BRICKS, BENDS AND BYPASS – DESIGN AND EXECUTION CHALLENGES FOR THE NORTH YARRA DEVIATION SEWER REHABILITATION PROJECT

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ABSTRACT:

Melbourne Water's North Yarra Deviation (NYD) sewer is a 90 year-old 2.6m diameter triple-brick lined sewer located under the Stony Creek backwash. The asset has been identified for upgrade for a number of years with recognition to the challenging environment to design and deliver the works.

The design criteria required a risk-based approach due to the depth, poor ground conditions, high water table and incomplete knowledge of brickwork condition.

Key challenges involved the management of sewer flows up to 2,200 L/s (up to 20% of Melbourne's sewer volume), removal of mixed and contaminated silt and bricks, creating a safe working environment, lining 200m of 2.6m diameter sewer including bends with grouted spiral-wound HDPE technology, and rehabilitation of 5.5m diameter, 14m deep manholes featuring 80 year old penstocks, motorised gears and valves.

A functional design was completed by KBR that determined the parameters and constraints for rehabilitation design to maximise the range of options for rehabilitation. John Holland-KBR Joint Venture lead detailed design and project delivery services including detailed definition, options selection and design and delivery of rehabilitation and bypass management with rehabilitation specialist Interflow and pumping specialists Welltech.

1. INTRODUCTION

Constructed in 1932, the North Yarra Deviation is a deep section of sewer located beneath the Stony Creek Backwash, adjacent to the West Gate Bridge. It is managed and operated by Melbourne Water and currently moves 15-20 per cent of Melbourne sewage flow - 1700L/s peak dry weather flows.

The deviator was constructed in a tunnel, with a triple brickwork bend at each end (85m each), and concrete 407m conduit in the middle. The NYD is 572.62m long with a diameter of 2.6m at a depth of 15m to 20m.

Figure 1: Standing in sewer within existing brick section after cleaning.

As the downstream network has been upgraded, the upstream sewers have been surcharged, likely causing the inside layer of the brickwork to collapse.

CCTV inspections have been carried out every two years for the past 20 years. While it had been known the sewer was deteriorating, the inspection in 2016 showed that some of the inner layer of bricks at each end had delaminated, bricks were loose and mortar missing. The concrete straight section was in much better condition. Melbourne Water identified it was now time to engage a D&C delivery partner to undertake rehabilitation works to restore NYD to its full strength and service reliability.

The tender involved the rehabilitation works for the brick arch sections and access shafts. This project was made technically complex by the size, asset condition, depth, flow conditions, location and the fact that it occurred underground in a high risk confined space environment.

The contract was a Design and Construct and included:

- surveying and reporting on sewer condition.
- cleaning and removing of silt, sediments and debris.
- a rehabilitation solution that would extend the life of the sewer by at least 50 years.
- the rehabilitation must be "structural" meaning it must be designed to take all loads assuming that the existing brick sewer has no remaining strength.
- rehabilitation must not reduce the sewer's flow capacity.
- the sewer system in the region must remain in full service during the works.
- the works are undertaken within the specified timeframe to accommodate West Gate Tunnel project works.

The project team and associated subcontractors were selected due to their experience in similar projects and commitment to successfully rehabilitating the North Yarra Deviation safely and without impact to Melbourne's sewer operations. Due to the nature of the project, no part of the project was straight forward and required the team to communicate and work together to problem solve. Each individuals' experience and knowledge contributed to the success of the project.

The project could not have been delivered without the efforts, commitment and people from Melbourne Water, John Holland, KBR, Interflow, Welltech Total Water Management, RBM Drainage, East West Dive and Salvage, and Scaffold Logistics.

2. BRICKS AND BENDS

In assessing suitable technologies, a range of options capable of delivering the required outcome was evaluated which are listed in the table below. It shows that a spiral wound liner was the most practical option from an installation as well as a service perspective.

OPTION	CHALLENGES TO OVERCOME	DECISION
Do nothing	Deterioration is reaching a critical stage and will continue resulting in a possible catastrophic collapse.	Rejected
Construct new pipeline	Difficult excavation as many underground services in the area. Difficult alluvial soil conditions for deep construction. Most expensive option.	Rejected
Shotcrete	Safety issues with extensive person-entry needed. Flow management issues. Ground water sealing. Relies on workmanship quality both in surface preparation and shotcrete spraying	Rejected
CIPP liner	Full bypass needed. Sewer diameter considered too large for this lining technology, limited to typically DN1200mm	Rejected
Segmental sliplining	Deep shaft excavation needed. Likely excessive loss of diameter. High cost likely.	Rejected
Spiral wound lining	Can be structurally designed to be independent of existing sewer. Experience of installing Ribline liners in similar diameter applications with similar installation conditions of access and partial flow.	Option selected

Ribline, an Australian developed steel-reinforced polyethylene liner from Sekisui Rib Loc Australia was selected as the preferred option. It has been used for trenchless renewal of deteriorated large diameter pipelines and culverts, initially in Australia and then around the world.

