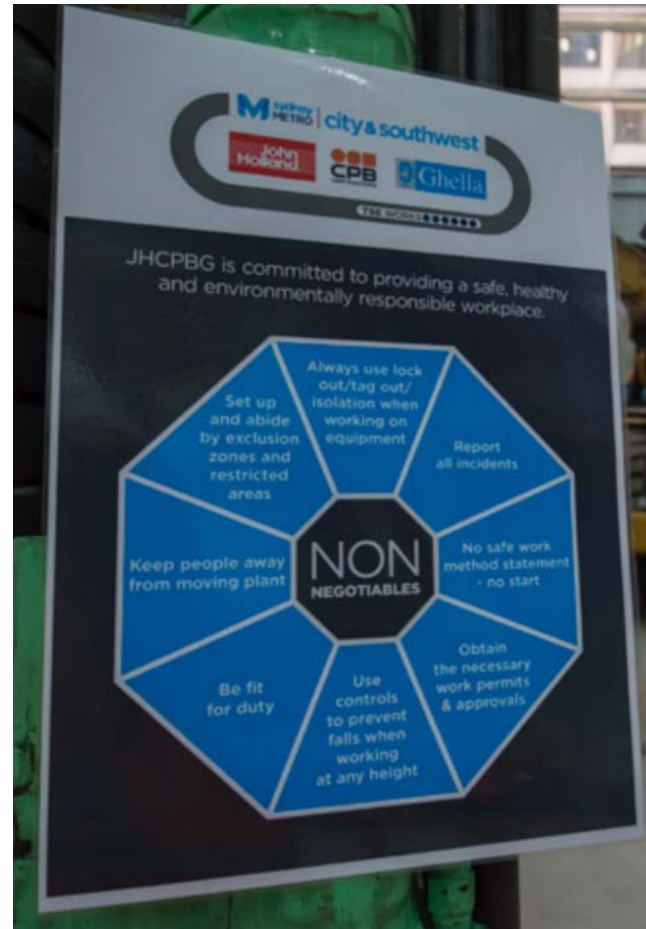
Every single worker took the threat seriously and implemented creative ways to ensure hygiene and safety at each site, while others switched to rosters or remote working. Some of the most innovative solutions included creative wash stations and site entries to reduce touch points, regular cleaning and adapting work pack processes to be fully digitised.



The number of people at prestarts was reduced and they had to remain at least 1.5-metres away from each other

Workplace Health and Safety

JHCPBG's safety innovations



Eight non-negotiable behaviours displayed on site

- Comprehensive on-boarding, supervisor skills training and clear non-negotiable behaviours
- Industry-leading occupational hygiene program
- New method to contain silica dust on small equipment trialled at Victoria Cross
- Off-site reinforcement-cage construction & modified telehandler attachment to reduce work at heights and collision risks
- Weekly internal television shows reinforced the project's safety messages
- Workshops with sporting stars Adam Goodes and Steve Waugh, helped to build resilience and well-being for over 900 workers
- Almost 200 people trained as mental health first aiders.

Safety was of the highest importance on this project as most day-to-day activities were high risk. Eight non-negotiable behaviours were developed to address the areas that significant research found to be the most likely to cause death or injury in major tunnelling projects. Inductions, the development of safe working methods and the ongoing pre-start briefings were structured around these behaviours to communicate a consistent safety message across the project.



Testing the HoloLens safety training device

Augmented reality technology was used to assist in training to work in mined tunnels, on the tunnel boring machines (TBMs) and at the precast facility. Inductees received TBM cutter change training using actual components, tools and methods.

Clearing the air

JHCPBG implemented an industry-leading occupational hygiene program aimed at controlling exposure to high-risk hazards for construction and tunnelling workers, including minimising exposure to crystalline silica/respirable dusts/diesel particulates. The risk-based program was recognised as the "most significant contribution to the improvement of workplace health" at the 2019 SafeWork NSW Awards. At the pre-cast facility, new safety innovations such as laser sensors and local dust extraction units fitted to hand tools for segment repairs, were implemented to improve the health and safety of those working on the production carousel.



Training inside the hyperbaric chamber before TBM Kathleen begins tunnelling

An innovative air extraction and filtering system was developed by a mechanical foreman at the Victoria Cross site to reduce the silicosis risk from harmful airborne dust.

