
LBB JV
LEIGHTON
BAULDERSTONE
BILFINGER BERGER

Scope of Work

The Clem Jones Tunnel (CLEM7) is Brisbane's first major road tunnel and the longest and most technically advanced tunnel in Australia. The project has an overall length of 6.8km and links the Inner City Bypass (ICB) and Lutwyche Road in the north of Brisbane to the Pacific Motorway and Ipswich Road in the south, with an entry and exit ramp at Shafston Avenue.

The CLEM7 is the first critical component of the Brisbane Lord Mayor's TransApex vision to ease congestion and cater for the city's future traffic needs. The tunnel, which has the capacity to carry more than 100,000 vehicles a day, bypasses Brisbane's CBD and 24 sets of traffic lights, reducing travel time by up to 30%, cutting fuel costs, vehicle emissions and improving safety. During the recent devastating floods in Brisbane the tunnel proved to be an important asset, providing evacuees with a vital and secure alternate route to the many roads that were impassable or closed due to flooding.

The Project was delivered by the Leighton Contractors and Baulderstone Bilfinger Berger Joint Venture (LBBJV) under a lump sum design and construct (D&C) contract. A 'fast track' design and construction approach was adopted, which enabled LBBJV to deliver the Project seven months ahead of schedule and on budget for their client RiverCity Motorway (RCM), who is in a Public-Private Partnership with Brisbane City Council (Council). The Project cost $3 billion, which includes financing costs and the $2.1 billion of design and construction cost.

The scope of work included excavation and fitout of two parallel twin-lane tunnels, 4.8km each in length, as well as links to Brisbane's road network by 18 bridges, six entry and exit portals and 155,000m^2 of road, including a three-level interchange.

Tunnel construction included:

- 41 evacuation cross passages between the two mainline tunnels every 120m;
- A long passage for evacuation from the Shafston Avenue ramps;
- Five underground substations, each consisting of four individual tunnels excavated in the space between the two mainline tunnels;
- A dedicated tunnel in each tube, beneath the road surface for cabling; and
- A smoke duct in the ceiling of each tunnel, 9.2m^2 in cross section, to extract smoke in an emergency and to manage air quality in congested traffic.

The tunnel route runs beneath the Brisbane River. The majority of the tunnel is designed and constructed as a fully tanked structure, with only short sections designed as drained tunnels.

The tunnel has state-of-the-art mechanical and electrical (M&E) systems, including:

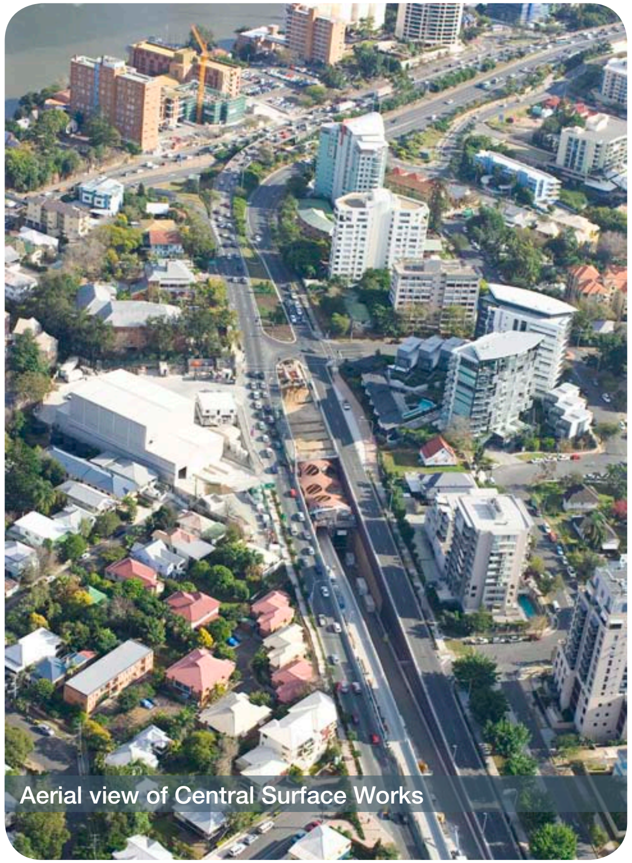
- High and low voltage reticulation including two 33kV surface intake substations and five underground substations;
- Tunnel and emergency lighting systems, street lighting and architectural lighting;
- Tunnel ventilation, including 119 jet fans (comprising 98 off 30kW jet fans in the mainline tunnels, and 21 off 45kW jet fans in the Shafston Avenue ramps) and two surface ventilation stations, each housing five 150m^3/s normal ventilation extraction fans, as well as five 100m^3/s smoke extraction fans;
- Communications systems within the tunnel, including radio rebroadcast, emergency telephone, mobile telephone, two-way radio and PA systems;
- Traffic Management Systems, including electronic signage, overheight vehicle detection and warning system and CCTV;
- Automatic Video Incident Detection System;
- Fire Systems, including detection (both point type detectors and fibre optic “fire wire”), suppression (zoned fire deluge system within the traffic space and foam suppression in the low point sumps) and associated fire pump stations/fire brigade boost points;
- Control Systems for traffic management and plant management, including a Tollroad Control Centre with a 24 hour, 7 days-a-week manned control room;
- Tunnel pumping stations, including two low point sumps in the mainline tunnels providing a total volume of 270m^3, another major sump at the base of the southern vent tunnel with a volume of 545m^3, as well as smaller pump stations;
- A groundwater treatment plant to treat tunnel groundwater from the drained sections of tunnel prior to discharge into local waterways; and
- Four ambient air quality monitoring stations to provide real-time monitoring at ground level and elevated locations in proximity to each of the ventilation outlets.

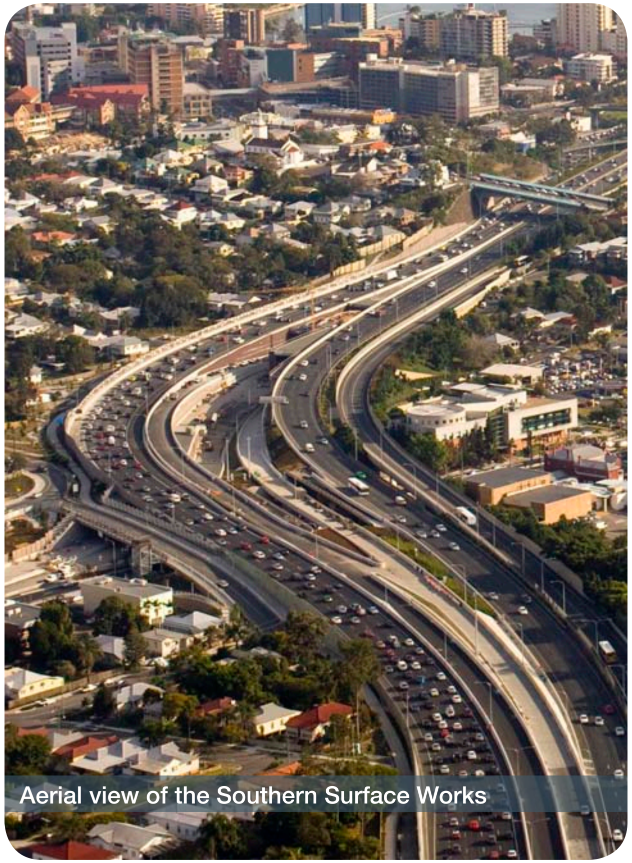
The Northern Surface Works included:

- Widening of Lutwyche Road;
- Construction of 12 new or widened bridges to connect the CLEM7 with the newly widened Lutwyche Road and Inner City Bypass (ICB), including a three level interchange;
- Construction of the northern portal and approach ramps;


Aerial view of Northern Surface Works

- Construction of surface buildings including the Tollroad Control Centre, 30m high northern ventilation outlet, surface substation and fire pump room;
- Construction of a re-routed shared pedestrian and cyclist path; and
- Erection of noise barriers on Hale Street.


Aerial view of Central Surface Works


Aerial view of the Southern Surface Works

The Central Surface Works included:

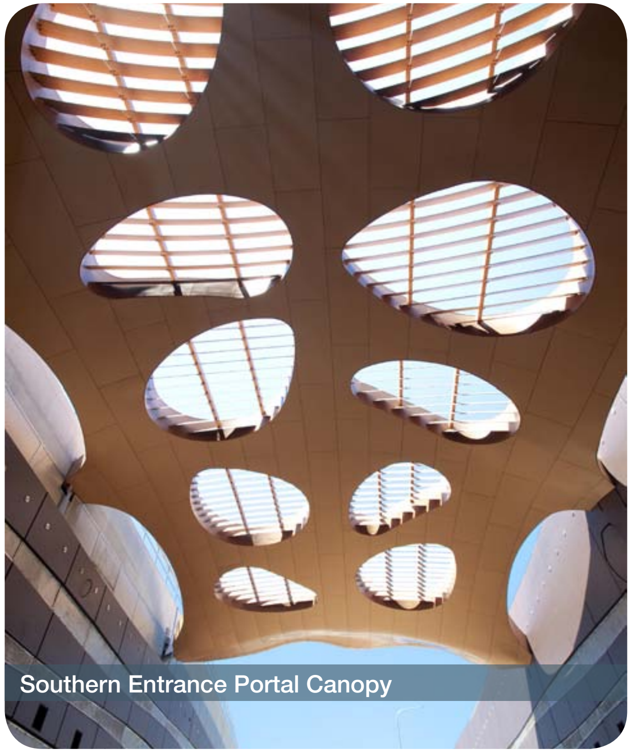
- Widening of Shafston Avenue to allow for one lane entering the tunnel and two lanes exiting the tunnel in the median; and
- Construction of the Shafston Avenue portals.

The Southern Surface Works included:

- Construction of the southern portal in the median of Ipswich Road;
- Widening of Ipswich Road to maintain the same number of through traffic lanes;
- Construction of an underpass for northbound Ipswich Road traffic to allow the ramps to be constructed from Ipswich Road and the Pacific Motorway;
- Construction of the Ipswich Road pedestrian underpass;
- Widening of the Pacific Motorway to accommodate the tunnel connection, including widening of three bridges (including a rail bridge) and demolition of a footbridge across the motorway;
- Construction of an additional northbound lane on the Pacific Motorway;
- Construction of the new Harrogate Street footbridge across the Pacific Motorway;
- Construction of a dedicated 1.4km long bikeway and pedestrian pathway; and
- Construction of the 44m high southern ventilation outlet and surface substation.

Additional surface works scope included $24 million of Public Utility Plant (PUP) relocations, local road adjustments and extensive landscaping works, including the creation of a new park adjacent to the southern ventilation outlet.

The scope also included the roadside free-flow electronic tolling system. The back office scope of the tolling system, which includes all the business elements, including payments and toll evasion notices, was delivered by RCM.


Southern Entrance Portal Canopy

The Project included landmark urban design elements, including:

- The southern and northern ventilation outlets, which use the Poinciana and Jacaranda trees as inspiration for the design of the façade, fitting the brief 'to complement and celebrate the city's natural assets'; and
- Spectacular portal canopies that combine function and art by providing a transition between the light outside and inside the tunnel, allowing motorists eyes to adjust to the driving environment.

Unique attributes of the CLEM7

- The first project in Australia to use two large double shield Tunnel Boring Machines (TBMs) driving simultaneously through hard rock, with a compressive strength of over 100MPa.
- The largest major civil infrastructure project in Australia to rely solely on recycled water for construction.
- Reconfiguration of the arrangement and staging of construction on the Pacific Motorway, Woolloongabba to mitigate the disruption to the 150,000 vehicles that use it daily.
- Development of a real-time noise and vibration monitoring system utilising modem connected equipment with a web-based interface to verify predictions.
- World leading fire and life safety design with both tunnels fitted with longitudinal ventilation, deluge and smoke extraction and a state-of-the-art smoke duct.
- Use of a radio frequency identification (RFID) tagging system during construction to transmit a person's location wirelessly. The system was designed to monitor all people and assets in the tunnel to improve safety and operational efficiency.
- Installation of cable tunnels during the TBM operation, allowing mechanical and electrical services to be installed in parallel with civil construction.
- An improved loop ramp configuration at the Shafston Avenue entrance which helped reduce program time and geological risk.
- Re-design of the ramps at the Woolloongabba and Bowen Hills connections to improve connectivity, traffic flow and reduce construction risk.
- Induction of more than 13,000 people, with another 3,800 undertaking recognised training programs.

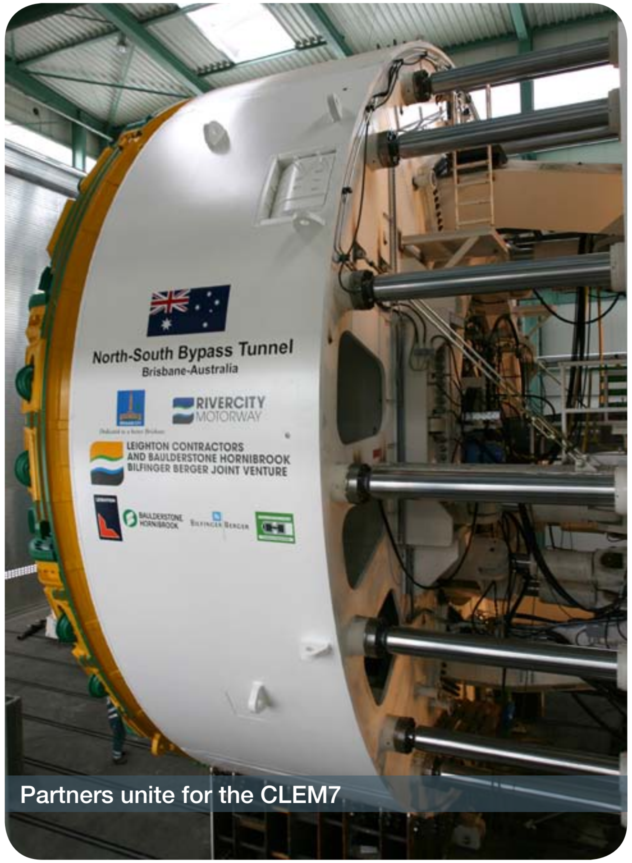
Type of Contract Used

In April 2006, Council entered into a Public-Private Partnership with RCM to finance, design, build and operate the CLEM7 for a period of 45 years. In turn, RCM contracted LBBJV to design and construct the Project under a hard dollar contract that was "back-to-back" with the requirements of the Project Deed between Council and RCM.

At the same time, RCM contracted Brisbane Motorway Services (BMS) to operate and maintain the motorway. Although there was no contractual relationship between LBBJV and BMS, each had obligations to each other by way of an 'Operations and Maintenance Interface Agreement' that was part of each of their contracts with RCM.

