TRENCHLESS REHABILITATION OF CITY OF GOLD COAST'S DN600 SEWER RISING MAIN

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ABSTRACT:

Rehabilitation of the Eastern Force Main for the City of Gold Coast (City) saw the Southern Hemisphere's first installation of a kevlar reinforced Primus Line pressure liner in a sewer rising main.

The City experienced a failure of the critical DN600 mild steel, cement lined main running under Biggera Creek just upstream of the Broadwater, one of the Gold Coast's most popular marine recreational areas. The sewer rising main was submerged, encased in concrete and had four vertical bends along its length and a horizontal bend on each side of the creek. Dry weather flows were able to be diverted, but this was only a short term measure as peak wet weather flows would overload the system.

A long-term, rapid response solution was required.

Construction of a new sewer using HDD was ruled out as too time consuming. Slip lining was not an option as an adequate size HDPE pipe could not be accommodated within the host pipe due to the bends.

Thorough evaluation by the City's Water and Waste directorate resulted in Primus Line being chosen for the project despite it never having been used in a sewer rising main in Australia.

Cooperation between the City, Queensland Urban Utilities (QUU) and Sydney Water (SW) resulted in a suitable class and size of Primus Line being rapidly made available, along with the connections and tools needed for installation.

Site specific challenges including tidal conditions limited work on the pipe to a 3 hour window during low tide. Despite this, the relining portion of the project was completed in only 3 days.

1. INTRODUCTION

The Gold Coast is Australia's sixth largest city with a population of over 600,000. It is a globally recognized tourist desitination recording over 12 million visitor nights per year and is one of the fastest growing cities in Australia, with 15,000 people moving to the city each year. In 2018 the Gold Coast also hosted the Commonwealth Games.

Sewage from north of the city is conveyed primarily within two large rising mains. The DN600 Eastern Force Main runs up the eastern seaboard of the city whereas the DN1200 Western Force Main runs inland. Both Mains convey sewage to the Coombabah Sewage Treatment Plant.

