NORTHERN SEWERAGE PROJECT
THE QUIET ACHIEVER

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ABSTRACT

The Northern Sewerage Project (NSP) is one of the largest, most complex wastewater tunnelling projects in recent Australian history.

Overcoming challenging geology and complex site conditions in a dense urban environment, the $650 million project involved construction of 12.5 kilometres of sewer tunnels in Melbourne's north.

Environmental sustainability was central to the project's design – a key goal being to virtually eliminate sewage overflows into the Merri and Moonee Ponds creeks after heavy rain.

Now fully commissioned, the new sewers provide capacity for 70,000 new homes across northern Melbourne. It was finished $135 million under budget and six months ahead of schedule.

KEY WORDS

Melbourne Water, Yarra Valley Water, John Holland, Aurecon, Sinclair Knight Merz (SKM), Tunnel Boring Machines (TBMs), glassfibre reinforced plastic (GRP) tunnel lining, deep shafts, drill and blast, variable geology, water infiltration, construction noise, acoustic sheds, air treatment facility.

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INTRODUCTION

Melbourne's Northern Sewerage Project (NSP) is one of the largest, most complex wastewater tunnelling projects in recent Australian history.

Overcoming challenging geology and complex site conditions in a dense urban environment, the $650 million project involved construction of 12.5 kilometres of new sewer tunnels, and was delivered $135 million under budget, six months ahead of schedule.

Providing for Melbourne's future growth

Environmental sustainability was central to the project's design – a key goal being to virtually eliminate sewage overflows into local creeks and improve the health of Melbourne's iconic Yarra River and Port Phillip Bay.

With a population now exceeding four million, Melbourne has recently experienced an unprecedented period of growth. A fully functioning metropolitan sewerage network is a vital component in the city's overall public health system.

The new sewer – designed to last well into the next century – has greatly increased the capacity of the existing system to service the city's growing population. Now fully commissioned, it provides capacity for the construction of an additional 70,000 new homes across Melbourne's northern growth corridor.

Tackling key challenges

Running through eight suburbs, the project faced significant social, political, technical, logistical and construction challenges – in many instances working directly adjacent to and beneath approximately 2,500 private properties.

One of the project's key challenges was the need to deal with variable and unpredictable geology in some areas, and to identify the most suitable technology available to excavate through it.

Most construction work for the new sewer took place between 15 and 64 metres below ground, using three custom-designed, state-of-the-art Tunnel Boring Machines (TBMs). In order to complete the project in the shortest timeframe possible, construction took place 24 hours a day, six days a week for 4.5 years.

With more than 216 people employed across both stages of the NSP during its peak, and approximately 6,500 residents within the construction footprint, there was the potential for ongoing community disruption.

A key requirement was the need to minimise the impact of construction noise on nearby residents, due to their close proximity to construction activities. The project team implemented a series of measures to reduce noise wherever possible, such as the construction of innovative acoustic sheds over the three main production shaft sites.

PROJECT SCOPE

The NSP is an essential infrastructure project that has greatly increased the capacity of Melbourne's sewerage system to meet the needs of the city's growing northern suburbs and is helping to protect the environment.

The new system has the capacity to accommodate an additional 70,000 new homes within Melbourne's northern urban growth corridor around Craigieburn and Epping.

The NSP was delivered by Melbourne Water (Stage 1) and Yarra Valley Water (Stage 2), with John Holland as the construction partner for both stages. Other project partners included Aurecon as superintendent and project manager, and Sinclair Knight Merz (SKM) and Jacobs Associates as designers.

Stage 1 commenced in August 2007 and involved the construction of five large-scale construction sites and eight kilometres of deep-tunnelled sewer, connecting to the existing sewerage system near the Merri Creek in Coburg North and the Moonee Ponds Creek in Pascoe Vale.

Stage 2 commenced in September 2007 and involved the construction of three large-scale construction sites and 4.5 kilometres of deep-tunnelled sewer, running north from Carr Street in Coburg North, to L.E. Cotchin Reserve in Reservoir, which connects into the existing sewerage system in the north.

Running through eight suburbs and three diverse municipalities, the project faced significant social, political, technical, logistical and construction challenges as it took place in a highly urbanised environment – in many instances working directly adjacent to and beneath private properties.