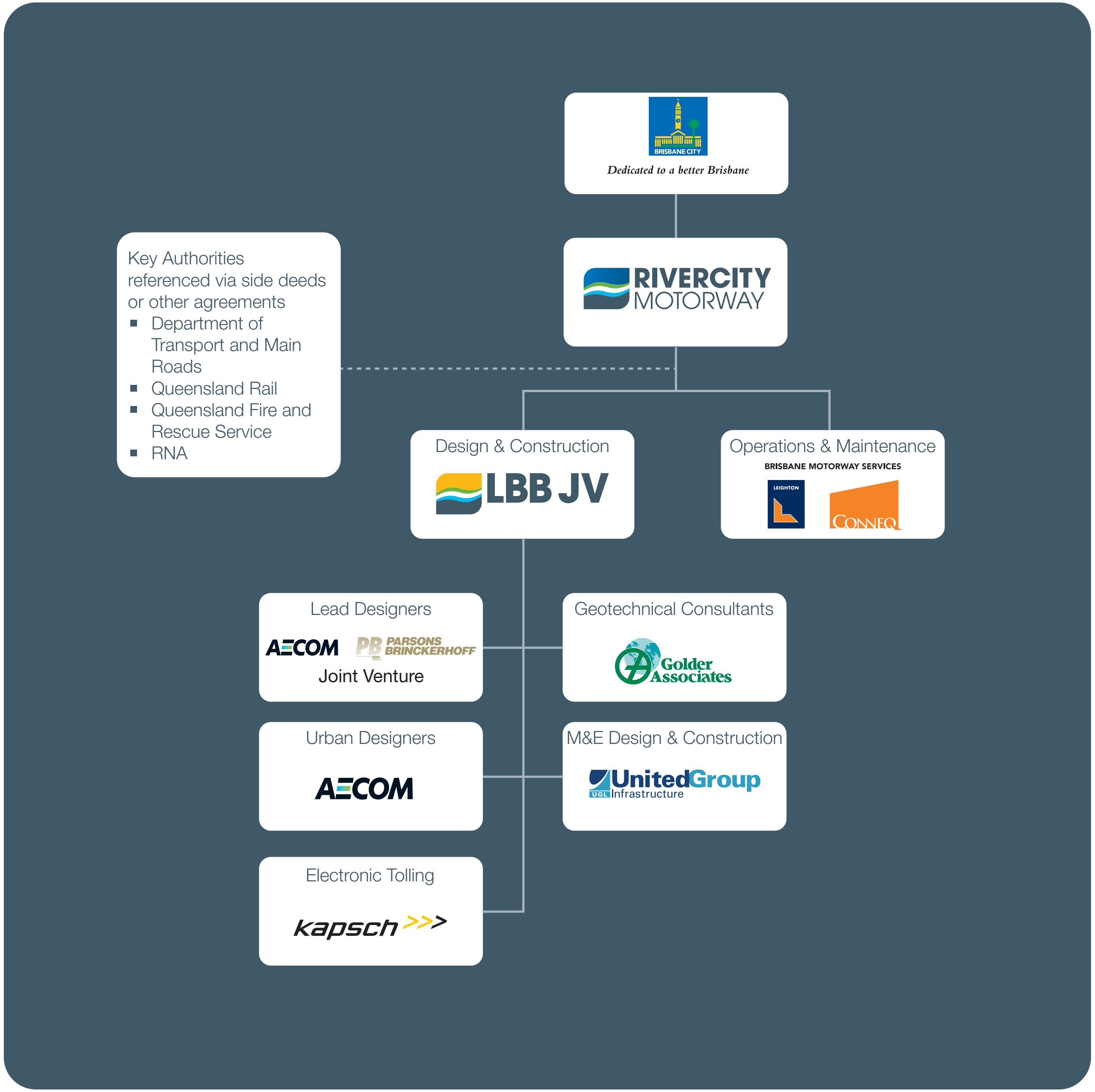
The Project Deed included a number of Side Deeds and Agreements to accommodate the significant interests of key stakeholders and authorities, including:

- Queensland Department of Transport and Main Roads (DTMR), who own and operate the Pacific Motorway, which required significant construction works as part of the Project;
- Queensland Rail, who have assets in the north and south ends of the Project that were altered as part of the scope; and
- Queensland Fire and Rescue Service, who, through Queensland Emergency Services had a significant role in reviewing the design and construction of the fire and life safety systems for the tunnel, as well as the Operational Incident Management Plan.



Partners unite for the CLEM7

LBBJV had a number of Consultancy Agreements with design consultants, including lead designer AECOM Parsons Brinckerhoff, geotechnical consultants Golder Associates and tunnelling designers Bilfinger Berger Technical Bureau. LBBJV subcontracted out a number of key areas of specialised work under contracts that were back-to-back with the conditions in the D&C Contract (and therefore the Project Deed). The contractual arrangements are represented in the diagram to the right.



1. Outcomes Achieved Against Planned Targets for Key Project Parameters

The Project did not have a formal Key Result Area structure; instead outcomes and performance were regularly evaluated through close consultation with the Client. The Project exceeded expectations in many areas and delivered an end product of exceptional quality and one of the safest tunnels in the world.

1.1 Safety

From project award in May 2006 to project close-out in July 2010 the CLEM7 engaged over 13,000 people with 13.7 million man hours worked. The rolling Lost Time Injury Frequency Rate was just 1.2 at tollroad opening in March 2010 and the final 1.5 million man hours up to project close-out were completed without a lost time injury.

LBBJV was named Winner of the 2010 National Safety Council of Australia (NSCA) National Safety Awards of Excellence – ExxonMobil Business Excellence through OHS&E Management Award. In awarding the distinction to LBBJV, the NSCA said:

"This project's achievements included:

- *Turning the $3 billion mega-project's rolling Lost Time Injury frequency rate (LTIFR) from a peak of 9.2 in December 2008 to just 1.2 at tollroad opening in March 2010*
- *Completing the final 1.5 million manhours up to project close-out in July 2010 without a lost time injury and*
- *Opening the roadway seven months ahead of schedule and within budget*

Their submission showcased how the project team recognised and resolved safety performance issues and successfully integrated these improvements with the operating business system of CLEM7 to produce the excellent results outlined above - no mean feat on a project of this size and complexity."

Details of how LBBJV's leadership team achieved this huge improvement are described in Section 3.5 - Occupational Health and Safety.

At its peak, the CLEM7 brought together some 2,100 people from many parts of the world to work on the Project. Our challenge was to unite 350 staff, 700 wages employees, 850 subcontractors and over 200 consultants into a safety culture that many of these people may not have experienced before. Our approach needed to be simple, practical and effective to ensure that we could align all our people into a way of thinking and working that put safety ahead of production.

We achieved this through the establishment of a strong safety culture, underpinned by the CLEM7 "Safety Roadmap" - a project-specific, tailored safety handbook comprising rules, procedures and instructions.

The Safety Roadmap was issued in hard copy for easy reference to each manager, supervisor and foreman responsible for personnel and was updated regularly with new information and continuous improvements. Its distinctive name and physical presence in offices across the Project was all part of the drive to build and maintain a positive, united and ever-present safety culture on the job.

Another cornerstone of the Project's safety culture was the Safety Leadership Team (SLT), which consisted of the Project Director, Deputy Project Director, Interface Manager, General Superintendent, Safety Manager and area Project Managers. The SLT worked with all levels of the project team to integrate health and safety performance into the normal everyday operating business systems and sent the clear message that safety was our biggest priority.

Experienced personnel and a proven safety system completed the team's ability to proactively manage safety on the job. The CLEM7 drew on past experience and new technologies to provide effective solutions to safety risks. For example, the Project utilised a radio frequency identification (RFID) tagging system during construction, which located and tracked every individual within the tunnel and was utilised to track assets

Mobile Working Platforms for M&E fitout

underground to improve operational efficiency.

A key initiative that minimised safety risks and increased productivity was the mobile working platforms, designed and commissioned by LBBJV for the M&E fitout of the tunnel. The majority of the M&E fitout was carried out from these platforms, which included a high-level working platform and a hoist to raise equipment. This innovation ensured a secure and dedicated working space for M&E fitout that was physically separated from other activities and allowed the safe passage of all other tunnel construction traffic underneath, eliminating the need for multiple elevated working platforms and the inherent risks associated with them.

Travelling Smoke Duct forms

Another initiative was the travelling form for the smoke duct, which, like the mobile working platforms, was designed to allow vehicle movement to continue beneath it while smoke duct slab construction continued overhead.

LBBJV established a stringent safety reporting culture, centred on "learning through thorough reporting". Over 440 incidents were investigated with more than 200 Safety Alerts put in place as a consequence. This culture made a tangible difference by ensuring senior management got to the root cause of the incident or near miss enabling effective measures to be implemented to reduce the risk of an occurrence.

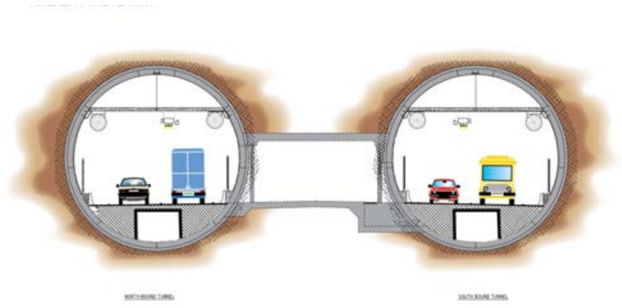
1.2 Time

The CLEM7 was opened to traffic on 15 March 2010, almost seven months ahead of the contractual date for tunnel completion. LBBJV adopted a ‘fast track’ design and construction approach and structured its construction team and program so that it was able to deliver the built elements in autonomous cells.

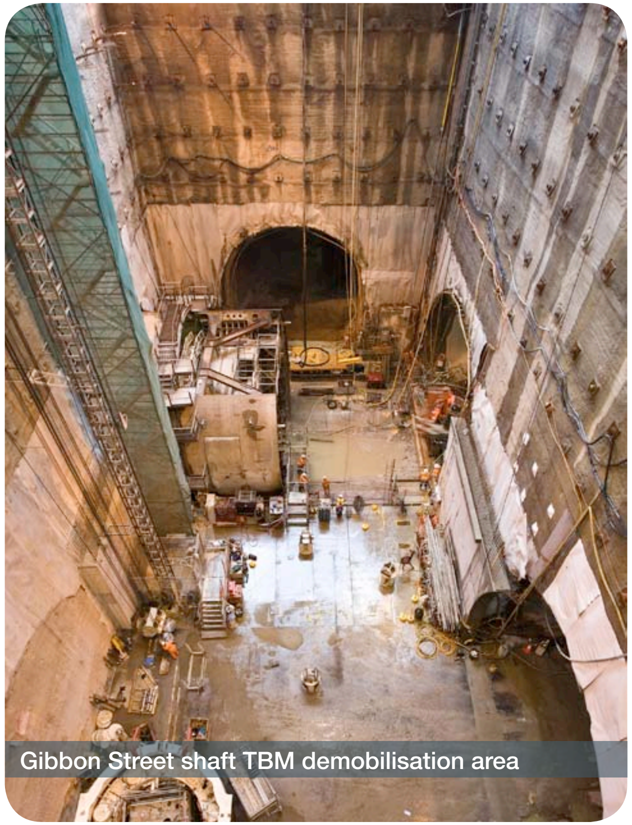
The construction program was driven centrally by the Project Director, who set an aggressive early completion date, and was managed locally by each of the seven area Project Managers who were responsible for preparing a program to meet the target. Each area program was fed into the overall project program. Each Project Manager reported progress on a weekly basis to the Construction Director, while milestone dates were agreed and reported monthly for all major project elements.

The tunnelling activities were on the critical path and in recognition of this LBBJV dedicated a lot of attention to two key areas, namely:

- Tunnel design, construction methodologies and access logistics - intense and thorough review and planning was carried out, resulting in a number of key initiatives that significantly reduced the Project’s duration, including:
  - Portal design changes to facilitate early access to mainline tunnel excavation.
  - Use of two purpose-built tunnel boring machines (TBMs), rather than one as contemplated in the Client’s reference design, which significantly reduced the duration of tunnelling.
  - Use of double shield TBMs allowing for excavation advancement coincident with tunnel lining, again reducing the tunnelling program.
  - Introduction of temporary construction-stage shafts to increase the number of tunnel excavation fronts.
  - Concurrent construction of cross passages and mainline tunnels.
  - Use of purpose-built travelling forms that allowed smoke duct construction to progress overhead without interrupting tunnel construction traffic.



Tunnel Cross Section



Gibbon Street shaft TBM demobilisation area

Construction of Cable Tunnel

- M&E scope and its interface with the rest of the Project, with the following key time-saving initiatives being implemented:
  - LBBJV converted the executed lump sum contract with United, the M&E subcontractor, to an alliance, with a gain share/pain share arrangement for M&E labour costs. The alliance created a no-blame environment, which promoted transparency and fostered a joint approach to solving challenges resulting from the interface between the excavation/civil fitout works and the M&E fitout. It also allowed for greater resources flexibility by drawing on the pool of resources available to both LBBJV and United.
  - Introduction of a separate cable tunnel underneath the road surface in each tunnel, enabling high voltage cable pulling activities to proceed early and unimpeded by concurrent works.
- Introduction of innovative purpose-built mobile work platforms that enabled the M&E fitout activities to progress without interruption overhead in the tunnel envelope proper whilst allowing unimpeded traffic flow beneath the ongoing activities.

These initiatives successfully improved the past tunnelling performance achieved and in doing so have made a valuable contribution to the industry.

The collective experience of the team was that on major projects there are many areas that, if not effectively managed, can adversely affect program. These areas include planning, procurement, authority issues, environmental issues, community issues, spoil management and quality close out. Recognising fully this "weakest link in the chain" effect, and its potential impact to the project end date, LBBJV placed a great deal of emphasis on teams recognising and assessing the tasks ahead and implementing solutions at a sufficiently early stage to avoid delays.

The project team developed and implemented a Completion Plan, which included a comprehensive process to identify and manage every individual task required to open the tunnel safely to traffic.

This process effectively managed the completion risks, providing transparency of the status of completion tasks and certainty in relation to the completion date to all key stakeholders.

1.3 Cost

Cost certainty was paramount on CLEM7; whilst some clients may have access to additional funds to pay for unforeseen circumstances that arise during the project delivery phase, a concession company such as RCM has extremely limited flexibility in this regard. For their part, RCM aimed to ensure cost certainty by signing LBBJV to a hard dollar lump sum contract written to ensure that, as the design and construct contractor, LBBJV took the lion's share of the project delivery risk. However, contractual relationships alone do not give certainty and many such tightly written contracts have still resulted in costly variations for the Client.

From the outset LBBJV senior management set out to establish and maintain an open and cooperative relationship with both RCM and Council in regard to all matters, including commercial matters. We recognised that fostering a positive relationship had many more mutual benefits than, for example, chasing multiple variations.

This openness included early identification by LBBJV of issues that may impact scope and/or cost and working with RCM and Council to solve the issues to mutual satisfaction, rather than simply valuing and submitting variation claims.

This collaborative approach resulted in the final contract sum remaining within 3.2% of the original $1.998 billion contract amount. By industry standards this is extraordinarily low, given the complexity of the Project, the lump sum nature of the contract, the speed at which the Project was delivered and the “overheated” nature of the industry at the time of delivery.

1.4 Quality

LBBJV’s targets with respect to quality were to resolve all quality issues in a timely manner and provide transparency and documented traceability of Qualtiy Assurance (QA). This section describes how LBBJV successfully achieved both these targets.

Although the contract did not require it, LBBJV made the decision to develop a project-specific Quality Management System that was independently certified to ISO 9001. This was done primarily to make the management system more flexible and responsive to the specific needs of the Project, the Client and other stakeholders.

Developing the system and providing training to users was a significant commitment, requiring dedicated resources over four months in preparation for the first certification audit. The benefits of this investment were well worth it – the end result being a practical, simple system that reflected LBBJV’s plan for delivering the Project, using processes that addressed project-specific requirements, rather than shoe-horning the Project into a pre-existing system.

The Project was continuously reviewed during delivery by an Independent Verifier (IV), which included a team of experts in their fields. The IV’s role was to verify that the Project met all the requirements of the contract, including technical and other specifications, as well as issues like fitness for purpose and best practice. The IV’s review was holistic, starting at the design phase and continuing through construction planning, construction implementation and, finally, documentation including construction lots and as-built records. The IV certified each design package and the design as a whole, inspected the constructed works to confirm they complied with both the certified design and the contract requirements and finally, signed off the Project as being complete and safe to open to the public.