Figure 2: Ribline machine positioned in sewer.

Calculation in accordance with international standards for sewer relining including adjustments based upon the verified condition of the asset confirmed that the installed Ribline liner has sufficient strength to withstand all loads on the sewer, assuming the existing structure is fully deteriorated with no remaining strength.

Following review of the calculations showing that Ribline met the design Specification, Interflow and JH-KBR JV produced plans that demonstrated to Melbourne Water that processes could be put in place to successfully install the liner while meeting all the requirements of working in extremely demanding conditions.

While Ribline can be installed with some flow in the pipeline, bypass pumping was needed on this project to limit these flows to practical levels and maximise working windows to enable works to be undertaken safely. This was a complex procedure due to the volume of sewage, the depth of the sewer and the above ground location of the project.

Large volumes of silt and debris needed to be removed from the sewer before liner installation could commence. Sewer depth, flow conditions and the type of debris, with silt mixed with bricks and other large objects made this a complex process.

The deteriorated manholes and access shafts required cleaning, and coating with calcium aluminate cement. This is a cementitious material applied by spraying over a surface that has been totally cleaned of acid attacked concrete. This was a major project component with two shafts over five metres in diameter and up to 18 metres deep needing to be rehabilitated.

Approximately 75 per cent of the work was completed in confined space. John Holland systems and processes were implemented to ensure confined space was managed to industry best practice levels. Additionally, an innovative temporary access stair cage was installed - which had been developed in previous John Holland tunnelling projects – that provided increased safer access with no need for davit arm and harnesses.

Figure 3: Caged safety ladder in situ in manhole.

Kanga loader improved efficiency and safety

Prior to work in the sewer commencing, advanced laser and sonar profiling was carried out to determine the extent of asset deterioration, sewer dimensions and the depth of silt and debris in the invert. The use of sonar allowed the conditions to be measured below the water level, without the need to reduce the flow level and avoid any man entry to confirm the volumes to be removed.

Profiling showed that there was silt and debris up to 500mm deep and wall delamination of up to 125mm. Debris included sheets of bricks that had delaminated from the sewer wall, and some large objects of the type that inexplicably find their way into sewers.

Typically, silt is removed from sewers by high-pressure water jetting, and for large sewers, by manual methods involving shovels and carts. For this project, Interflow further developed a "Kanga" loader that allowed safer and faster silt removal.

A wheeled, open-ended, removable container, shaped to match the tunnel invert was attached to the front of the Kanga and pushed up the sewer collecting silt as it goes. When full, this container was transported back to the access chamber. The removable container was then lifted to the surface by crane and the silt deposited securely in a sealed bin ready for transportation off-site.

Figure 4: Kanga lifted into manhole

The remote-control system of the Kanga, allowed the it to be operated from the base of the access chamber, without an operator needing to access the deteriorated sewer.

As well as the safety benefits of minimised person entry into an inherently dangerous work environment, developments have resulted in major productivity improvements. Up to 22 tonnes of silt and debris could be removed in an 8-hour shift. This is a 4 to 5-fold increase compared to jetting or other available methods.

New ribline liner able to install in bends

While Interflow has experience of installing Ribline in deep sewers of this diameter in live flow conditions, this project added the complexity of two 45 metre sections of the sewer deviating through 80° bends on a 30-metre radius. Typically, spiral wound liners must be installed in straight lines.

An adaption was made to the Ribline profile which allowed the possibility of continuous winding through these bends.

Ribline lining strip has three ribs over its 126mm width. Typically, continuous steel strip is encased in each rib. To enable the liner to be wound continuously around the bend, the steel strip is omitted from one of the ribs which is slit at its base. As the liner is wound around the bend, the slit rib opens slightly on the outside of the bend and closes slightly on the inside. This allows the profile to stretch or compress as it winds through the wide side and tight side of a bend – with a concertina effect.