CONTRACT

One of the unique features of the NSP was the "relationship-style" contract established between the project partners:

- Melbourne Water and Yarra Valley Water – clients
- John Holland – construction partner
- Aurecon – superintendent and project manager
- Sinclair Knight Merz (SKM) and Jacobs Associates – designers.

A formal system was developed to define and govern the relationships between these parties, and to remove barriers, encourage maximum contribution, and enable all parties to achieve success.

Works were procured on a cost reimbursable, performance incentive basis, and the combined teams worked together from a central site office in Coburg North, close to the eight construction sites.

A strong emphasis was placed on forming a collaborative working environment to maximise project opportunities. There were also regular meetings to brief the superintendent and the clients on current and forthcoming works, and to discuss any concerns with regard to progress. The relationship contract model included:

- A formal meetings procedure
- A project control group
- Key performance indicators
- A relationship charter
- A staged dispute resolution process.

Open dialogue was encouraged between the partners but formal pathways were clearly defined and followed for key decision-making. An updated organisation chart was maintained and circulated to clearly show designated lines of communication.

Melbourne Water and Yarra Valley Water commenced geotechnical and hydrological investigations four years in advance of construction works. This provided a large amount of invaluable data, which guided design and construction methodology as well as formed the contractual foundation of the project, the Geotechnical Baseline Report.

Early involvement of the contractor, John Holland, ensured planning and design were in line with a buildable solution while any hurdles were overcome through analysis, consultation and flexibility.

PROJECT DELIVERY

Speed of tunnelling works

The NSP was delivered six months ahead of schedule largely due to the speed of tunnelling works, which required an innovative combination of Earth Pressure Balance (EPB) and Hard Rock TBMs, roadheader excavation, controlled drill and blast, hand mining and pipe-jack excavation.

The TBMs were carefully selected, modified and tested to provide significant production rate advantages over those of conventional excavation. They were able to work around-the-clock, whereas drill and blast activities were limited to day shift only to minimise disruption to local communities. This involved careful scheduling and flexible project management to redirect resources depending on changing project parameters, and to ensure critical timelines were met.

The smooth bore of the TBM tunnels also minimised the amount of backfill required around the glassfibre reinforced plastic (GRP) pipes, compared to the amount required around a conventionally-excavated profile, which saved time, resources and money.

To meet its tight construction schedule, the NSP recognised early on the need to work outside normal hours, while minimising the impacts on the community as a result of construction noise.

Multi-million dollar acoustic sheds or enclosures were constructed over the three main shaft sites to contain noise from 24 hour tunnelling works at Brearley Reserve, De Chene Reserve and Newlands Road.

Breakthrough tunnelling approach
Detailed early planning and the flexibility to adapt set the NSP apart from comparable projects.

The project team deviated from the original plan to launch two of the TBMs separately in Stage 1, and decided instead to launch them concurrently from a single 65 metre deep shaft at Brearley Reserve, Pascoe Vale South. This enabled the two main tunnels to progress simultaneously, maximising speed and production efficiency.

“Gemma”, a four metre diameter EPB TBM, commenced tunnelling in a southerly direction in May 2008 at the same time as “Victoria”, a three metre diameter EPB TBM, began tunnelling north-west.

These two TBMs achieved a tunnelling double-header, breaking through into their respective shafts within two days of each other. The success of this approach is likely to influence tunnelling projects across Australia for several years to come.

On Stage 2, the project employed drill and blast techniques for the first 600 metres of one of the tunnel drives, in conjunction with TBM tunnelling in the opposite direction. This resulted in considerable time and cost savings.

Stakeholder management and community relations
Throughout the planning, design and construction phases of the NSP, detailed consultation with residents, businesses, local councils, schools and other stakeholders was a vital part of the project’s success. The project’s key stakeholders included:

- Darebin City Council
- Moonee Valley City Council
- Moreland City Council
- The Department of Sustainability and Environment
- EPA Victoria
- The Department of Planning and Community Development
- VicRoads
- Transurban
- Friends of Merri Creek
- Merri Creek Management Committee.

With approximately 6,500 residents within the construction footprint, the NSP team designed a comprehensive community relations strategy that went beyond standard industry practice to address community impacts and environmental concerns.

The team held over 80 community forums and presentations, and provided unprecedented access to the media to report on works taking place up to 65 metres below ground.