Critical to the successful implementation of the Quality Management System was LBBJV’s top down, unequivocal support of the value of effective quality management to the end result. This meant that quality management was continually kept front of mind at all levels in the project team. Quality management had a key role at weekly senior management meetings to ensure the progressive close-out of all quality issues, thereby avoiding a situation where a large volume of issues remained unresolved over time. This senior management approach was instrumental in providing a methodical and transparent process for RCM, Council and the IV so that signing off the Project for opening to traffic was a very smooth and predictable process – a significant achievement on such a large, lengthy and complex project. The end result was telling, a project that had less than 70 minor defects across its entirety at completion and an end product that is proving very reliable for the Client and Operations and Maintenance Team.

Another important decision by LBBJV was to establish an independent QA Team, which included QA engineers dedicated to each of the area Construction Teams, but accountable to the Project’s QA Manager.

This injected rigour into the QA process and ensured an independent review of the quality being achieved and the QA documentation.

The Project created more than 5,600 work lots, each of which was prepared and closed out by the relevant engineer and, importantly, checked by the independent QA engineer. This created a robust process that generated a lot of confidence in the records produced and ensured that the works were verified expeditiously and progressively. All documentation associated with a lot was captured electronically in the project collaboration/document management system. Once all records for a construction lot were completed, checked and uploaded to the document management system, the IV was notified and could audit the construction lot. Any issues raised by the IV were satisfactorily resolved through a process involving the IV, the independent QA Team and the Construction Teams.

Planning for completion began over two years prior to tunnel opening and was managed under the QA System to ensure the necessary level of rigour and reliability. The entire area of project works was graphically represented on a map and divided into over 200 geographic areas. For each area a QA Tracking Sheet was created, which listed all relevant documents associated with that area of work, including design documents, relevant certificates, construction lot records, non conformance reports, shop drawings, warranties, acceptance records from service utilities and asset owners for works on their assets and lists of all inspections carried out and the outcome of those inspections, including resolution of any issues. Each Tracking Sheet had to be verified as complete and signed off by the Project Manager responsible for the main works in that area.

One of the essential elements of success of the QA system was traceability. In total 22,000 QA documents, 18,000 drawings (including 8,300 as-built drawings) and over 600,000 files related to completion and QA records were produced. From the outset, LBBJV made a conscious decision to set up a system based on providing the capability to stakeholders to trace the history of any QA issue. To achieve this all QA and completion records are filed together on one system and are traceable via the geographically defined areas across the entire Project. The Tracking Sheets (described above) provide the links between records relevant to the geographic area.

It is therefore possible to provide forward traceability from, for example, the design lot through site changes and minor variations to construction lot records and the as-built records and drawings, and backward traceability, from geographical locations to certified design lots, shop drawings and construction records.

Ready accessibility of records was provided for all stakeholders through the web-based project collaboration/document management system. This transparency created confidence that the works were being constructed correctly and the documentation required to be submitted at the end of the Project would be available. The upshot was that on the day the project team formally advised the Client the works were complete, and the tunnel ready for operation, the IV was able to confirm this was the case that same day and did not take any of the 15 days available to him under the Project Deed to make his assessment. Furthermore, all project-related issues, including all as-built drawings, were confirmed as being 100% closed out by the IV within 16 weeks of the tunnel opening to traffic – a feat that is unprecedented on such a large job.

All in all, QA Management was a tightly managed and well documented process that added great value for the Client by providing confidence that the end product was of a high quality, supported by excellently documented records.

Further information about quality management is provided in Section 3.4 - Planning and Control of Design and Construction Operations.

1.5 Environment and Sustainability Outcomes

The CLEM7 team was particularly cognisant of the need to consider its local surroundings during construction, in particular the environment and community. From the outset, management wanted to set a new benchmark for environment and sustainability practices on infrastructure projects.

LBBJV developed a detailed Construction Environmental Management Plan (CEMP) which provided the framework for the team's environmental efforts and achievements, and guided the Project through the requirement to comply with the conditions set by the Coordinator General (CoG), key elements of which were the control of construction noise, dust, vibration, community engagement and approach to sustainable development.

In general terms LBBJV managed:

- Noise and dust at main tunnel sites supporting 24 hour, 7 days-a-week tunnelling operations by erecting acoustic-lined work sheds over all tunnel entrance worksites;
- Regenerated noise and vibration from tunnelling by developing a predictive model that provided the Community Relations Team with the information to communicate to residents and businesses the expected timing, duration and affect of tunnelling activities;
- Community engagement through the Community Engagement Plan; and
- Sustainable development, which is best demonstrated by the preservation of mangroves at Enoggera Creek and the Project's self sufficient water management program saving 1,500 mega litres (ML) of town water during Brisbane's drought.

The outcome of this very proactive environmental program was that after some 32 months of heavy engineering construction work in, under and around Brisbane's inner city, LBBJV was compliant with all the CoG conditions and only incurred two minor breaches from Brisbane City Council's local laws for small quantities of lightly sedimented water going down street side drains.

Through the CEMP and integrating sustainable thinking and practices into the wider project team, the Project shaped a number of innovations and exceeded environmental expectations in several areas.

For example, in response to Brisbane's severe drought, LBBJV decided to make the Project self sufficient for construction water, which meant it would operate its construction activities without drawing from Brisbane's drinking water supply. Following an extensive investigation, LBBJV implemented an innovative water management system that included the following infrastructure:

- Two reverse osmosis water treatment plants – one supplying the precast concrete plant and the other supplying the TBMs, which drew water from Enoggera Creek, treated it to remove salt and discharged the brine through a long pipeline along the route of the ICB to the Brisbane River;
- Seven ultra filtration water treatment modules which produced general construction water, wash water and water for dust suppression;

- 55km of pipework to provide treated water to the tunnel and surface sites as well as return water to the plants for treatment before re-use; and
- 40 water tanks for capture of run-off water, stormwater and to act as holding tanks for treated water with combined storage capacity of 5ML.

A dedicated team comprising five water treatment operators, five fitters, an electrician and a water engineer, all supervised by a Water Systems Manager, were required to operate and maintain the water management system. Following a series of trials, optimum levels of output were achieved both in terms of quality and consistency.

Another area where the Project exceeded expectations was in the management of noise and vibration. Due to the proximity of the tunnel to high density inner-city business and residential areas, 24 hour, 7 days-a-week tunnel activity had the potential to cause significant impacts to the community. The risk was that to manage the impacts, the operating times for the TBMs and roadheaders in some areas might need to be restricted, thereby impacting the overall program.

The team's approach to this was methodical and thorough and included:

- Predicting noise and vibration from tunnelling using historical data from other projects;
- Verifying the predicted impacts by gathering noise and vibration data early on when the TBMs were somewhat remote from properties;
- Developing a predictive model based on the collected data;
- Continually monitoring and verifying the predicted impacts via a real-time noise and vibration monitoring system utilising modem-connected equipment with a web-based interface;
- Communicating the predicted timing, duration and the affect of impacts from tunnelling reliably and accurately to residents and businesses, based on the wealth of gathered data; and
- Developing and implementing a solid plan to respond to the social impacts of tunnelling activities, which included a ready-to-go suite of expedient solutions so that community issues could be efficiently and effectively responded to and thereby minimising the risk of delay to tunnelling.

Refer also to Section 2.3 - Environment and Section 3.6 - Environmental Management Leadership


Keeping the community informed was a priority

Respecting the community

1.6 Stakeholder Satisfaction

LBBJV worked in a transparent, practical and cooperative way with all stakeholders, believing that a reasonable and sustainable approach to stakeholder issues would provide the best outcome all round. This philosophy proved correct and served the Project well; LBBJV built stakeholder trust and confidence, which in turn lead to a constructive environment to effectively communicate and work with stakeholders and to resolve any issues.

The breadth of stakeholders was considerable and included:

- Clients - RCM and Council, including the Lord Mayor, Campbell Newman, who took a close personal interest in the Project;
- Operations and Maintenance Contractor, BMS;
- Immediate community in proximity to construction sites;
- Travelling public who were potentially affected by traffic changes;
- Broader community across Brisbane who were interested in the massive engineering feat occurring in their city and the legacy it would leave;
- Authorities whose assets were affected by construction of the tunnel, including DTMR, Queensland Rail and all the service utilities, including Energex, Telstra, Origin Energy (gas) and Brisbane Water; and
- Government and regulatory authorities, including EPA and Emergency Services.

The Project's biggest stakeholder group was the community. The dedicated Community Relations Team worked tirelessly to build effective and open relationships with local communities and key community representatives and groups to enable the smooth delivery of the Project.

The project worked closely with the Queensland Fire & Rescue Service

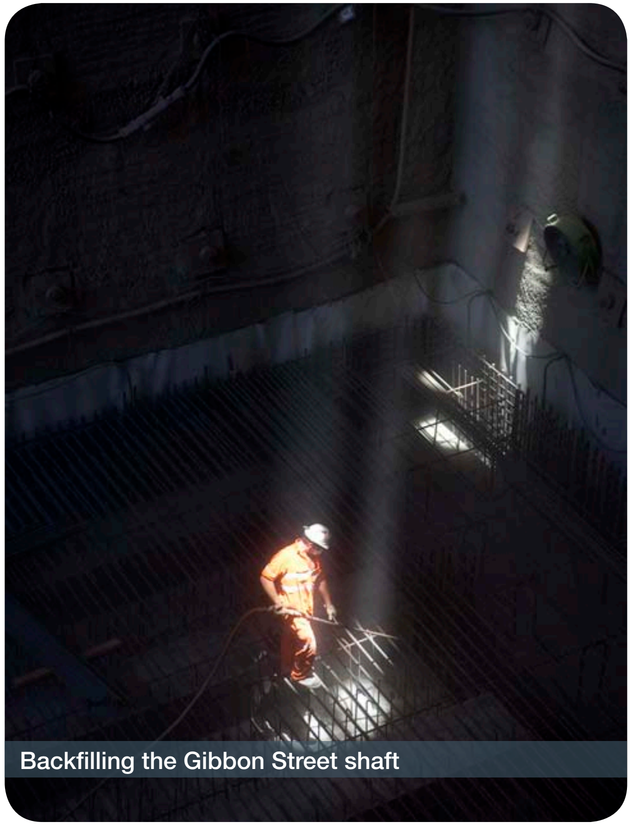
By involving the community in every step of construction, the team was not only able to keep impacted locals well informed and up to date, but was also able to make them feel like part of the overall success of the Project.

Towards the end of the Project in 2009, LBBJV undertook an assessment of the effectiveness of the community engagement activities through an external survey and from data based on communication records gathered during the Project, including:

- Community relations database of community interactions;
- Feedback forms;
- Tunnelling consultation review documents;
- Council evaluation of LBBJV six monthly compliance report; and
- Media news clippings.

An impressive 90% of survey respondents agreed that inconvenience was minimised as a result of the open, honest and regular consultation approach adopted. The survey also indicated a very high satisfaction rate with the information tools used throughout the Project in terms of accuracy of information, relevance, language and timeliness. The external survey and evaluation exercises also indicated that, on the whole, the Community Relations Team built strong relationships with the surrounding community which consequently lessened the impact of construction. In particular the community's high satisfaction with the response and timeliness to individual issues and the high quality of information the community received were key indicators of a successful engagement program.

TBM breakthrough at Shafston Avenue



Backfilling the Gibbon Street shaft

From the Client's perspective, this was an extremely well organised, well implemented project that delivered an excellent piece of major infrastructure with minimal internal and external issues. LBBJV's professional and collaborative approach meant the Client did not have to waste time and energy dealing with avoidable distractions or vexing commercial or contractual issues.

The success of the Project from the Client's perspective is summed up by RCM's CEO, Flan Cleary:

"This was a very complex contract, constructing twin tunnels 4.8km long, 60m under the Brisbane River, and to:

- *Complete seven months early;*
- *End up with only minor cost change arising from Council requested modifications;*
- *have no contractual claims on completion;*
- *Complete the largest road tunnel in Australia with negligible defects; and*
- *maintain excellent community relations during the contract period, was an incredible achievement.*

As the client for the Design and Construction contract, RCM can only congratulate LBBJV for the way the work was managed, the technical competence of the construction team, the attitude of working together with all parties and to the final outcomes that were achieved.

Despite the fixed price / fixed time nature of the contract, communications between Council / RCM / LBBJV and the Independent Verifier were conducted in an open and frank manner. When there were issues, as there inevitability were, these were discussed, robustly if necessary, and resolved. Excellent communication and timely resolution were one of the key factors in achieving the project outcomes listed above.

This is one of those projects where all parties can look back with great pride at what has been achieved."

Another key stakeholder was BMS, the CLEM7's Operations and Maintenance Contractor, who was represented on the Project from a very early stage. LBBJV had robust dialogue with BMS through all stages from design development through to construction to ensure operational risks were fully understood and addressed in the design, and to deliver value on a whole-of-life basis.

For example, services within the dedicated cable tunnel underneath the roadway were eliminated following a risk analysis conducted jointly by LBBJV and BMS.

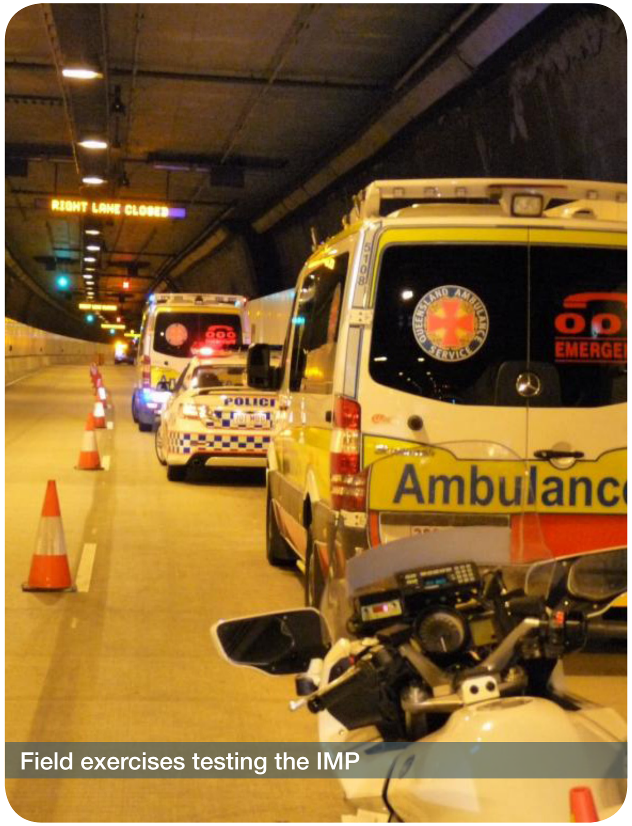
Having established that the cable tunnel could operate safely without these services, their elimination significantly reduced the regularity and scope of maintenance inspections in the cable tunnels and delivered associated capital and operational cost savings.

Another example of a design initiative providing stakeholder benefits is the tunnel ventilation system which utilises extraction through the smoke duct and smoke fans during times of high congestion to provide air exchange at the Shafston Avenue ramps (i.e. polluted air is drawn off via the smoke duct at Shafston Avenue merge/diverge locations and replaced with additional air drawn through the Shafston Avenue ramps into the mainline tunnel). This initiative minimised the number and size of in-tunnel jet fans and negated the potential requirement for a third ventilation station, and any increase in tunnel cross section, again realising whole-of-life savings.

Brisbane's two traffic authorities - DTMR for the Pacific Motorway and Council for all other roads - had a major stake in the Project. The sheer number and significance of the traffic changes required to build the CLEM7 was unprecedented in Brisbane.