Chain of Responsibility

Chain of Responsibility (CoR) legislation made it imperative that JHCPBG minimised road safety risks. JHCPBG collaborated with NSW Police, Transport for NSW and other government agencies to provide training to all supervisors and project managers. The leaders and owners of all our major sub-contractors participated in regular sub-contractor forums to focus on key issues and share learnings.

Finishing Strong

To address the risk of complacency and burnout at the height of the project, JHCPBG developed a unique program for workforce and sub-contractors involving two of Australia's sporting greats, Adam Goodes and Steve Waugh. Close to 1000 people attended interactive workshops focussed on attitude, purpose, well-being and resilience, with overwhelming positive feedback.



Finishing Strong workshops

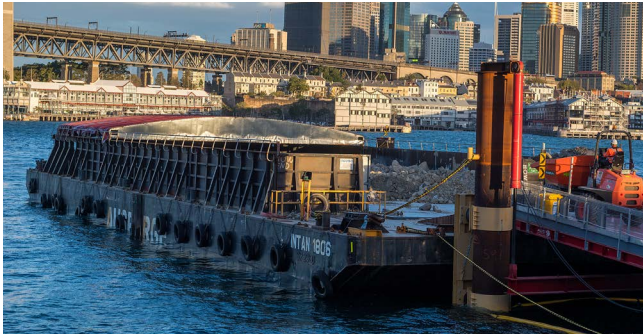
Reinforcing the safety message

To strengthen the ongoing safety message across the project, a bi-weekly internal TV program was introduced to reinforce safety messages. The program featured staff, workforce and sub-contractors across all sites presenting, in their own words, safety innovations and applauding people who have been recognised in the project's monthly awards for safety and other contributions. The program has been recognised internationally, winning global recognition at the 2020 International Association of Business Communicators (IABC) Gold Quill Awards.

Leaving a legacy

Sustainability solutions and highlights

JHCPBG's key environment objective was to maximise efficiencies to reduce our energy, water, materials and waste footprint. The project was recognised by the Infrastructure Sustainability Council with a leading rating of 96.4 – the highest score ever awarded to an Australian infrastructure project.