Community forums were held throughout the planning, design and construction phases of the project to provide opportunities for residents and businesses to receive updates on the project and raise questions and issues of concern. The feedback from these forums informed the way various construction activities were undertaken.

A thorough site selection and consultation process took place to determine the route of the sewer and the location of the worksites to provide the best outcome for all stakeholders.

Once the project sites were determined, community consultation also took place on key issues such as:

- The design and location of the new Air Treatment Facility
- Trucking haulage routes
- Minimising impacts from noise, dust and vibration
- Optimising access for construction traffic to project sites while minimising potential disturbance to nearby residents
- Where possible, ensuring pre-existing activities around project sites could continue throughout construction
- Revegetation and landscaping.

Throughout the life of the project, issues were eliminated wherever possible. If they could not be resolved, those people affected were kept well informed of what was happening and what to expect at all times.

Regular, planned and timely communication ensured very few complaints and many positive interactions between project employees and the community. A toll-free 24 hour Community Contact Line was established to respond promptly to community concerns, while a quarterly newsletter, community information booklet, and regular information bulletins helped keep residents up-to-date.

Dealing with variable geology

Geotechnical and hydrological investigations started four years in advance of works commencing. This provided a large amount of invaluable data, which guided design and construction methodology, and formed the basis of the contractual foundation of the project, the Geotechnical Baseline Report.

Another unique feature of the NSP was the time and effort spent designing the TBMs, enabling extremes of hard, strong basalt and soft running sand materials to be excavated.

The project team spent a year working with the manufacturers (Herrenknecht in Germany and Robbins in the USA) to design the TBMs so they could cope with the variable geology identified in the Geological Baseline Report.

Through clever design and advanced technology, the TBMs had the built-in flexibility to maintain excellent production rates. The EPB TBMs were selected to allow for operation in both pressurised (closed) and non-pressurised (open) modes to cope with varying ground conditions while the hard rock TBM was deemed the most suitable for the dense rock conditions encountered on Stage 2 of the project. In some areas this rock was up to five times harder than concrete.

Despite the comprehensive ground investigation, predicted conditions proved different to actual ground conditions at times, and tunnelling methods were adapted to suit. A good example was when the team encountered weak siltstone rather than hard basalt in one of the tunnel launch chambers.

The excavation method therefore changed from drill and blast to a roadheader machine with associated changes to ground support. In this instance, instead of an 80 metre long launch chamber, a 212 metre long launch chamber was excavated before the ground conditions were suitable for launching the hard rock TBM.

With the water table only seven metres below the surface in most places, all tunnels had the potential to drain the water table, potentially resulting in damage to surface structures. Several extended water-bearing zones were encountered with inflows well in excess of 30 litres per second, but despite these high flows the ground surface remained unaffected and tunnelling activities continued unabated.

The project's EPB TBMs were more than up to the critical task of being able to support the tunnel face during excavation, further ensuring there were no impacts on any surface structures.

Support for the face was provided via a mix of compressed air and excavated material. The excavation rate was then balanced between the material being removed from the head of the TBM and the force of the groundwater and unexcavated rock pushing in on the compressed air/excavated material mix in the head of the EPB TBM.

This environment required specialist training for the workforce who were periodically required to enter the head of the TBM. Their training was similar to that of a professional diver. Although underground not underwater, the risk of the "bends" was very real and decompression was required after each intervention.

Managing air quality

The NSP was acutely aware of the importance of maintaining good air quality and minimising dust during construction. The community, local councils and other government agencies all demanded an absolute minimum impact on air quality to protect human health and wellbeing.

As a result, the project team spent considerable time developing a series of measures to meet this challenge such as:

- Using concrete or asphalt where possible to seal unsurfaced site areas
- Placing crushed rock over those areas of the sites not already covered by concrete or asphalt
- Keeping site areas clean with regular sweeping and, when necessary, spraying with recycled water (either groundwater or captured rain water) to suppress dust
- Ensuring excess material was washed off the wheels of exiting vehicles, with vehicle wash areas and rumble grids adjacent to entry/exit gates
- Using tarpaulins to cover trucks removing excavated material from the sites
- Checking all site vehicles, plant and equipment on arrival to ensure they were fitted with properly maintained emission control equipment.