For both authorities, having a private contractor (LBBJV) effect so much change across the inner city traffic network was unfamiliar territory, taking them outside their normal processes and introducing risks with which they were uncomfortable. LBBJV worked closely with each authority to develop an acceptable assessment and approval process for traffic changes. Initially the agreed process was cumbersome, however, as LBBJV demonstrated their reliability and responsiveness, the authorities' confidence grew in LBBJV's ability and the processes it had developed, and they became more flexible and entrusted LBBJV with more responsibility. During the Project there were no significant traffic issues, despite LBBJV implementing hundreds of traffic switches.

As the first major tunnel project in Brisbane, LBBJV had to take a pioneering lead in working with Queensland Emergency Services agencies, including Queensland Fire and Rescue Service, Queensland Police and Queensland Ambulance in developing the fire and life safety systems and operational plans for the tunnel. LBBJV developed the Operational Incident Management Plan (IMP) for the motorway, working closely with BMS and Emergency Services agencies.



Field exercises testing the IMP

LBBJV also prepared and successfully ran comprehensive desktop and field exercises to test the IMP prior to opening the tunnel to traffic. The Queensland Fire and Rescue Service were sufficiently impressed with the CLEM7 IMP that they want to replicate its scope, format and contents on future tunnel projects in Brisbane.

2. Complexity, Difficulty and Optimisation of the Construction Task

2.1 Magnitude of Task, including Logistics, Interface and Constraints

The CLEM7 is one of the largest and most complex infrastructure projects ever undertaken in Australia. The Project involved technically complex solutions to diverse engineering challenges, detailed logistical planning and management of the many interface issues presented by the massive scale of the Project in its constrained inner city location. The project team showed great skill in finding innovative engineering solutions to the many challenges encountered, all the time managing the diverse and sometimes conflicting issues presented by multiple worksites, safety, geology, traffic, quality, cost, time, community and environmental considerations.

The CLEM7 is one of the largest and most complex infrastructure projects ever undertaken in Australia.

LBBJV was awarded the Contractor Excellence award for the CLEM7 at Infrastructure Partnership Australia's 2010 National Infrastructure Awards.

"The 6.8km tunnel is one of the largest and most complex road projects in Queensland's history" said IPA executive director Brendan Lyon. "Leighton Contractors and Baulderstone have been recognised for their excellent design and delivery of this complex project ahead of time".

Patron Saint of tunnels St Barbara

Tunnel Excavation and Civil Fitout

Two TBMs and 10 roadheaders excavated 3.5 million tonnes of rock and lined over 11km of tunnels and ramps in 26 months. At the time of the tunnel's construction, the TBMs, affectionately named Matilda and Florence, were the biggest diameter hard rock double shield TBMs ever to have operated anywhere in the world, each measuring 12.4m high, 260m long and weighing 4,000 tonnes at a cost of $50 million each. LBBJV's decision to use two TBMs was a critical factor in our ability to deliver the Project seven months early.

The TBMs excavated those sections of mainline tunnel that have a uniform cross section (approximately 8km of tunnel). Those sections involving tunnel widening for merges, diverges or curve widening for sight distance purposes were excavated and supported using conventional tunnelling techniques, which in this case involved roadheaders. The roadheader-excavated sections of tunnel had to be accessed, excavated and supported in advance of the TBMs' arrival to allow the machines to traverse through the roadheader section to continue. It was therefore fundamental to the Project's early delivery to get the interface between roadheader and TBM tunnel sections right, both technically and from a programming perspective, as any delay to the TBMs meant a delay to the tunnel opening date.

LBBJV contracted German company Herrenknecht to supply the TBMs, which were purpose-built according to specific geological conditions of the tunnel route. The machines were manufactured and tested in Schwanau, Germany, then disassembled and shipped to Brisbane for reassembly.

The TBMs simultaneously excavated the rock and placed precast concrete segments to make the permanent, water-tight lining of the tunnel. They also placed 3,742 precast box concrete culverts to create the cable tunnel underneath each road surface making the machines, literally, a moving factory.

Requiring a crew of 22 workers per shift, the TBMs, during peak production, averaged approximately 15m per day with the best day's production being 34m.

Encountering water in rock features that connected to the Brisbane River posed a risk of flooding the tunnel. To address this, we maintained two probe holes in front of the TBM excavation face to identify water-bearing geological features, which could then be grouted at high pressure ahead of the face. To further minimise disturbance, the TBM was operated in single shield mode through sensitive areas.

Matilda starts her journey

In the roadheader sections, approximately 23,000 rockbolts and nearly 100,000m^2 of waterproofing were installed and 54,000m^3 of shotcrete were applied.

Progressively as TBM excavation and lining was completed, the cross passages and substations were excavated between the two mainline tunnels using the roadheaders. After excavation, the cross passages and substations were water proofed, concreted and fitted out with permanent fixtures.

DUTTON PARK
Boggo Road Gaol
Park Rd Railway Station
SOUTH BRISBANE
QUT
BRISBANE CITY
SPRING HILL
HERSTON
Royal Brisbane Hospital
WINDSOR
WOOLLOONGABBA
Captain Cook Bridge
Brisbane Botanic Gardens
BRISBANE RIVER
Princess Alexandra Hospital
Armstrong Holden
Mount Olivet Hospital
Story Bridge
RNA Exhibition Grounds
Mayne Rail Yard
Brisbane Cricket Ground (GABBA)
KANGAROO POINT
FORTITUDE VALLEY
BOWEN HILLS
Buranda Railway Station
EAST BRISBANE
NEWFARM
NEWSTEAD
LEGEND
SURFACE WORKS AREA
TROUGH STRUCTURE
CUT AND COVER TUNNEL
ROAD HEADER EXCAVATED DRIVEN TUNNEL
TBM EXCAVATED DRIVEN TUNNEL
TBM WITH INITIAL ROAD HEADER
CROSS PASSAGE
BRIDGE STRUCTURE
MEDIAN ISLAND
VENTILATION TUNNEL/SMOKE DUCT
RIVERCITY MOTORWAY
LBB JV
Dedicated to a better Brisbane
Disclaimer:
THIS IS A CONCEPT DRAWING, AS OF 27/07/06, AND SUBJECT TO CHANGE DURING THE DETAILED DESIGN PROCESS.


T2
T3
T4
A
B
C
D
E
F
G
H
I
K
L
M
N
T1
VIEW T1
SECTION T2
SECTION T3
SECTION T4
SECTION A
SECTION B
SECTION C
SECTION D
SECTION E
SECTION F
SECTION G
SECTION H
SECTION I
SECTION K
SECTION L
SECTION M
SECTION N
NOMINAL CROSS SECTION

With so much concurrent activity in the tunnel, managing safety, logistics and interfaces was a continual challenge. For example, in order to create a window in the program to excavate the cross passages and substations, LBBJV set up different working patterns for the TBMs, with the northbound TBM on a 5.5-day roster and the southbound TBM on a 7-day roster. This allowed roadheader excavation of the cross passages and substations to occur on weekends from the northbound tube, which would not have been possible during the week, when unimpeded access was required for the almost continual delivery of materials to the TBM workfront.

After the TBMs broke through at Gibbon Street our challenge was to disassemble and remove them as quickly as possible to open up construction access to the tunnels from Gibbon Street. The disassembly was programmed to be completed in 11 weeks per machine, however LBBJV came up with a plan to demobilise both machines concurrently and hence both machines were demobilised in just 14 weeks. The disassembly activities were split between the front and the back of the machines and included 150 over-sized and over-weight truck movements.

CLEM7 is the first project in Australia to use two large double shield TBMs driving simultaneously through hard rock, with a compressive strength of over 100MPa.

Preparing for Construction

Significant temporary infrastructure was required before any tunnelling could begin, including site facilities, shafts, tunnel portal and shaft enclosure buildings, road closures, service relocations, widening and more. Space was at a premium at each site and where possible existing buildings were used as offices and crib facilities.

In preparation for tunnelling two access shafts were excavated, one at Kangaroo Point and one at Gibbon Street, Woolloongabba. Roadheaders and other equipment were lowered down these shafts to excavate from multiple points along the tunnel route simultaneously. Both access shafts were back filled at the end of construction.

Drill and blast methods were used to expose the tunnel face and create the northern entry and exit portals, with 75,000m^3 of rock being excavated before the roadheaders started the northern drive in preparation for the TBMs' arrival on-site.

LBBJV took the initiative of erecting sheds over the three tunnelling worksites to minimise noise, dust and light impacts. These custom-designed sheds were double clad and fitted with acoustic panels. The largest of these sheds cost $8 million and was located at the main (TBM) tunnelling site at the northern portal. It measured approximately 120m long, 95m wide and 17m high and took four months to construct.


Precast factory


Spoil handling conveyor belt


Spoil handling silos and water treatment plant

The shed was the hub for the removal of over three million tonnes of excavated material, delivery and handling of 38,000 precast box culverts, almost 4,000 precast box sections, 45km of water mains, 119 jet fans, almost 2,000 lights and all the people, plant and other materials for the temporary and permanent works.

Supporting Tunnel Activities

Tunnel excavation and fitout activities required continuous delivery of materials to maintain peak production, requiring detailed planning to ensure sufficient materials were ordered, delivered to their relevant staging area and on to the relevant “coal face” on time to avoid program delays. Adding to the complexities of this task was the very congested nature of the TBM tunnel site.

The laydown area was confined to a small footprint within the tunnel shed, which meant there was minimal on-site room to store precast segments and other materials required to feed the TBM production chain. Therefore the team had to run the deliveries on a just-in-time basis, with a buffer of only two days of TBM production stored at the shed.

A $20 million state-of-the-art factory was purpose-built to manufacture the precast concrete segments to line the tunnel. Heritage-listed hangars from Brisbane’s former airport and a new purpose-built factory were used to house robotic and automatic welding machines, a production carousel and heat curing system, as well as the concrete batching plant.

Eight segments and one keystone fit together to form a complete ring of tunnel lining. Each segment is 40cm thick, 4.5m long, 2m wide and weighs approximately 8.5 tonnes. In total, 38,000 segments were manufactured at the factory with each having to be within a tolerance of just 0.3 of a millimetre.

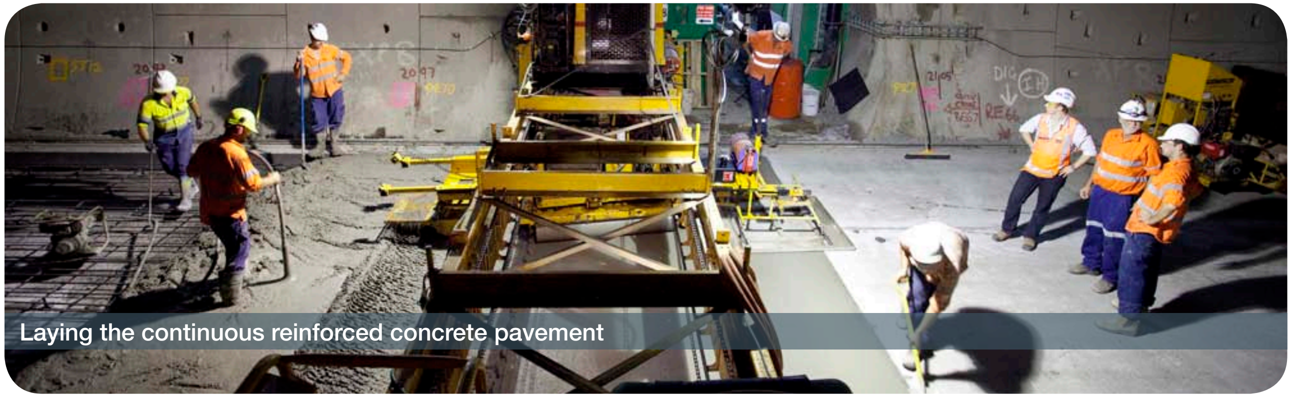
All rock excavated by the TBMs was transported to the spoil handling facility via a conveyor belt system continuously feeding out from the back of the TBMs. Each time the machines moved forward, another belt section was added ending up with two conveyor belts, each over 4.8km long. There were two silos, one for each machine, which could hold 10,000 tonnes of spoil each, enabling the spoil to be stockpiled during periods when haulage was not permitted. Haulage trucks ran 24 hours, 6 days-a-week excluding morning and afternoon peaks.

The trucks were loaded within the spoil handling facility and driven to the old Brisbane Airport site where the spoil was re-used in a development by the Australian Trade Coast Corporation.

Each tunnelling worksite housed its own workshop and store area. The workshop had a dedicated team of mechanics and electricians responsible for keeping equipment readily available and in service. Equipment included the Terberg trucks (specialised push/pull trucks with semi trailers), which were used within the tunnel to deliver materials to feed TBM production, including the pre-cast concrete segments and box culverts for the cable tunnel, pea gravel and secondary grout.

Civil Fitout

As the TBMs progressed, leaving a fully lined tunnel behind them, civil fitout activities commenced immediately. The first activity was construction of the smoke ducts, constructed using a purpose-built travelling formwork system operating 24 hours, 7 days-a-week in both tunnels. A formwork table was erected, the corbels were then reinforced and concrete poured then the smoke duct reinforcing steel was laid and the concrete slab was poured. Once the slab was cured the formwork table was moved to the end of the slab and the cycle repeated.


Laying the continuous reinforced concrete pavement

There were 28 separate 6m formwork tables used in each tunnel simultaneously and the concrete was poured at a rate of 126m per week per tunnel. Other major civil fitout activities included cast in-situ concrete lining and blockwork for the five underground substations, two low point sumps and 41 cross passages (delivered at a rate of one cross passage per week).

One of the last major activities was laying the continuous reinforced concreted pavement (CRCP). The pavement was laid at a rate of 180m per day on continuous night shift to ensure surety of concrete delivery using a GOMACO cylinder finishing machine. Steel reinforcing was placed by a mobile jig during the day while the 9.5km of paving was completed at night in four months and achieved or bettered the specified 40 bump count.

Slip form concrete traffic barriers and architectural panels were then installed down each side of the tunnels, achieving a peak rate of 1.2km of architectural panels per week.

Mechanical and Electrical Fitout

LBBJV awarded the contract for the M&E fitout to United. LBBJV had a dedicated team of mechanical and electrical experts overseeing United's work in every aspect.

Before excavation had finished a team of more than 200 people had started installing the 119 jet fans, close to 2,000 lights, 165 emergency phones, over 200km of cabling and some 45km of fire water main needed in the tunnel. The M&E installation team, which peaked at 350, worked around the clock installing cable and progressively fitting out the tunnel, commissioning sections one by one and bringing them online.

The result is a tunnel with world leading fire and life safety systems that operates in a practical, efficient and safe way to meet the specific operational requirements of the local emergency services agencies.

One of the earliest tasks was working closely with the State's energy provider, Energex, to ensure that major changes required to their network were designed and constructed in time for tunnel energisation and commissioning activities. Energex's work involved providing two high voltage 33kV supplies to the Project from completely independent sources within the network - one coming into the Project at a surface substation in the north and another at a surface substation in the south.

Operational fire and life safety risks were a key focus for the project team, the Client and the authorities. LBBJV brought together an experienced team in all areas of fire and life safety, from design, construction, testing and commissioning through to preparation of operational plans. The project team worked closely over several years with all emergency service agencies to develop the design and then the operational Incident Management Plan for the CLEM7. The result is a tunnel with world leading fire and life safety systems that operates in a practical, efficient and safe way to meet the specific operational requirements of the local emergency services agencies.

Tolling

LBBJV went out to tender for the design, supply and installation of the roadside tolling system, awarding the contract to Swedish company Kapsch TrafficCom.