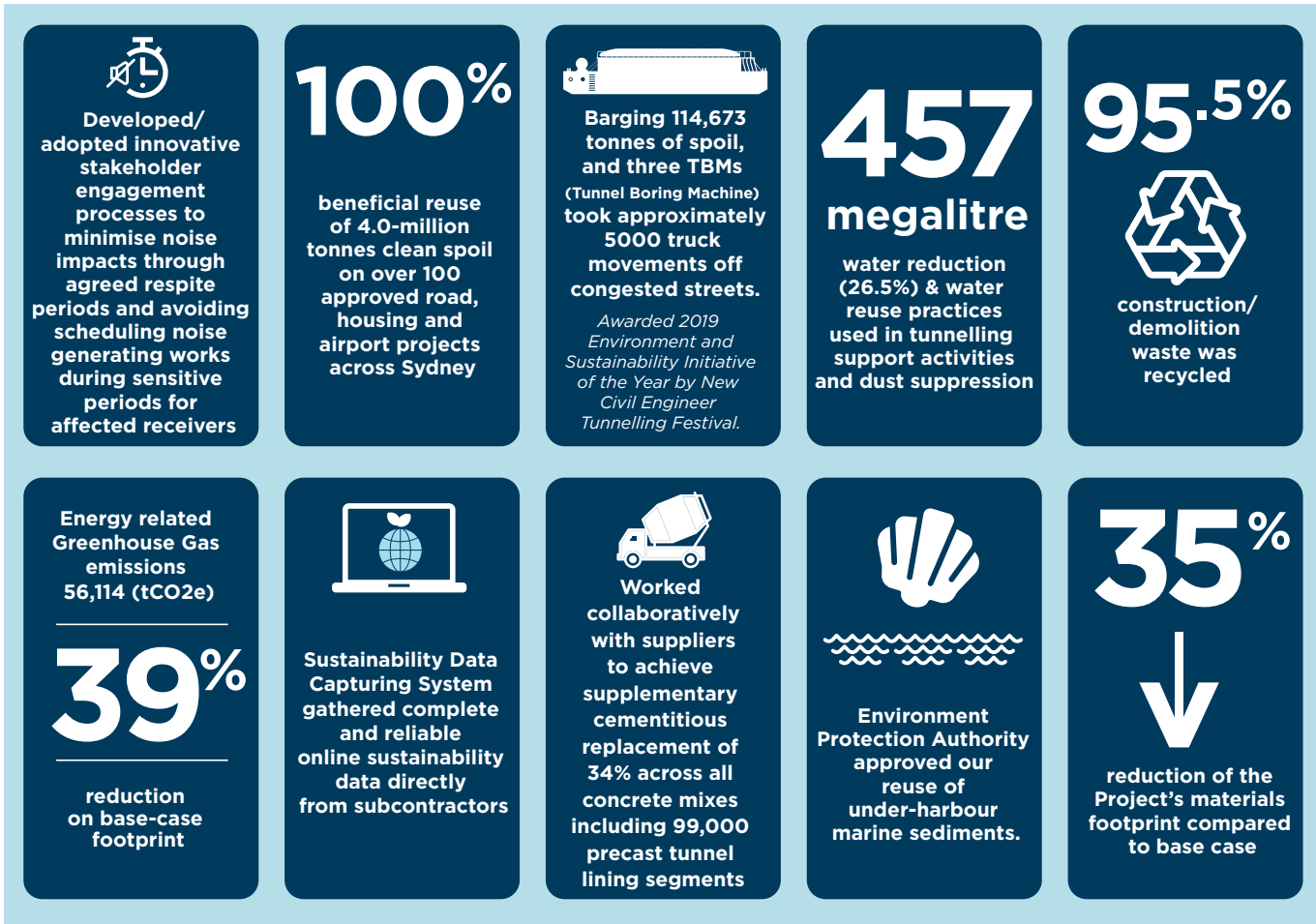


Barges on Sydney Harbour used to remove spoil from harbourside sites



A TBM shield is lowered into the Chatswood dive by a 280-tonne gantry crane which was sustainably reused for TBM assembly across the project

The project was also awarded an Australian first innovation by the Australian Tunnelling Society (ATS) – our TBM assembly methodology enabled reuse of a 280-tonne gantry crane across three worksites which reduced the cost, resource usage, noise impacts, and safety risks associated with this critical task.



Heritage

Specialist heritage consultants investigated sites for Aboriginal and historic heritage significance before excavation began. With many sites in the areas of first settlement, several historic and heritage listed buildings also needed to be protected during works.

A major heritage item, the oldest European style boat made in Australia found to date, was discovered at the Barangaroo site and carefully retrieved for restoration ([Please view facebook video here](#)).

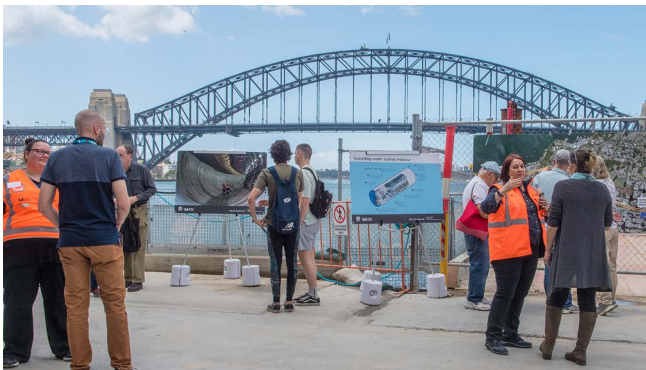


Small boats like the one found at Barangaroo would have been like the ute of the day, ferrying goods to different locations around Sydney Harbour



180-year-old timber boat uncovered during excavation at Barangaroo

Engaging the community



Open days and information sessions gave local communities the opportunity to visit the sites, meet the JHCPBG team and learn more about the project

JHCPBG's Community Team effectively consulted with stakeholders to create an environment of trust, openness, and involvement. Our aim during construction was always to minimise disruption, delay, and inconvenience to nearby residents and businesses. JHCPBG set an industry leading approach for stakeholder engagement with over 3,000 residents and businesses surveyed to develop preferred alternative respite-periods, ensuring community preferences were considered in minimising noise impacts and building community relationships.

Our team



A values-based, One Team culture fostered innovation, safety and excellence in engineering & sustainability to achieve early, high quality completions. A collaborative approach facilitated commercial resolutions to incorporate design/scope changes needed for later fit-out and developments, allowing the client to advance Metro delivery.

“The success of a project starts with getting it right during the bid. Understanding the risks and issues and working through them sets us up for project success.”

Terry Sleiman
Project Director



Proudly supporting
Sydney Children's Hospitals Foundation



Thank you to our JHCPBG staff, workforce, consultants, sub-contractors and suppliers who raised \$1.15million in support of our Project Charity Bear Cottage