Specialist environmental staff were employed to monitor compliance with EPA requirements for air quality. To ensure full transparency, and in accordance with the conditions of the project's planning approval, a background air quality monitoring study was undertaken prior to construction, and ambient air quality monitoring was carried out each week at Brearley Reserve from the beginning of construction in August 2007 through to the end of October 2009.

This period covered the peak spoil truck movements to and from the site. Monitoring data was posted on the project website so that anyone with an interest in the potential impacts of noise and dust was able to monitor compliance.

Ambient air quality monitoring was undertaken in Heliopolis Street and Mitchell Parade, Pascoe Vale South, within 100 metres of the Brearley Reserve shaft site. This site was considered representative of the background air quality in the local region.

Comprehensive air quality monitoring equipment – the same as that used by the EPA – was installed at Brearley Reserve to measure particulate matter. Weekly tests showed the air quality around the NSP was well within the normal range, ranging from "fair" to "very good".

MAJOR ACHIEVEMENTS

Installing a high tech tunnel lining

Newly constructed sewers have historically included a sacrificial concrete in situ lining as a barrier against the corrosive wastewater environment, but the NSP went a step further.

The team instead decided to install a corrosion-resistant lining of glassfibre reinforced plastic (GRP) to deliver a 100 year-plus design life. The smoother surface will be easier to maintain than traditional concrete-lined sewers, leading to quicker maintenance turnarounds and less disruption to surrounding communities.

A further advantage of these GRP pipes, supplied in six metre lengths as opposed to traditional 2.4 metre long concrete sections, is that they have fewer joints per tunnel length than conventionally lined tunnels and an impermeable cross section, virtually eliminating groundwater ingress despite hydraulic heads of up to 30 metres.

Purpose-built pipe carrier

Transporting the six metre lengths of GRP pipe along the tunnels was made easier by purpose-built hydraulic pipe carriers, designed by John Holland specifically for use on the NSP.

The pipe carriers were used to both transport the pipeline sections from the shaft to the placement location, and also to lift and install them, ready for the subsequent annulus grouting process. The purpose-built pipe carriers were very successful, allowing target rates (>90 metres day) to be achieved.

Efficient spoil removal process

The logistics of managing spoil removal from the long, narrow drives was made easier by constructing a switch (or passing station) in the tunnels so that locomotives and their trains running to and from the TBM, could pass. This minimised the time spent waiting for the train to remove the excavated spoil and increased efficiency.

A vertical conveyor was used at the deepest shaft site, Brearley Reserve, to hoist spoil to the surface to ensure ongoing efficiency, while servicing the two TBMs excavating the north and south drives. At the other, shallower shafts, a gantry crane was used to hoist the muck skips that were then tipped into muck bins on the surface (ready for transport to approved disposal sites).

Minimising construction noise

To meet its tight construction schedule, the NSP recognised early on the need to work outside normal hours, while minimising the construction noise impacts on the community.

One innovative technique that made this possible was the construction of multi-million dollar acoustic sheds or enclosures over the three main shaft sites to contain noise from 24 hour tunnelling works at Brearley Reserve, De Chene Reserve and Newlands Road.

The sound proofing materials used in the acoustic sheds were similar to those used in modern cinemas. All evening and night works were undertaken within the acoustic sheds with the doors closed. In addition, freeway-standard acoustic panelling was erected around the project's largest construction site at Brearley Reserve to further minimise impacts from construction noise during daytime operations.

Other measures used to contain noise levels and disturbance to residents were:

- Limiting the hours of operation of daytime shifts from 7.00am to 5.30pm, Monday to Saturday, with no spoil truck movements past 1.00pm on Saturdays
- Reducing noise at key construction sites with acoustic hoarding, ranging in height from 2.4 to four metres
- Negotiating to purchase properties next to some construction sites at the request of residents
- Undertaking noise amelioration measures to some properties next to construction sites
- Minimising equipment noise with sound-insulated compressors
- Minimising impacts on residential streets by controlling vehicle movements to and from sites.

Demonstrating sensitivity to neighbours
Some construction methods, particularly tunnelling by drill and blast techniques, had the potential to cause disturbance to local residents.

Doorknocks were conducted with all residents likely to be affected by blasting activities. Residents were provided with fact sheets explaining how these activities were being managed, and details of the project's dedicated 24 hour toll-free Community Contact Line. Drill and blast activities were restricted to the day shift only, with community relations staff present on site at the time of all blasts to address any real-time concerns with nearby residents.