The split of scope of the tolling system saw LBBJV responsible for the roadside system, while RCM was responsible for the back office system, including all processing and payment of tolls and toll evasion handling. This split introduced an interface risk that was mitigated by paying enormous attention to specifying and coordinating the interface between the two systems and was partially solved by LBBJV working closely with RCM in an alliance style atmosphere that saw RCM also appointing Kapsch to deliver the back office system.

LBBJV's delivery of the roadside system was particularly challenging due to the location of the tolling point under the northern portal canopy. This location required an unprecedented level of technical coordination of all the elements in this area, including the transitional lane configuration, with three lanes merging to two under the toll point, the portal canopy and the high density of installed mechanical and electrical equipment, including architectural and transitional lighting.

Construction of the Northern Portal canopy

Northern bridge construction

Notwithstanding all these technical and interface challenges, the tolling system was commissioned without incident and at tollroad opening was fully functional with no teething problems – a rare achievement. This stands as a credit to the meticulous planning and coordination of the diverse works in the portal area and the thorough approach to the design and commissioning of the tolling system.

Surface Works

Generally the design and staging of the surface works was reviewed to reduce the dependencies between work areas as much as possible, which reduced potential delays due to interface issues. All works in the existing road network were carried out under live traffic conditions, therefore requiring more detailed planning than usual and increasing the safety risk to workers and the community.

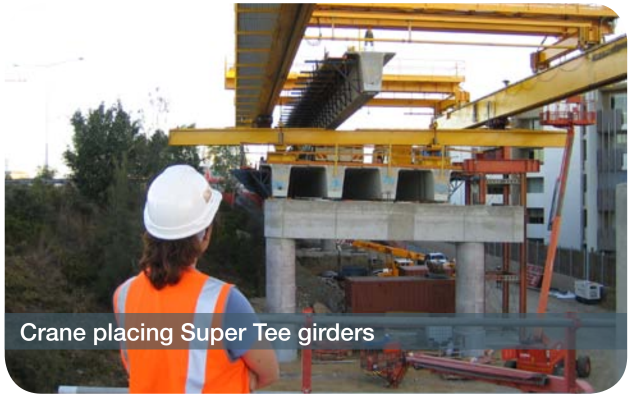
The Northern Surface Works site presented a highly complex challenge from a logistics and interface perspective. Within this area was a large scope of work with incredible diversity – including the main temporary tunnel and support works, portal excavation and fitout, four buildings, major civil road works and 2.3km of bridges as part of a three level interchange. Significantly, the site was also the location from which the 260m long TBMs were assembled and launched, and subsequently the main access for 24 hour tunnelling, including materials delivery and storage. Responsibility for the works in the northern site spanned across four Construction Teams, so to ensure effective management of the site as a whole, one team – the Northern Surface Works Team – was given overall responsibility, including site establishment and all tunnel temporary works.

This decision proved invaluable over the Project's life because a clear delineation of authority enabled short communication paths between the four teams and simplified the best-for-project decision making process for the Project Director.

The canopy portals, which were designed by Edaw AECOM, are one of CLEM7's "signature" urban design elements. Each canopy is a one-of-a-kind structure with each piece of steelwork, roof and ceiling being unique – they were put together like a giant jigsaw puzzle. Between the three canopies there are over 4,300 unique pieces and 390 tonnes of steelwork.

The Northern Bridges Team had the challenge of building a highly complex, multi-level bridge interchange, which sat above the Northern Surface Works site and was bordered by the 80kph ICB, the sensitive ecosystem of Enoggera Creek and the busy Mayne Railway Yard. With nearly 300 Super Tee girders required to build the northern bridges, securing their timely supply was key to the success of this part of the Project.

The peak of construction activities led to a shortage of skilled labour and materials like fly ash and stressing strands during early 2008 and required constant close monitoring of the actual construction progress and priori tisation of the critical path items for Super Tees across the Project.



Crane placing Super Tee girders

LBBJV ensured supply of on average four Super Tee girders per week to meet program by providing increased supervision and support of the precast company supplying the Super Tee girders. LBBJV applied creative ideas like redirecting supplies from LBBJV to the supplier or resetting an existing mould to allow casting of two deeper girders simultaneously, as well as financing and resourcing this modification, which allowing the supplier to maintain production and satisfy the delivery program.

The team had to develop clever construction methodologies that eliminated or minimised the need to close lanes of the ICB. For example, the bridge span across the ICB was constructed during a single 36-hour-weekend full closure, during which the girders and hoarding were erected. The remainder of the works to complete this span were carried out over traffic using the launching gantry.

The Northern Bridges Team had to construct two of the new bridges early on to create a direct access from the site to the ICB. The connection made clever use of the permanent works in securing a 24 hour spoil haulage route that eliminated the need to use local roads and provided a better solution for the community.

The early delivery of these two bridges required completion of one full span per week on average (after the initial substructure construction and learning curve considerations). This aggressive program was made more difficult because both bridges were over the Queensland Rail Mayne Yard and the works had to be done under track closures. The productivity level of one span per week was then maintained throughout construction of the northern bridges until their completion.

All southern surface works were carried out in an extremely tight corridor bounded by traffic, residents and businesses. Traffic management was particularly critical because we had to ensure minimum impact on the key arterial connections to the Brisbane CBD from the south (Pacific Motorway and Ipswich Road) and east (Shafston Avenue which connects to Lytton Road and Wynnum Road).

Generally, full traffic capacity had to be maintained on these arterials during daytime hours. Temporary traffic closures were permitted at night which enabled changes to traffic staging and completion of works during these short term closures. In addition, the Cleveland Rail Line ran through the site, adding a further significant constraint.

These constraints challenged us to come up with innovative design solutions and construction methodologies, including for example:

- Constructing the Pacific Motorway bridge over the Cleveland Rail Line mostly out of precast elements, allowing the bridge to be mainly assembled over a single weekend railway shutdown; and
- Devising a temporary support structure and demolition method for an existing footbridge over the Pacific Motorway to complete the task in a single 6 hour overnight full closure of the motorway.

The Southern Surface Works involved installation of a culvert in the railway embankment of the Cleveland Railway Line, immediately adjacent to the Ipswich Road Bridge to create a new pedestrian passage.

The culvert installation involved a weekend shutdown of the railway line, removal of a section of the railway line, excavation down to approximately 4m, installation of the culvert, backfill and then reinstatement of the railway line prior to the Monday morning rush hour. This event occurred like clockwork due to excellent planning by the Southern Works Team.

Traffic

Significant and ongoing traffic changes were required on a daily basis to enable the surface works to be built. Traffic switches were the pivot point for construction programs, with major work scopes being delineated by traffic staging and traffic switch dates set as crucial milestones. No changes to roads or footpaths could be undertaken without approval from the relevant road authority, requiring submission of detailed traffic plans, which included:

- Justification of the traffic change by demonstrating that the traffic staging and construction methodologies had been optimised to minimise traffic impacts; and
- Modelling demonstrating that the traffic impacts of the proposed changes were not going to cause impacts to traffic flow and capacity.

Over 130 comprehensive Traffic Control Plans, in excess of 500 traffic switches and over 1,600 traffic permits were required across the Project. A dedicated Traffic Team managed this huge task, working closely with each area Construction Team.

LBBJV was responsible for operation and maintenance of the roads within the Licensed Construction Area, including the major arterials. We installed five CCTV cameras at key points to facilitate monitoring of the roads, with feeds back to a monitor in the Traffic Manager’s office.

Public Utility Plant Relocations

Forty major PUP relocations had to be carried out as part of the CLEM7 works, while many others had to be located and protected during the works. All relocations had to be completed either before works commenced in an area or coincident with works in the area, which meant programming and timely execution of these relocations was paramount. LBBJV appointed a dedicated PUP Team to manage the design and utility authority approvals process, after which the construction task was handed over to the area Construction Teams. The PUP and area Construction Teams worked together closely to ensure scope, constraints and timing were well understood and to communicate all authority requirements.

All relocations were completed without adversely impacting the construction works program and to the satisfaction of the utility authorities.

2.2 Community

It was acknowledged from the outset that four years of construction, at numerous sites across the city, surrounded by thousands of residents, businesses and motorists, could not be achieved without impacts to the natural, cultural and urban environment. In response, Council started a widespread public awareness campaign prior to the award of the contract and recognised that it was vitally important that the winning tenderer carry on and expand this communication program and respond appropriately to the needs of the community.

Weekly, and later fortnightly, meetings occurred with the Project Director, Deputy Project Director, Interface Manager, Community Relations Manager and Environment Manager to discuss issues in the public domain and ensure they were effectively and appropriately managed.

Four years of Ekka displays

The visitors centre


Royal Children's Hospital School art

All community considerations were incorporated into a Community Engagement Plan, which detailed the following key tools:

- Advance personal warning system for TBM activity to affected residents, who were door knocked, phone called and/or notified by letter;
- Community notices distributed to targeted residents and businesses regarding upcoming works and their potential impacts;
- Construction updates distributed every three months along the alignment;
- A project website containing interactive maps, construction information, community notices and a tunnelling progress map;
- Information sessions held prior to major activities;
- A 24 hour, 7 days-a-week freecall number for public inquiries or complaints;
- A complaint and issues procedure and database;
- A Project Visitor Education Centre open to the general public and school groups;
- Two Community Liaison Groups;
- Newspaper advertisements to advise of upcoming construction activities and traffic changes;
- Information boards placed at key locations across the Project to inform the public of the local project plans;
- A schools program, involving local children and those attending the Royal Childrens Hospital School; and
- Various charity initiatives.

The Community Relations Team was well resourced and had sound procedures in place to implement the Community Engagement Plan. Four site coordinators (CRCs) managed stakeholder issues at a site level and formed strong bonds with both the project team and the community. The CRCs spent half their working week on site understanding the programs and methodologies and ensuring the lines of communication with the Construction Team were always open, enabling them to understand what community impacts were coming up and proactively manage them.

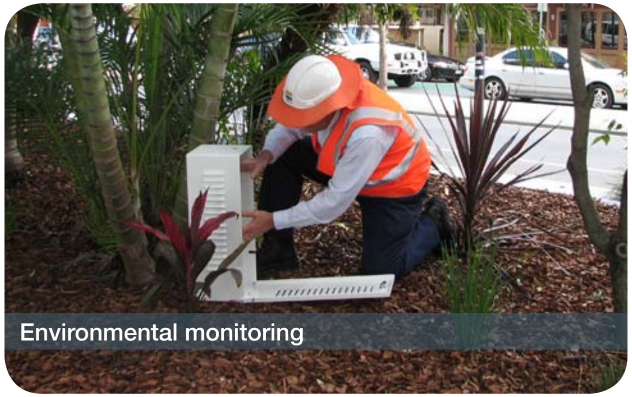
One of LBBJV's main aims was to build the Project without reducing the standards or daily living patterns of the surrounding community. This required an individual and ongoing engagement approach in order to better understand what those patterns were and how to mitigate accordingly. It was important to identify these issues early and provide a solution, which could range from temporary relocation, change in work methods, acoustic treatment to a residence or work area or simply advance notification.

Generally, the CRC would develop relationships by door knocking or phone calls. If it was difficult to get in contact correspondence was posted inviting the individual to call the Project to discuss the work.

One of our most significant community achievements was operating the TBMs 24 hours-a-day in the heart of the city with minimal disruption to residents and businesses. This was mostly due to the personalised advance warning system we had in place, which not only provided targeted, effective and timely communication, but also demonstrated our steadfast commitment to and respect for the communities within which we were working. This consultation methodology was so successful and highly regarded by Council that it was made a mandatory requirement for the next Council-sponsored tunnel project, Northern Link.

Over 3,400 face-to-face consultations occurred over the life of the Project and hundreds of agreements were made with business owners and individuals.

LBBJV managed an unprecedented level of public access to a live construction site, with over 600 site visits/bus tours conducted.



Environmental monitoring

These visits, along with information sessions encouraged community participation and ownership. An Open Day in December 2007 was a particular success with over 4,000 people visiting the first TBM.

The end result of LBBJV's careful planning and implementation of a thoughtful and effective community engagement program was no major delays to the Project as a result of stakeholder dissatisfaction and a reduction in the number of complaints over the course of the Project.

2.3 Environment

The scope and scale of the environmental management task on the CLEM7 were significant and included:

- Noise and vibration from surface works;
- Surface noise from sites supporting 24 hour, 7 days-a-week tunnelling;

Noise monitoring

- Regenerated noise and vibration from 24 hour, 7 days-a-week tunnelling;
- Noise and lighting from night works required due to daytime traffic restrictions;
- Dust from surface works and tunnel support activities;
- Water management;
- Erosion and sediment control;
- Heritage, including heritage buildings and archaeological indigenous heritage;
- Flora, including construction on the banks of and across Enoggera Creek;
- Contaminated soils; and
- Dangerous goods storage and management.

The Project's work sites were located in proximity to high density residential, hospitals and business areas. The works were being delivered to an aggressive program, including a 24 hour, 7 days-a-week tunnel program, which left few options for respite if communities were affected by the environmental impacts. So the clear focus and energy was on up-front planning of the site layouts and site infrastructure, as well as the works themselves, to eliminate or minimise environmental impacts.

One excellent example of this is the team's innovative solution to managing potential noise and traffic congestion from the 24 hour spoil haulage operation from the main tunnelling site in the north. In order to eliminate the need for the spoil trucks to use local roads to access and egress the site, LBBJV came up with the concept of a temporary bridge connection, utilising the permanent new bridge structures to provide direct access between the site and the ICB.

Across the Project, night works were required when working on roads or near railways, which lead the team to investigate and implement portable noise barriers using a wave-bar noise control product.

This product was adapted for use over construction fencing to provide a noise barrier with the required surface density of 16kg/m^2. This product was also attached to the spoil silos to reduce noise from tunnel rock hitting the sides of steel silos.

Another example of the complexity of the environmental challenges and our success in optimising results is the team's achievement in preserving the mangroves lining Enoggera Creek at Bowen Hills. The multi-level interchange at the northern end of the tunnel necessitated multiple new crossings over Enoggera Creek. The challenge was to develop a method enabling construction of the new bridges and five drainage outlets within the sensitive tidal ecosystem of Enoggera Creek causing minimal disturbance to its mangrove community, bed and banks.

The solution involved limiting the number of access points through the mangroves for construction of the substructure and piling, and included:

- Using a self launching gantry to install the Super Tee girders, eliminating the need for big crawler cranes commonly used for this task;
- Using purpose-built temporary jetties, avoiding the use of an earthen or rock pad for bridge construction;
- Progressively launching the jetties from the previously constructed section, preventing additional construction work within the creek;
- Removing mangroves only if they directly conflicted with a jetty pile; and
- Surveying and marking the mangrove areas to be trimmed and cleared, and using a qualified arborist, who worked from a basket supported by cranes to prevent any damage to the aerial roots and avoid disturbance of the creek bank.

The result was that the impact on Enoggera Creek's bed was minimal and mangrove disturbance was reduced by 50% compared to using standard construction methodologies, with impact confined to one riverbank and to a footprint that was only marginally wider than the area impacted by the permanent structure. The Department of Primary Industries and Fisheries (DPIF) confirmed the exceptional nature of the work, stating, "DPIF has reviewed the results and considers the Project to be a case study of best practice works methods to which DPIF now refers in the assessment of similar proposals".

CLEM7 became the first major civil infrastructure project in Australia to be entirely self sufficient and reliant on recycled water, setting a new performance benchmark for major construction projects across Australia. One of the key benefits of the water management system was that, whilst it was implemented specifically for the CLEM7, it was designed in such a manner as to allow it to be easily transferred, replicated or adapted to other major civil infrastructure projects across Australia.

Refer also to Sections 1.5 - Environment and Sustainability Outcomes and 3.6 -Environmental Management Leadership.