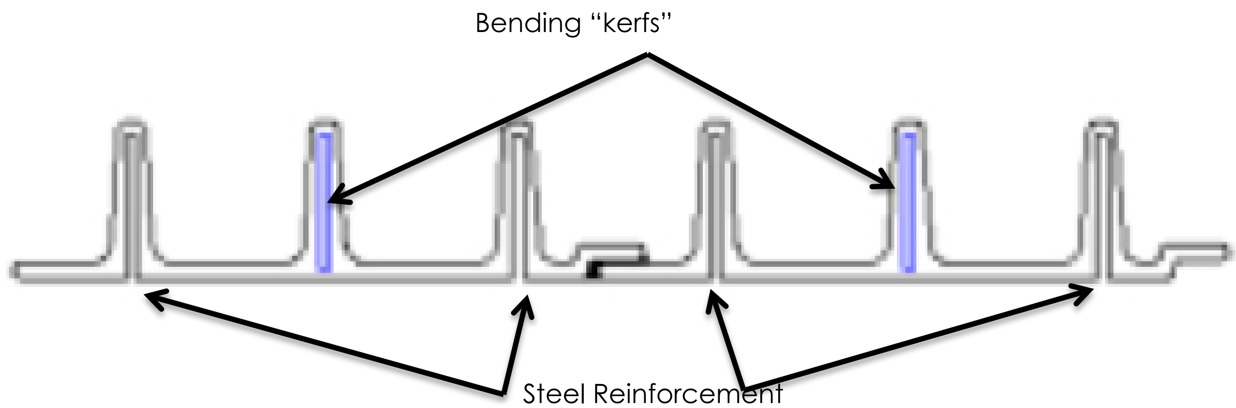

Figure: 5: Cross-section of Ribline bend profile.

The strip used on the North Deviation was sufficiently adaptable to allow smooth, continuous installation around the bend.

3. BYPASS

On Award of the project the project team worked closely with Melbourne Water and key approval stakeholders to finalise the best methodology with stakeholder input and ensure the appropriate approval processes were undertaken.

The northern manhole, NYM003A, is located on Crown land and therefore approval was required from Department of Environment, Land, Water and Planning (DELWP), with Parks Victoria as the land manager. To prepare for the approval and understand its extent it was critical to identify the area required for the works the JV involved the project's bypass pumping subcontractor, Welltech Total Water Management. This ensured confidence that the information provided to DELWP was unlikely to change, approvals knowledge was shared with the subcontractor and delivery requirements were already considered within the proposed plan. Following the submission of the approval, the approval was received promptly confirming the project did not require a planning permit.

In parallel to the DELWP approval, JH-KBR JV investigated whether the old decommissioned syphon could be used as the bypass route, which would eliminate a lot of risk of bypassing the sewerage flows and provide less risk to wet weather flows. A small remotely operated underwater vehicle ROV was used to survey to the syphon. The syphon was found that it had completely silted up and therefore not a viable option.

Figure 6: Stony Creek Backwash with adjacent bypass pipeline.

However, the upside was that JH-KBR JV identified the use of the Syphon manhole NYM003 as the wet well to house the two large Welltech pumps.

In the original tender submission JH-KBR JV's proposed bypass pipe route was to either float or sink the pipe across Stony Creek Backwash. The risk of the pipe crossing Stony Creek including recognition that the potential route may require a permit to destroy Victorian cultural heritage.

The project team and Welltech investigated alternate routes and identified the opportunity to lay the pipe along Hyde St adjacent to the bike trail and under the West Gate Bridge to Manhole NYM001C. VicRoads and Bicycle Network input was provided to guide the location of the pipe providing ease in approvals and a route that avoided sensitive cultural heritage areas.

4. EXECUTION CHALLENGES

This project was made technically complex by the size, asset condition, depth, flow conditions, location and the fact that it all occurred underground 15 to 20m deep, in a high risk confined space environment.

Complexity was experienced when the team needed to measure the existing sewer system. The original 1930's drawings were in hand, however the team needed to check measurements for the design and construction of the penstock. To access the sewer a manbox was suspended from a crane to measure the shape of the pipe where the Penstock was required to be installed.

The old timber plugs were installed in 1930's and needed to be removed for the bypass pipework which was used to build the original NYD manholes. Various options were investigated from remote drilling machines to ROV's, but non were viable. The team from East West Dive and Salvage offered a solution which used hydraulic operated drills and chainsaws to cut the timber plugs. The project team worked closely with the divers to design the methodology and new plugs which were installed at the end of the project. The team observed the wisdom of the Board of Works when removing the original plugs – the red gum used was still in great condition – and therefore the team used the same material for the new plug.