In addition, the project undertook regular vibration monitoring along each of the tunnel alignments and at sites where blasting occurred, ensuring the project did not exceed the maximum allowable limits or restrictions for peak particle velocity.

Pre- and post-construction property inspections were offered to around 2,500 private residential and commercial properties. While surveying properties during pre-construction is common for Australian tunnelling projects, a commitment to re-surveying all properties post-construction is not. However, it was important for the project team to demonstrate its understanding that people's homes and businesses were their most valued asset.

Over 1,000 surveys were conducted. The project's efforts to reduce construction impacts, and the monitoring undertaken throughout the project, confirmed the surrounding properties experienced no adverse impacts.

Leading health and safety measures

The project's Health and Safety Management Plan was the central pillar for managing occupational health and safety (OHS) risks and opportunities.

All key risks identified prior to mobilisation were addressed in the plan, by linking them with adequate controls to mitigate or eliminate the inherent risks associated with those activities. A number of procedures were highly effective and contributed to the success of the project by managing high-risk activities such as confined space entry and working at heights.

The NSP had a strong focus on training to equip all employees with the necessary skills and knowledge to perform their work effectively, and to identify and manage risks.

Training was applied at all levels of the project including senior management, line management and the general workforce to promote a team approach and create a safe, productive workplace. Some examples of key training programs include:

- OHS inductions
- First aid
- Confined space entry
- Working at heights
- Traffic management
- Environmental risks
- Community engagement
- High risk licences to operate specific plant and equipment
- Risk management.

The project's safety initiatives resulted in remarkably low incident numbers on the project – only three Lost Time Injuries (LTI) over a period of 4.5 years of construction (772 LTI-free days) and 2.2 million hours.

In addition to formal training programs, the project carried out weekly toolbox meetings to engage work crews directly and discuss in detail issues or procedures relevant to them.

For example, working at the bottom of shafts is always a high-risk environment. Complacency can set in for dogmen working regularly at the shaft bottom and for workers traversing the base of the shaft. These risks were identified early and regularly addressed in toolbox talks.

LESSONS LEARNED

The NSP project management team prepared a post-project review document that captures all lessons learned, from inception through to delivery and completion of the project.

One of key lessons learned on NSP occurred following the removal of the final sections of hard rock from the tunnel known as the Northern Intercepting Sewer #3 (NIS #3), (Jukes Road, Fawkner to L.E. Cotchin Reserve, Reservoir) in October 2009, as lining activities commenced.

During tunnel lining the project team tried a number of methods to minimise water infiltration, which had the potential to inhibit the GRP pipe grouting process. The final solution was the result of trial and error, requiring significant groundwater control measures along the length of the tunnel and modifications to the grouting methods.

Managing water infiltration
Water infiltration from the tunnel walls was recognised early on as an issue of concern throughout the length of tunnel NIS #3 as flowing water could wash out the grout used to join sections of GRP pipe.

An extensive array of water control measures were developed during lining works to avoid this outcome, including strapping and pinning 100mm diameter PVC drainage pipes to the invert of the tunnel. Any discrete flows of water from the crown, walls or invert of the tunnel were collected in funnels and channelled into a 25mm hose. This hose was then plumbed into the drainage pipes. Where water infiltration was not discrete (i.e. general seepage into the tunnel), the wet area was covered with a drainage mat, the edges sealed with shotcrete and the mat wrapped around the adjacent section of drain pipe that was perforated to receive the water inflow.

New measures needed
Despite these efforts, the team discovered that not all water could be collected this way, and that the grouting operation also created its own “bleed” water. Therefore, prior to any pour, a pump hose was dropped into the downstream end of the pour and the area dewatered.

The floatation force during the grout filling of the pipe annulus was considerable and therefore a major concern since the gradient vertical alignment of the GRP pipes was critical to the success of the entire project. A “holding down bracket” was vigorously tested to ensure it had sufficient capacity to withstand the forces acting on it. This “holding down bracket” or “spider” consisted of a steel collar encircling the GRP pipe. Six cups were welded onto the perimeter of the collar and jacks placed into these, which were then extended until they were in tight contact with the tunnel wall.

An unforeseen problem

The first of two GRP pipes was lowered into the Jukes Road shaft and successfully grouted into the tunnel by 19 November 2009. An inspection of the grout at this point revealed a good grout mix, enabling the next six pipes to be lowered for installation and grouting.