2.4 Heritage

TBM vibration was a key focus throughout construction, particularly given the number of historic buildings and structures along the tunnel alignment – including in particular the Story Bridge, several buildings within the historic RNA showgrounds, and Leckhampton House and St Mary's Church, both at Kangaroo Point. Mitigation of vibration impacts was a priority, with the project team developing and implementing real-time noise and vibration monitoring systems.

Comprehensive condition surveys of over 1,000 heritage and non-heritage properties were carried out and a report prepared in each case, which documented any existing issues or damage, such as cracking. This was a massive task that had to be completed before construction works in each area could commence. Effective consultation with each property owner ensured they understood the purpose of the inspection and the process. In some instances, structural supports were provided at properties where it was considered vibration could have an effect.

Cultural Heritage Management Plans were developed by specialist heritage architects and engineers where any listed heritage property was predicted to receive greater than 2mm/s vibration. These management plans included detailed condition surveys, vibration and settlement monitoring protocols and corrective action mechanisms. The key was close consultation with the owners. The end result was that there was no damage to property and no delays to the Project.

The Environmental Impact Statement identified places of indigenous cultural heritage significance that could be impacted by construction. The Coordinator-General's Conditions required that there be ongoing liaison with the relevant native title claimants and that the Proponent, Council and indigenous groups consult on the issue. Accordingly, two committees were formed with representatives from each of the two native title claimants, Council and LBBJV. Indigenous representatives were on site as monitors whenever there was surface disturbance in the areas identified as being of potential significance. No items of interest were found during the Project.

2.5 Project Financing and Initiation

The CLEM7 was delivered via a Public-Private Partnership between RCM and Council, and was the first tollroad to be funded in partnership with a local council, with a debt facility of A$1,839 million and a contribution from Council of A$503 million. The total amount of the debt facility at the end of construction was A$1,336 million.

The debt was structured so that a contribution was not required from Council until completion of the tunnel's construction. This meant the construction project risk was entirely removed from Brisbane ratepayers and allocated to the project financiers, who were able to price the risk accordingly. A syndicate of 24 banks was formed to finance the debt.

An equity contribution was effected by way of an Initial Public Officer (IPO) where A$691 million was raised through the issue of 691 million securities in RCM. LBBJV provided a further equity contribution at the end of construction totalling A$155 million with an issue of an additional 155 million securities to LBBJV.

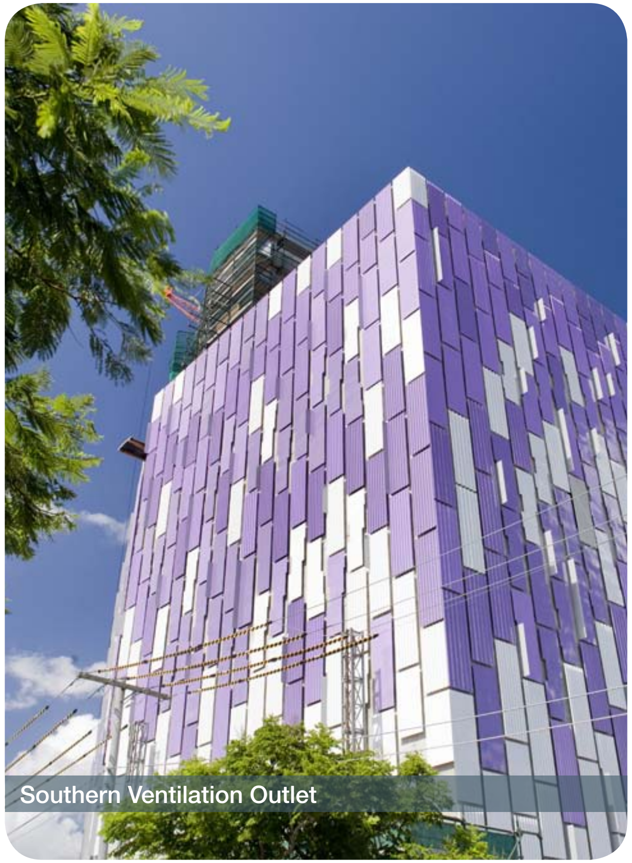
The financing structure incorporated a flexible financial arrangement that allowed for early completion, providing a strong incentive for LBBJV to complete the Project as early as possible.

During the tender phase LBBJV worked with Council, RCM and BMS to provide options for consideration, including more significant lane capacity, a variety of different tunnel wall and road pavement finishes and a number of additional tunnel entries and exits. Working hand in hand with RCM, LBBJV was instrumental in finalising a winning tender that reflected client feedback, incorporated a fully underwritten option that featured a totally new western entry and exit to the tunnel from the ICB and provided for significant additional noise barriers and landscaping on some of the approach roads to the Project.

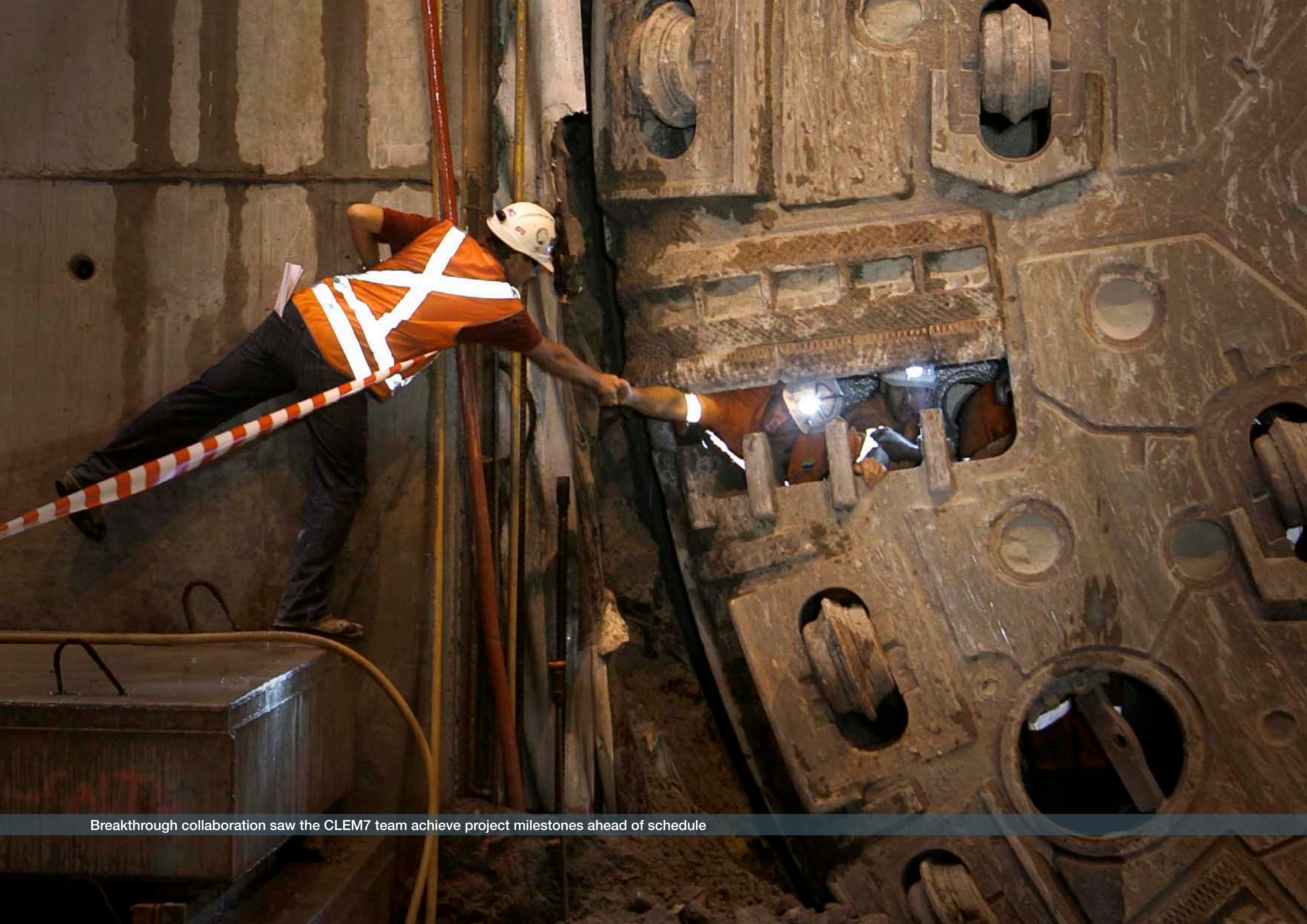
The Project represents a thoroughly integrated finance, design, development, operation, maintenance and delivery process, which drew on the strengths of all parties and stands as a testimony to the value of collaboration. A dedicated partnering approach involving Council, RCM, LBBJV and BMS saw cooperation in working through the financial close issues, including final environmental and planning approvals that were tailored to LBBJV's specific design.

The CLEM7 has won the following awards for its project financing achievements:

- 2006 PFI Award – Asian Infrastructure Deal of the Year;
- 2006 Finance Asia Achievement Awards – Best Project Finance Deal; and
- 2008 IPA National Infrastructure Award – Financial Excellence.



Southern Ventilation Outlet



Breakthrough collaboration saw the CLEM7 team achieve project milestones ahead of schedule

3. Leadership and Management of the Project Delivery

3.1 Project Team Relationships

The Project had a senior leadership team comprising the Project Director, Deputy Project Director and key senior managers. Sitting below this team was a staff of some 300 people organised in teams reporting to a member of the leadership team (refer organisation chart provided after Section 3).

In order to make construction manageable, the Project was split into seven areas of delivery, which was equivalent to seven $300 million jobs running simultaneously. This created sensible-sized projects for our Project Managers to run, both from a technical and a commercial perspective. Each of the seven areas of delivery was run as an autonomous project and there was a healthy competitiveness between the Project Managers to achieve deadlines and budgets.

However, equally there was a strong sense of the greater LBBJV team and its collective achievements, demonstrated by the high level of interface management and cooperation to push progress forward each day. As well as working closely together on planning and coordination, the various teams shared resources including staff, labour, contractors and suppliers on a “best-for-project” basis and exchanged ideas and methodologies.

The Construction Director delegated management of key suppliers and subcontractors working across the Project to individual Construction or Project Managers. This ensured that suppliers had one key representative to deal with and that issues were dealt with in a consistent and timely manner.

A key interface for each of the seven Construction Teams was with the functional teams, including the Design, Safety, Environment, Traffic, PUP, Community, Quality and Commercial and Administration Teams. In general, representatives from the functional teams were incorporated in each Construction Team to facilitate communication and the exchange of ideas between the construction and functional teams.

Project team relationships were mature and decisions were made on a “best-for-project” basis. Weekly coordination meetings helped facilitate coordination between the teams, as well as day-to-day interaction at all levels and across all teams.

The CLEM7 office a place of collective ideas

Central to the Project's success was the upfront decision to locate in one office, Council, RCM, LBBJV, lead designer AECOM Parsons Brinckerhoff, geotechnical consultants Golder, urban designers Edaw AECOM, M&E subcontractor United, the tunnel operator BMS and the IV. This achieved a collaborative working environment, ease of access to all parties, enhanced cooperation, effective communication and time-effective resolution of issues. To accommodate this large team, a five-floor project office was established in South Brisbane.

LBBJV chose to work in a highly collaborative arrangement with BMS, the operations and maintenance team contractor for over 12 months of intense preparations for the transition from construction to operation. LBBJV's aim was to ensure that, through being involved in site inspections, commissioning exercises and preparation of the operations and maintenance manual, BMS was well prepared for operating the motorway. As an example of the level of collaboration between the two organisations, BMS operators were incorporated into the D&C Commissioning Team. This initiative was positive for both parties, assisting LBBJV by providing additional resources during the peak of commissioning and providing BMS with extended time in the Control Room (beyond the planned training) to improve their operators' familiarity with the systems.

3.2 Innovations Generating a Legacy for the Construction Industry

The Project's challenges drove many innovations and firsts, examples of which are described below, as well as in Section 3.8 Use and Development of New Technologies.

International tunnelling projects have traditionally been delivered with excavation and civil works in one package followed by M&E fitout either at the completion of all fitout or as an entirely separate contract. However, in Australia the industry has taken a different approach by overlapping these activities, although the results of this have been mixed and the source of significant problems on most past tunnel projects.

One of the significant challenges of the scope overlap is the logistical separation of work activities whilst at all times maintaining the highest safety standards. To address the need for safe work activity separation, LBBJV came up with an innovative approach by designing purpose-built mobile work platforms that enabled the M&E fitout activities to progress overhead in the tunnel envelope proper whilst allowing unimpeded traffic flow beneath the ongoing activities.

The platforms achieved two main things:

- Safety – they eliminated the need for scissor lifts and other moveable work-at-height equipment for the bulk of the M&E installation. In particular, such equipment is notoriously dangerous in an enclosed, tight tunnel environment; and
- Work efficiency – they allowed the almost constant transportation of personnel and materials to proceed uninterrupted beneath the platform, while the M&E fitout proceeded overhead.

LBBJV put together the specification for the mobile work platforms and worked closely with a local fabricator to make a prototype before commissioning another eight – three in each tunnel for M&E activities and another two for civil fitout activities.

So successful was this innovation that it has now been adopted by the industry on subsequent tunnels as the standard modus operandi.

Another clever work separation solution that was instrumental in achieving early completion was the introduction of a cable tunnel. The cable tunnel was formed using prefabricated box culverts, laid on the floor of the TBM tunnel, all carried out as part of the TBM activities. This provided significant program advantages by allowing the major high voltage cable haulage activities to proceed in this dedicated space, rather than in the mainline tunnel, where it would have to be coordinated with the myriad of other activities occurring in that space.

LBBJV used progressive methodologies for assembling and commissioning the two giant TBMs at the northern portal. The assembly was carried out within a large, purpose-built shed using four gantry cranes, allowing the precision 24 hour, 7 days-a-week operation to be completed without any interruptions due weather, which often affects the use of large mobile cranes.

Using a concept developed by LBBJV working with the TBM supplier and a local transport company, a substantial portion of the TBM backup equipment was assembled off-site and then transported fully assembled – 11m wide and up to 85 tonnes in weight – over public roads to the portal. This initiative saved time during this critical stage of getting the TBMs ready for production.

CLEM7 was the first major tunnel project that was 100% self sufficient for water, utilising ultra-filtration modules and reverse osmosis plants. The technology used on the CLEM7 is portable and it is intended that the system will be reused either completely or in modular parts on future construction projects. This innovative water management system sets a new benchmark for alternative, self-sufficient water supply.

LBBJV's use of double shield TBMs in hard rock at this large diameter - hitherto not tried - has provided a significant step forward for the industry, enabling it to complete tunnel jobs faster and more safely and cost effectively in the future.

3.3 Entrant's Contribution to the Design Process

LBBJV contributed a number of key initiatives to the design, which provided safety benefits during construction and/or operations and maintenance phase, significant program benefits and substantial cost savings.

A number of these initiatives were introduced during the tender phase and contributed to LBBJV successfully winning the contract in a competitive tender process. Other design initiatives were part of a continuous improvement process during the design and construct delivery phase.

Tender Phase Design Initiatives

LBBJV substantially modified the Client's reference design at all three tunnel access points to capitalise on outcomes from traffic modelling, construction planning and Design Team review.

At the connection to Pacific Motorway and Ipswich Road the changes were primarily driven by:

- Construction safety, program and cost benefits realised through concentration of portal construction within a single area, effectively isolated from adjacent properties and roads, including the Pacific Motorway, allowing motorway traffic to be largely unhindered during construction;
- Minimised construction stage and operational stage impacts to the community by co-locating the Ipswich Road on- and off-ramps, thereby minimising their footprint and the extent of their impact;
- Program and cost benefits, which enabled the deletion of lane merge/diverge points from within driven tunnel sections; and
- User safety benefits realised through the provision of short two-lane connections with Ipswich Road in lieu of long in-tunnel single lane ramps.