Manhole NYM001C is located under 220KVA high voltage overhead power lines approximately 17m from the top of the building that required to be demolished and near high pressure petroleum fuel lines, included the jet fuel line to Tullamarine Airport where the team installed solid hoarding around these pipes to protect them during demolition and traffic barriers near vehicle traffic.

JH-KBR JV tender submission identified the removal of the building that was on top of the manholes and cut and remove the whole manhole lid to provide better access and ventilation. Early in the project it was discovered that as well as the Melbourne Water electricity meter, Mobil Exon had a meter on the building which ran telemetry and safety systems of the petroleum pipes. A solution could not be reached to remove the Mobil Exon meter off the building and the building could not be demolished. This resulted in revisiting planning and methodology stages of the works. Upon review further complexities needed to be added to successfully complete the project which included:

- a solution was to do a minor demolition work to allow access for the equipment to clean and reline the sewer.
- a temporary gantry needed to be engineered and fabricated to lift the equipment in and out of the manhole.

The project required the removal of the old redundant penstock and operating equipment. The largest piece weighted approx. 3.5T and measured 3m x 4m. As the whole lid could not be removed off to get access with a crane, a scaffold system needed to be built to get access to the old equipment and to cut into smaller pieces so it could be lifted out using small lifting gear. During the works high H_2S and volatile gas levels were being experienced. Therefore, the proposed approach to use oxyacellene was deemed too risky to cut out the redundant equipment. The project team changed to high pressure water cutting to eliminate the risk. This changed the timeframe from a 3-4 day process to a 3-4 week but eliminated the risk to our workers.

Figure 7: new manhole cover after lift onto manhole.

Ventilation fans were installed at five access points to ensure that safe atmospheric conditions were maintained to enable works within the confined space. A rescue plan was in place in the event of emergency, which included Breathing Apparatus on standby and regular rescue rehearsals.

Cleaning and spraying the walls of the deep manholes and access shafts required construction of temporary working platforms to allow the concrete rehabilitation works to be carried out. Scaffold was installed within the manhole to allow work decks at every 2.5 metres.

Manhole (NYM003A) lid was removed to aid access and ventilation during the works. To reinstate a new lid the project team identified it would cast the lid in one piece onsite and lift into place. This allowed the team to significantly reduce the time working near the manhole, eliminating live edges and fall from heights, removed the need for a wide load transport on roads and the 6m diameter lid was safely installed onsite in one piece. The efficiency saved time for the project. Additionally, the lid was designed to precast a HDPE liner underneath the lid to increase its asset life.

The Project was awarded to JH-KBR JV in January 2018 with a project completion date of 30 May 2019. The team completed works on 31 March 2019.

The team started on site from March 2018 undertaking preliminary works including demolition works in June. DELWP consent was received in mid-July to allow the main works to commence.

The dates above were only applicable for the upgrade of the southern section of the North Yarra Deviation. However, during the works the project identified an opportunity to undertake the upgrade of the northern section while still completing the works in time for Broadspectrum to enter the area for bridge upgrade works and causing no interface with neighbouring West Gate Tunnel project works.

The team was driven to deliver double the amount of work (north and south sections rehabilitation) to deliver Melbourne Water an upgraded asset, utilise the existing bypass pump set up, and provide value for money across all works completed within the same completions date.

5. CONCLUSION

The project team delivered one of Melbourne Water's higher risk and challenging projects in recent years with no safety incidents, early and on budget. Additionally:

- delivered a project of firsts – Ribline Polyethylene Spiral liner pipe installed around corners and Kanga loader with unique and tailored excavation bucket.
- completed approximately 75 per cent of the work in confined space. It was successfully navigated safely by an experienced project team, expert subcontractors and industry leading processes and systems.
- the project team achieved an excellent safety result with no recordable injuries and a zero Total Recordable Injury Frequency Rate (TRIFR).

Challenges like our growing population, the changing urban environment and climate change require an evolution of the sewerage system to ensure that Melbourne remains a liveable and sustainable city for generations to come. The rehabilitation of the North Yarra Deviation is a critical part of the Melbourne Water sewerage system. The successful delivery of this project safely, on time and within budget by John Holland-KBR Joint Venture is an important component of Melbourne Waters overall Sewerage Strategy in achieving its commitments to our customers of Healthy People, Healthy Places and Healthy Environment.