However, despite only partially filling the annulus of these pipes, an “out of tolerance movement” occurred, and it was realised that all of the pipes had to be removed and reinstalled before any work could continue. This was a major project setback, requiring all of the pipes and the hardened grout to be removed and the tunnel cleaned to its original excavated profile.

Further investigation and rework required

A thorough investigation revealed the GRP pipe movement occurred when a support jack slipped. What was not fully considered when the “spider” was developed was the nature of the ground conditions into which the jacks were anchored.

The tunnel walls were highly fractured, irregular and weak. Further modification of the pipe support – including a seventh vertical jack and a curved channel section for crown support – were incorporated into the design, while a larger bearing plate was used for those jacks positioned in obvious problem areas.

Rework took until early 2010 when pipe installation resumed. By this time the contractor, John Holland, had designed a purpose-built pipe installer, fabricated by local company Crib Point Engineering. This machine had the capacity to either pull the pipes together using a winch mounted on the machine, or to drive a new pipe into the already installed pipe.

The six reinstalled pipes were successfully grouted in three stages, an approach agreed by all project partners as the correct way forward. With these lessons learned, the remaining sections of tunnel were all completed faster and without any further delays.

Lessons for other projects

Following the experience on tunnel NIS #3, the project team concluded that wet tunnels require discrete water control measures (as well as a long-term drainage scheme) to keep the water pressure from impacting on grouting until the final tunnel liner is grouted and cured in place.

To avoid movement of pipes, the number of jacks and the condition of the tunnel wall against which these jacks are braced should be carefully considered. High grout temperatures adversely impact grouting production rates as well as the quality of the backfill. By modifying the grout design and changing its sequencing this issue can be addressed.

CONCLUSION

After the 4.5 years of construction, the NSP was fully commissioned on 11 November 2011. This milestone was marked by an official ceremony with the Victorian Minister for Water, The Hon. Peter Walsh, in attendance.

A well-informed community
Towards the end of the construction process on the NSP, a series of community surveys were distributed to all residents, business owners and key stakeholders in the vicinity of shaft sites and along the tunnel alignment to give people a chance to have their say about the quality and quantity of communications materials.

Almost 80 per cent of respondents rated the frequency of communications during construction as "good" or "excellent", with the same percentage reporting that the information provided was clear and easy to understand.

A Positive Incentives Register was also maintained to monitor positive feedback from the community and other key stakeholders throughout construction of the project. The project received over 300 items of positive feedback, with many focused on the project's commitment to communicating impacts and keeping the people involved in the project at all times:

> *"Firstly, congratulations on a fantastically organised and well communicated project. As a local resident, we have been really impressed at how little an impact the project has had on our community and have very much appreciated the way in which project timeframes and any inconveniences have been communicated."*
> **Resident, Brearley Reserve.**

Satisfied clients
Melbourne Water and Yarra Valley Water were both satisfied with the strong and healthy working relationships they developed with their project partners over the life of the NSP.

> *"Together we have delivered a project that fosters a culture of continuous improvement, achievement and quality, supported by systems and procedures that in every aspect ensure these outcomes. Yarra Valley Water and Melbourne Water have every confidence John Holland as contractor, together with designers SKM and Jacobs Associates, and Superintendent and Project Manager Aurecon, have constructed a quality asset that will last for the next 100 plus years."*
> **Mike Filby, Melbourne Water, Project Director NSP1**
> **David Elliott, Yarra Valley Water, Project Director NSP2**

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REFERENCES

"Project Pushes Ahead", *Contractor Magazine*, November 2008, pages 10-16.

"Tunnelling Melbourne's Future", *Trenchless Australasia*, December 2008, pages 44-46, Australasian Society for Trenchless Technology.

"Navigating the Northern Sewerage Project", *Trenchless Australasia,* December 2009, pages 54-57, Australasian Society for TrenchlessTechnology.

"The Finishing Touch", *Contractor Magazine*, May 2001, pages 18-21.

"Breakthrough for Melbourne sewer project", *Water Engineers Australia*, Vol. 4, No. 8, November 2010, page 6, Engineers Australia.

"Melbourne sewer project", *Civil Engineers Australia*, March 2011, page 64, Engineers Australia.