At Shafston Avenue the northbound connection was substantially re-modelled to accommodate concerns with geotechnical risk and the tunnelling program. In the reference design the Shafston Avenue on-ramp was long in order to achieve the necessary vertical drop at an appropriate gradient prior to joining the main tunnel, which was at depth to go under the Brisbane River. LBBJV converted the northbound connection ramp to a loop arrangement, which enabled early access via a pilot tunnel for roadheaders to work multiple fronts, and connection to the main tunnel well away from a weak zone of rock.

The reference design assumed the use of a single TBM, with conventional roadheader or drill and blast methods identified for excavating the tunnels south from Shafston Avenue – a distance of more than 1,200m.

Through extensive planning, focussed on design changes, considered in concert with construction methodologies, LBBJV determined that using two TBMs would bring significant program benefits and therefore was able to demonstrate that the substantial upfront investment in two TBMs would more than cover itself through program benefits. In addition, maximising the use of TBMs for the tunnelling had huge safety benefits, as the chosen TBM excavation and lining methodology ensured that the tunnel workforce was continuously protected by the TBM shield until the permanent lining was erected.

TBMs also progress much faster than roadheaders, hence another significant benefit of LBBJV's tunnelling methodology was that duration of regenerated noise impacts was substantially reduced.

The construction planning team worked closely with designers to minimise the extent of the non-uniform sections of tunnel, where TBMs could not be used and therefore conventional (roadheader) tunnelling would be required. This was achieved through control of tunnel curvature to avoid sight distance-related widening, and maximising the extent of ramp connections in zones outside tunnels.

Post Tender Design Initiatives

Dedicated cable tunnels, which were formed using prefabricated box culverts, were introduced beneath the road surface in each tube to carry high voltage cables. The cable tunnels meant hauling and laying the main high voltage cables could be carried out in their own space, eliminating this M&E fitout activity from the busy main tunnel work front, with obvious safety and program advantages. Before LBBJV adopted the cable tunnel option the team had to work through various design, safety, and technical and construction feasibility issues.

For example, the cable tunnel posed a risk of differential settlement of the concrete road pavement because of the non-uniform support conditions resulting from the stiff culvert structure bounded on both sides by fill of lesser stiffness. A cement bound fill material was determined as suitable for the application, but the planned continuous pavement support construction methodology was not consistent with conventional cement treated gravel pavement construction, which requires a period for curing and strength gain without significant construction loading. In consultation with the design team, LBBJV conducted a series of laboratory trials to establish a technically robust and cost effective solution to the problem. The final solution involved the use of some 95,000 tonnes of crushed recycled concrete mixed with fly ash. This enabled continuous installation of backfill support with slow strength gain through reaction between the fly ash and available lime in the crushed concrete.

The cable tunnels were subsequently acknowledged by Queensland Fire and Rescue Service as a robust emergency egress route during tunnel construction.

LBBJV's tendered concrete pavement design envisioned the use of a conventional slip-form concrete paver to install the running lanes in a single pass, with separate pours required to install the concrete shoulders. The LBBJV team devised an alternative method to construct concrete pavements using a Gomaco Cylinder Finisher. This technique enabled completion of all pavement surfaces between barriers in a single pass, while saving in excess of 16km of dowelled joints that would have been required had the shoulders been separately poured.

During design development, the fire and life safety systems were enhanced to improve directional signage, lighting and alarms for public evacuating the tunnel during a fire. The enhancements resulted from a combination of international research of world's best practice, lessons learnt from local and international tunnel fires and an As Low As Reasonably Practicable (ALARP) study, which was used to confirm that the tunnel design provided the optimum fire and life safety system.

3.4 Planning and Control of Design and Construction Operations

LBBJV brought together an experienced team of expert designers from more than six companies to cover the diverse scope of the CLEM7's design. The design was carried out in 10 offices, over three continents, involving some 275 designers, presenting LBBJV with a challenging task to manage the complex interfaces between these specialist designers.

LBBJV's Design Management Team invested a lot of time and focus on the many interfaces between the various designers, authorities, approvers, community interests and the construction team. The LBBJV Design Director was accountable for management and delivery of approved "for construction" designs to ensure timely progression of procurement and construction. Effective design delivery required rigorous processes to ensure consistency and integration of each designer's work, safety during construction, safety, practicality and efficiency during operations and maintenance, and safety and convenience for motorists.

Other imperatives included recognition of environmental and community needs, and compliance with technical requirements set down by Council and affected authorities.

The integration and coordination of the design was handled well, with no on-site "surprises", all issues having been thoroughly considered and resolved during the detailed design process.

Design packages were reviewed by various stakeholders including the Client, the Project's Independent Verifier and the Operations and Maintenance Team, at key stages in the design process and a formal close out process was used to resolve comments raised.

A robust and well documented quality system accredited to ISO 9001 ensured that the detailed design was faithfully translated on-site through excellent quality planning and verification. The process involved:

- Preparation of detailed method statements and Inspection and Test Plans (ITP) to document how the works were to be constructed and verified, including safety and environmental requirements;
- Review by the independent QA engineer that all technical requirements of the contract and specifications had been identified and incorporated into the ITP;
- Selection of suppliers and subcontractors on the basis of their capability, followed up with inspections at suppliers' and fabricators' off-site facilities to ensure that the products being manufactured or constructed met the requirements of the specification prior to delivery;
- On-site inspections by site management, with the release of Hold Points at key stages of the work as defined in the ITP;
- Completion of thorough quality control records documenting all relevant construction data, including material test results and survey information;
- Regular and often joint on-site inspections by the Client, the Independent Verifier, QA Team representatives and LBBJV senior management;
- The thorough review and signing-off of each construction lot by the independent QA engineer to verify that all records were complete and demonstrated compliance with the design requirements; and
- Regular second and third party QA management system audits of the Project.

Planning and control of the specification and supply process for mechanical and electrical equipment for the CLEM7 drew on lessons learnt from previous projects in Australia to identify equipment that had been prone to unreliability or technical problems. The team used a risk-based approach, which included:

- Concentrated effort up front to ensure items with long lead times were researched well and ordered early;
- Identification of historical equipment problem areas and the root causes, as well as measures to avoid the same problems on CLEM7;
- Careful preparation of specifications to address and eliminate previously-identified problems;
- Investing in supply of high-quality and reliable brands;
- Fostering positive relationships with key suppliers; and
- An intensive Factory Acceptance Testing program to maximise confidence that delivered equipment would perform reliably and as intended once on-site.

Compatibility between underground space requirements for M&E installations and the actual civil design of those spaces was assured through:

- An interface agreement between relevant design parties confirming their obligations to cooperate and ensure compatibility under their respective consultancy agreements with LBBJV;
- Appointment of AECOM Parson's Brinckerhoff as the lead designer included the obligation to implement and manage a system to ensure ongoing checks were undertaken; and
- LBBJV's M&E Design Manager took a hands-on role in ensuring that the interface management and detailed checks took place, and that discrepancies were closed out.

Construction of the tunnel and associated underground spaces went smoothly in this sense, with very few incidences where M&E compatibility issues were referred back to the civil designer during M&E installation.

Timely completion of the complex M&E systems was identified as being of crucial importance to achieve early project completion and handover. LBBJV reviewed previous tunnel projects and identified that significant time had been lost in the completion phase because M&E systems had either not been sufficiently advanced and/or key components of these systems were incomplete.

To address this identified shortfall, a number of actions were taken to ensure these M&E systems were a focus throughout the Project and not just in the final months when tunnelling and civil works were generally complete, including:

- Early commitment to develop and build Mobile Works Platforms for M&E installation activities, so that M&E works could proceed safely and efficiently concurrently with the tunnelling and civil works;
- LBBJV prioritised completion and handover to United of the Tollroad Control Centre, the North and South Tunnel Ventilation Stations and the North and South 33kV Intake Substations, having identified with United that this would facilitate an early start of critical M&E activities; and
- LBBJV maintained an unwavering commitment and discipline to driving 100% completion of all elements of the M&E Systems to ensure they were complete and ready for final testing and commissioning. LBBJV recognised lack of completion as a weakness on previous tunnelling projects, resulting in program targets not being met. In turning this around, LBBJV eliminated the inefficiency resulting from long standing unfinished work and improved the transparency of progress reporting, because areas would not be reported as complete unless they were confirmed as being 100 percent complete.

Another area critically important to achieving the earliest possible completion was testing and commissioning for the M&E Systems.

An integrated six level commissioning regime was implemented for all M&E systems, comprising cable testing, energisation, controls system I/O Testing, local/device testing, module/subsystem testing and integrated system testing.

This six level regime was logical and methodical and was executed with such a high degree of discipline that advancement to the next level was not possible unless the tests in the preceding level had passed. In this way, the mass of components, cabling and equipment that made up each M&E system was tested and commissioned in a methodical manner and the results were well documented, thereby ensuring that any problem was detected at an appropriate stage and corrected. This process gave the Client, the Independent Verifier and the Operations and Maintenance Team confidence that the systems were fully functional and operational at handover.

3.5 Occupational Health and Safety

The project leaders were committed to maintaining a stringent safety culture, which they delivered through two key initiatives:

- Development of an easy to use ‘Safety Roadmap’ with rules, procedures and instructions as the practical tool to deliver the project’s safety requirements at the workface; and

One of the successful safety campaigns


Getting the most out of the pre-start process

- Formation of the Safety Leadership Team, which consisted of the Director, Deputy Project Director, Interface Manager, General Superintendent, Safety Manager and area Project Managers, who worked with all levels of the project team to integrate health and safety performance into the normal everyday operating business systems.

From project commencement, the senior management team championed the mantra “Safety First, Second and Third”. However, as production deadlines loomed, and high risk activities and workforce size increased sharply, this mantra became harder and harder for the project team to live up to. From project commencement in May 2006 to May 2008, the average manhours per month were 226,300, average turnover per month was $38 million, average monthly lost time injury frequency rate was 1.1, and average days lost per month were 10. However, this excellent safety record dropped sharply and between June and October 2008, the average manhours per month increased to 474,340, average turnover per month increased to $75 million, average lost time injury frequency rate increased to 5.6 and average days lost per month increased to 100, with the Project’s rolling lost time injury rate peaking at 9.2 in December 2008.

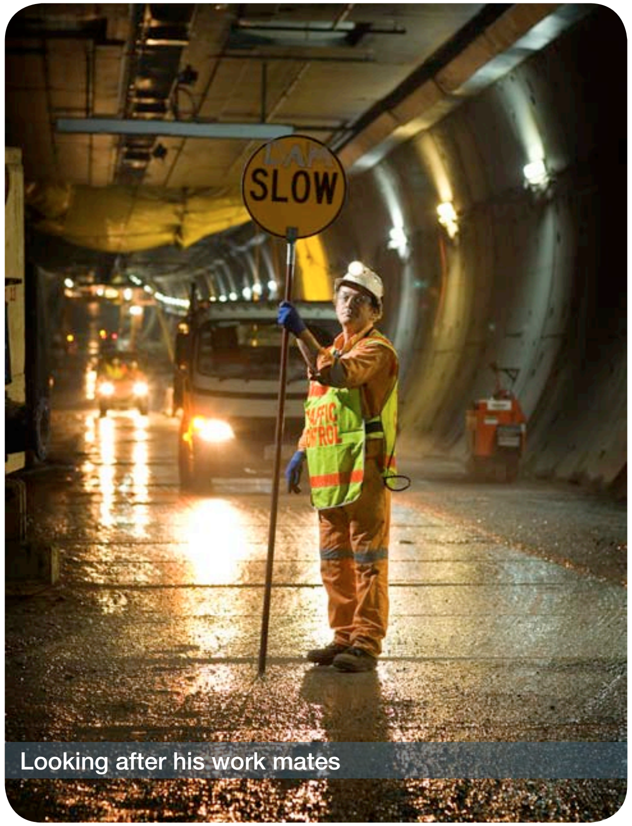
This degeneration in safety performance was one of the Safety Leadership Team’s greatest challenges, which they met, turning the peak rolling lost time injury rate of 9.2 to just 1.2 at tollroad opening in March 2010 and completing the final 1.5 million manhours to project close out in July 2010 without a lost time injury.

The Safety Leadership Team first had to establish the root causes behind this significant drop in safety performance before developing and implementing a strategic approach to recovery, which had to turn around safety performance and yet maintain two of CLEM7's key objectives in finishing early and within budget.

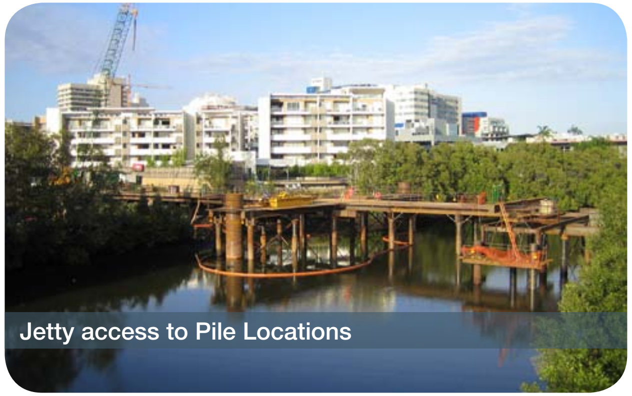
Following a series of internal workshops, seeking advice from industry safety experts, reviewing parent company audit findings and sending representatives to other projects to gain insight from their lessons learnt, the Safety Leadership Team determined that the most appropriate strategy to turn around safety performance was to instigate interventions at all levels throughout the Project. The interventions were all about improving communications and for this the Safety Leadership Team engaged specialist external training providers, held internal workshops and briefing sessions and participated in safety activities at the workface.

The interventions included:

- Joint weekly safety inspections by the Project Director, Interface Manager (to whom the Safety Manager reported), General Superintendent and the Project Manager responsible for the specific area of the Project. The Project Director and Interface Manager would cover areas on a rotational basis, sharing lessons and bringing fresh eyes into the workplace;
- Interactive workshops led by the Project Director, where senior managers explored what was working, what was not and how issues could be resolved;
- Instilling safety leadership in all front line supervisors through a training program provided by an external safety consultant;
- Dedicated training programs to improve the quality of Job Safety Analyses (JSAs) to ensure the information/instructions within them were fully utilised and the JSAs were not just a 'tick-and-flick' exercise;
- Revisiting the pre-start process to ensure that work teams were getting the most out of this pre-work meeting/process, and that participants were not just 'ticking a box';
- Publication of a monthly newsletter included recognition of a team's or individual's good safety performance;
- Establishing a 'buddy system' for people new to the Project to ensure that they learned how to work safely in a unique environment from experienced co-workers as quickly as possible;
- Expanding the tunnel induction program to include a tour of the work area as some people had never worked inside a tunnel environment before;
- Participants in safety inspections were encouraged to find at least three things that they thought needed improvement; and
- Manage out those people who did not have the same respect towards and support for a strong safety culture as that required by the Project.



Looking after his work mates



Jetty access to Pile Locations

Completed Substructure and jetty removed

Water treatment plant

3.6 Environmental Management Leadership

Leadership in environmental management on the CLEM7 started with the Board of Directors who required that LBBJV must stand alone and qualify for and maintain ISO 14001 certification, independent of the parent companies. LBBJV set the platform and communicated its requirements through the Construction Environmental Management Plan (CEMP). The Environmental Manager selected and managed a team of six environmental professionals who had the experience and drive to create understanding amongst those entrusted to deliver the requirements of the CEMP on the ground.

This leadership led to the following outcomes on the CLEM7 project:

- A project-specific Environmental Management System developed by LBBJV to obtain and maintain independent third party certification to ISO 14001;
- Quarterly, comprehensive review of environmental risks and performance by the senior management team;
- Preservation of mangroves during construction of the interchange bridges over Enoggera Creek;
- A comprehensive and responsive approach to potential regenerated noise and vibration impacts from tunnelling using a predictive model and real time monitoring, leading to "no surprises" for the community;
- A Self Sufficient Water Strategy, which saved 1,500ML of town water and was designed to be easily transferable to other civil infrastructure projects across Australia; and
- A dedicated Approvals Team to facilitate effective consultation with government authorities and regulators to manage the 98 separate environmental approvals required for construction activities and to track and audit the conditions attached to each of the approvals to ensure ongoing compliance.

Refer also to Sections 1.5 - Environment and Sustainability Outcomes and 2.3 – Environment.

3.7 Industrial Relations

The CLEM7 engaged over 13,000 people, represented by various unions. The main union represented on the Project was the Australian Worker's Union (AWU), while subcontractors generally had trade based enterprise agreements with the appropriate union, including United with the Electrical Trades Union (ETU) for the M&E fitout works and formwork subcontractors with Construction, Forestry, Mining and Energy Union.

LBBJV had an enterprise agreement with the AWU covering all wages personnel (labourers, tunnel workers, carpenters, fitters, electricians) employed by the joint venture. In addition, LBBJV had an enterprise agreement for all workers and tradespersons at the precast concrete factory.

All union issues where managed centrally by two senior managers in LBBJV to ensure consistency across the Project.

As our M&E Contractor did not have a close relationship with the ETU, LBBJV ensured it was intimately involved, working closely with both parties. The normal conditions encountered on a tunnelling site presented some real challenges for these parties that had to be overcome.

LBBJV's experience in disciplined and tight control of the industrial climate was instrumental in ensuring these issues did not spiral out of control.

Despite the large numbers of skilled and unskilled workers involved across many disciplines, LBBJV's thorough industrial relations planning and management, and good working relationship with the unions ensured there was no lost time due to industrial action.

3.8 Use and Development of New Technologies

LBBJV's large commitment to research and development resulted in extensive use of new technologies, ranging from big-ticket items, like use of the largest diameter hard rock double shield TBMs ever to have operated anywhere in the world to smaller items like the development of a hand held device to monitor ground water pressure more accurately than existing methods.

Our work started long before the first spectacular pictures of the TBMs were published. During the tender phase, work methods new to the Australian market were developed to achieve safer and faster construction, including:

- Introduction of an invert service tunnel to carry cabling underneath the final road pavement, the construction of which was integrated as part of the TBM "production line" operation; and
- Use of a rubber-tyred logistic system.

Both methods are now being used in other Australian projects.

Integrated approach to tunnel construction

Cable Tunnel


Acoustic sheds minimised noise disturbance


An Australian first - 100% video incident detection


New techniques in blast operations

The Project was the first Australian road tunnel to adopt a 100 percent video based automatic incident detection system, known as Automatic Video Incident Detection System (AVIDS). The AVIDS utilises 190 cameras inside the tunnel and 24 cameras on surface roads outside the tunnel to detect accidents involving stopped and slowed vehicles, as well as other incidents such as pedestrians or animals within the tunnel, smoke and fallen objects on the roadway. Detection of incidents is within seconds, therefore providing earliest possible response, and thus assisting in preventing the incidents escalating into major events. The AVIDS also collects traffic data – i.e. volume/occupancy per lane, flow speed per lane, which provides valuable data for the Operators' business.

The TBMs, the smoke duct formwork, the equipment for transport in the tunnel – including tunnel conveyors and trailers – and even the backfill material were specifically developed to optimise productivity and to comply with local safety standards and work practices.

LBBJV used or developed numerous other new technologies, including, for example:

- A full-sized trial, which led to the use of a combination of grout and pea gravel as backfill for the segmental precast concrete tunnel lining;
- Use of the largest integrated load-out system of its kind to manage the Project's 2.7 million tonnes of TBM spoil, including over 500m of acoustically lined conveyor and 6,000 m^3 buffer silos and load out facilities;
- Development and trialling of a new technique to prevent fly rock during drill and blast operations that utilised tensar and geofabric anchored with concrete blocks over the blast mats, which provided significant cost and time savings by eliminating the traditional practice of placing fill over the blast mats. This technique has since been used on other projects; and
- Use of the latest technology fibre optic linear heat detection cable, which is ideally suited for use in the tunnel environment because it combines the robustness required to operate in this harsh environment with the speed of detection and location accuracy – both vital in the event of a tunnel fire.

3.9 Training and Development Initiatives

A key project risk was centred around the ability of LBBJV to attract and retain the people with the relevant experience to deliver such a complex and diverse project. Whilst about 35 percent of the core staff requirement came from the parent companies, this still left a significant gap, requiring LBBJV to attract more professionals from the construction industry, which was already struggling to support the volume of work underway in Australia at the time. Coupled with this was the requirement for a large skilled or semi-skilled labour force to complete a very diverse range of construction activities.

In all some 13,000 people worked on the Project contributing nearly 13.7 million man-hours towards activities ranging from construction management and administration to tunnel works, road and bridge construction, services installation and commissioning, landscaping and the production of precast concrete products.

Not surprisingly, training became a key priority for LBBJV and an integral part of its business. Career development was provided for staff, while skills development was provided for wages personnel and subcontractors. Safety was the number one priority on the Project and a lot of effort went into training many people who had either not worked in the construction industry at all or not worked on projects of this size and complexity where safety is paramount.

In all some 3,800 wages personnel completed recognised skills development programs ranging from the operation of small tools to operating plant and equipment. Much of the training was very specialised such as:

- Driving the specialised push/pull trucks with semi trailers used within the tunnel to deliver the precast concrete segments to the TBMs;
- Laying the segments in the TBM; and
- Operating the launching gantry for the curved bridge construction over Enoggera Creek.

These were activities that had never been carried out in Australia before and so the legacy left by this specialised training is particularly significant.

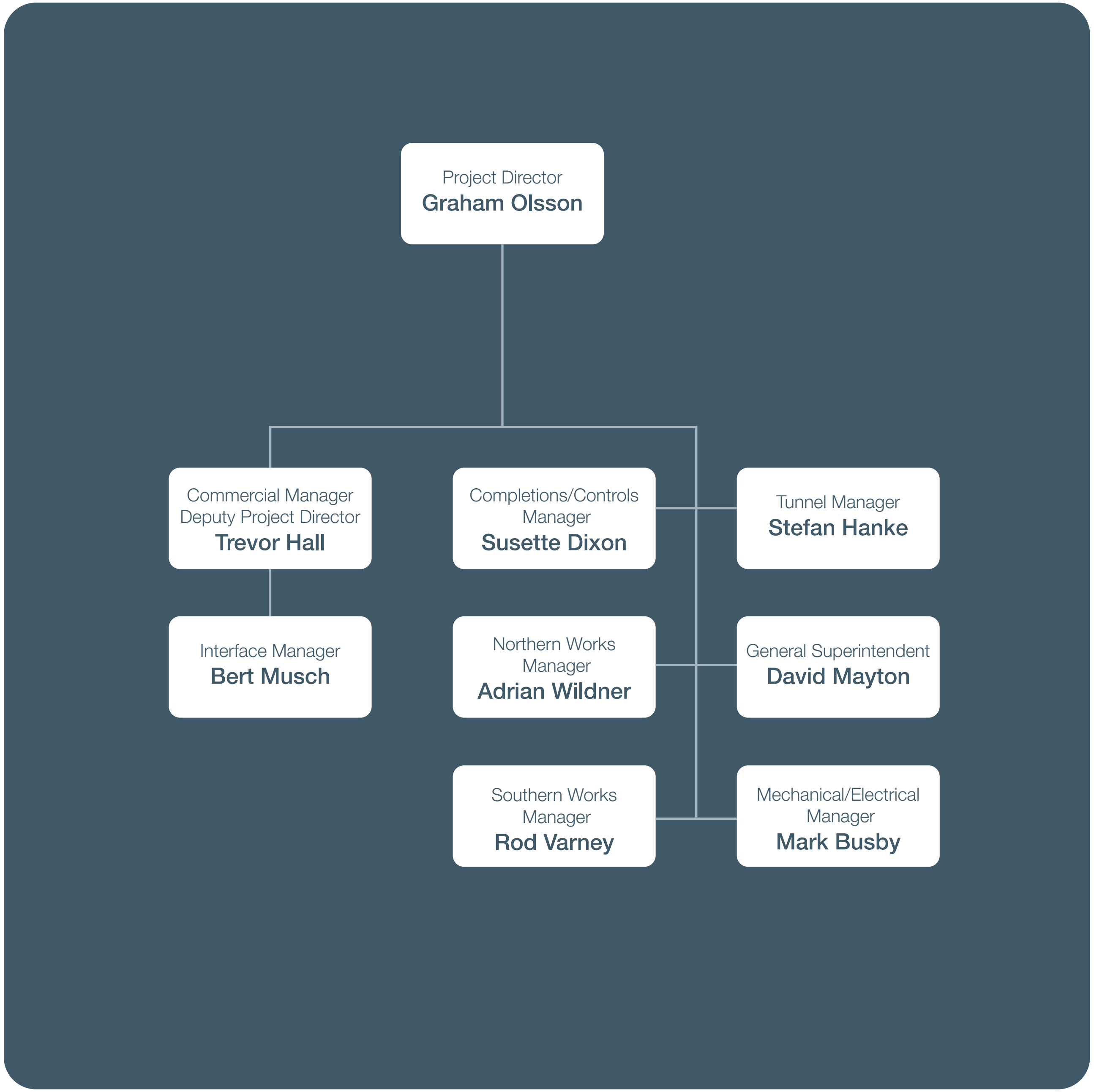
Specialist training was provided to upskill the team

The purpose-built precast concrete factory for the production of the segments required a completely new labour force. Working 24 hours, 7 days-a-week in a factory to produce 8.5 tonne segments to less than 1mm tolerance required a great deal of new skill training. Many of these people came from overseas and had little or no English and very little safety training or tunnel experience and so a ‘buddy system’ was developed to assist them in their transition into Australia and our workforce.

A key benefit from all this training is that it provided Australia and the construction industry with more experienced and skilled people to support the construction of similar projects in Queensland and other States.

Project Leadership Team

The Project had a senior leadership team comprising the Project Director, Deputy Project Director and key senior managers, as described in the organisation chart to the right. Sitting below this team was a staff of some 300 people organised in teams reporting to a member of the leadership team.



Graham Olsson

Project Director

Graham was initially appointed as Deputy Project Director, responsible primarily for all non-tunnelling construction. With more than a year to go on the Project, Graham took over the Project Director role whilst the Project was facing significant challenges. Graham played an instrumental role in driving the project team to an early finish, staying within budget and ensuring exceptional quality levels were achieved.

Graham's construction industry experience includes major projects delivered in challenging environments both in Australia and overseas. With his ability to close out projects and a background in M&E, Graham brought key leadership skills, focusing the team on a coordinated completion strategy, while improving safety performance.

Trevor Hall

Deputy Project Director, Commercial Manager

Trevor joined the team as Deputy Project Director when Graham took over the Project Directorship. Trevor's breadth of construction experience together with his strong business and commercial skills allowed him to take a firm leadership role from the outset, which provided important stability and drive for the project team in its final stages. Trevor was responsible for commercial management of the Project with direct reporting responsibility to the Board. As the Deputy Project Director, Trevor's leadership style was influential across the Project in the areas of safety, culture, and client relations, through to the critical elements of consultant/sub-contractor and supplier relationships.

Susette Dixon

Completions and Controls Manager

Susette was responsible for construction-stage traffic management, service relocations, electronic tolling, incident and traffic planning for the operational tunnel, quality management and project completion, including all approvals to open the tunnel.

She brought together a diverse team and injected focus to these areas to ensure certainty of delivery.

Susette's strong background in management on tunnel projects, in particular in the areas of external stakeholder management and fire and life safety systems positioned her well to successfully manage all deliverables and gain authority approvals to safely open the tunnel to traffic.

Stefan Hanke

Tunnels Manager

Stefan was involved in the CLEM7 project from the outset taking a lead role in the tunnel estimate stage responsible for the specialised tunnelling methods. Stefan was the brain behind the “Shafston on and off-ramp layout” which played a significant part during the tender as it was one of the key issues for the Client.

Stefan has over twenty years experience in tunnel construction and ten years in management roles. His wide international experience and strong technical knowledge across various tunnelling techniques, especially where geological conditions might vary, was an invaluable asset on this challenging yet rewarding project.

Bert Musch

Interface Manager

As Interface Manager, Bert was responsible for safety, environment, community, industrial relations and human resources. Bert managed a large team of professionals based both in the office and in the field to ensure that all these areas were proactively and effectively managed. Outstanding outcomes were achieved as a result of Bert’s leadership, and the Project developed strong relationships that minimised negative impacts on the community. An intense focus on safety assisted in significant reductions in injury frequency indicating real improvements in safety.

David Maytom

General Superintendent

As General Superintendent, David was responsible for the safe and timely delivery of the project works to time and cost expectations, whilst also ensuring that works were carried out in a well-planned and coordinated manner. David brings a huge wealth of major project experience, having been general superintendent on the Eastern Distributor, M7 and superintendent on Star City Casino and M5 motorway.

David undertook a hands-on delivery role for the tunnel works, including the interface with external work areas and co-ordination with the M&E contractor.

David was responsible for engendering a performance based and safety focussed culture within the construction team.

Adrian Wildner

Northern Works Manager

Adrian was responsible for all surface works at the northern zone of the Project including all temporary tunnelling works, as well as all permanent works, the tunnel portal and approach and Lutwyche Road.

Adrian managed a large multi-disciplinary team who were continually challenged by traffic interface issues, community issues, program deadlines and elaborate urban design elements, like the spectacular portal canopy.

Under Adrian's leadership the level of service for Lutwyche Road was maintained during construction and the team was able to guarantee access during business hours minimising the impact on surrounding businesses.

Adrian's years of on-the-ground experience and his knowledge of the constructability of large infrastructure projects provided the Project and the Client with certainty and confidence.

Rod Varney

Southern Works Manager

Rod was responsible for managing works at the southern zone including construction along Ipswich Road, Pacific Motorway roadworks, Gibbon Street shaft fitout, ventilation fitout, completion of the southern ventilation outlet and the surface works at Shafston Avenue. Rod coordinated traffic and construction staging to minimise construction impacts and improve project efficiency. As Ipswich Road is a main services corridor to Brisbane and the PA Hospital, Rod and his team had to liaise with the PUP Manager to ensure services were maintained while new installations were occurring. Rod also regularly liaised with key members of the Boggo Road Busway project team to arrange traffic and staging solutions to minimise construction impacts on each project team and surrounding stakeholders. Rod's relentless drive saw him and his team achieve many challenging milestones throughout the Project.

Mark Busby

Mechanical / Electrical Manager

As Mechanical and Electrical Manager, Mark was responsible for managing the major M&E Subcontractor, United, and a number of other smaller M&E subcontract packages.

Mark's focus was on design management in the early phases of the Project, as well as setting up for the construction phase, including planning interfaces with the tunnel excavation and fitout teams, logistics and developing methods to accurately report on and measure progress. Once M&E construction commenced in the tunnel, Mark managed his team to ensure that construction planning and execution was carried out in accordance with the approved design, all safety requirements and to program. Throughout the Project Mark provided strong commercial and contractual management of this major subcontractor.

Mark has a wealth of experience in managing the delivery of large technically complex mechanical and electrical projects, through design and construction phases.