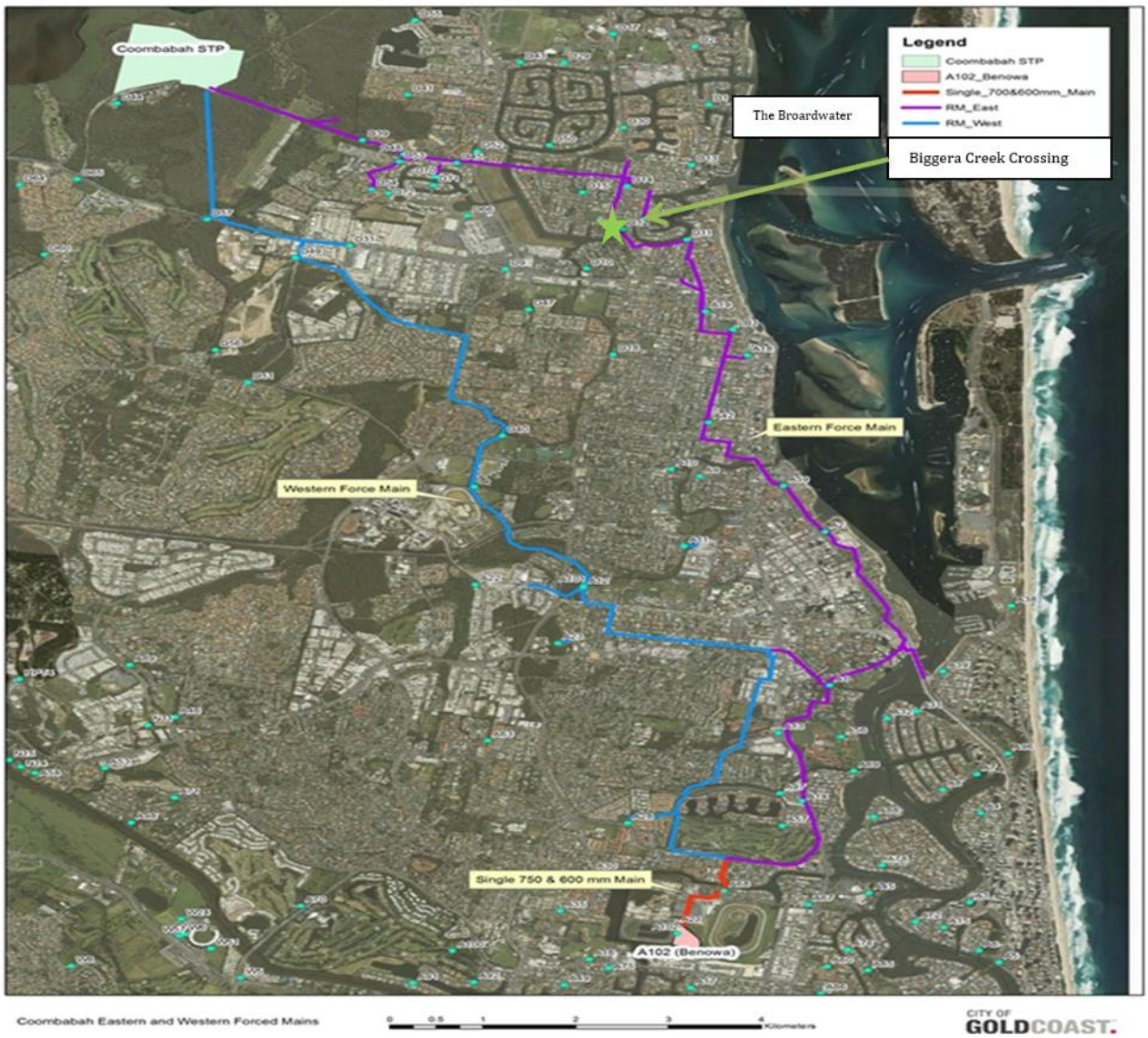

Figure 1. Eastern and Western Force Mains and the crossing location at Biggera Creek

The Eastern Force main was built in various stages during the 1970's and 1980's. It is notionally 600mm in diameter, varies in material between Mild Steel (MS) and Asbestos Cement (AC) along its length and is approximately 18km long. The main conveys sewage from approximately 200,000 people and on its journey to Coombabah, the rising main crosses beneath Biggera Creek via a DN600 mild steel, cement lined (MSCL) and concrete encased pipeline section.

At approximately 3pm on Friday 16 November 2018, the City was alerted to strange odours and discoloration of the Biggera Creek in the vicinity of the Eastern Force Main Crossing. On the same day the City's environmental team confirmed a break in the main. By that evening dive teams had completed a preliminary investigation and flows from the Eastern Force Main had been redirected to the Western Force Main. Local tankering was implemented and customers in the immediate vicinity had been door knocked to appraise them of the situation. Warning signs were erected to avoid swimming in the area and alerts via the Ciy's digital media network were issued.

As the main was encased in concrete and covered in large rocks, the dive teams found it difficult to ascertain the point and mode of failure. At that point it was decided that a repair method must be developed which could cater for a range of failure scenarios. Under Eastern Force diversion conditions there was a significant risk of potential overflow from surcharge events during wet weather so the repair of the Eastern Force Main necessitated a solution that could meet a very tight schedule.

Figure 2. Diving investigations on the Eastern Force Main crossing of Biggera Creek

2. IDENTIFICATION OF REHABILITATION OPTIONS

On Monday 19 November the City engaged with a number of internal stakeholders and construction/relining partners which are predominately in the City's infrastructure renewals programs to identify potential repair methods for the Eastern Force Biggera Creek Crossing. The following options shortlisted:

1. Repair via a HDPE slipline;
2. Repair via the Primus Line® System;
3. Isolate and re-purpose a DN375 watermain (running adjacent to the traffic brigde in Figure 2) in the area to a sewer rising main.
4. Temporary bypass line over the Biggera Creek Pedestrian Bridge.

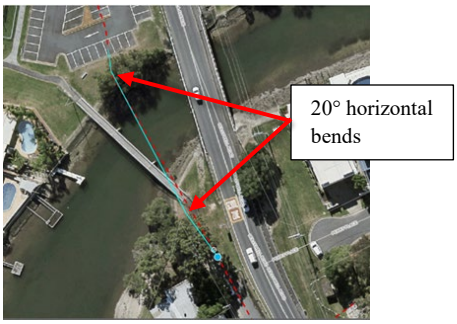

Figure 3. Plan of Biggera Creek crossing showing horizontal bends at each embankment

Due to the number of horizontal and vertical bends associated with the main, and the feedback from the City's Sewerage Network modellers that it was preferable to keep the main as near as possible to the original 600mm dia (for a long term viable solution), a HDPE slipline which would have likely resulted in a circa DN200 main was not considered viable. For the same reasons, repurposing the DN375 watermain was not preferred (although would have been adopted if a Primus Line® solution was not able to be delivered in a suitable timeframe). Finally, and although not investigated in detail, the structural adequacy of the pedestrian bridge to carry a DN600 main was questionable which eliminated this option.

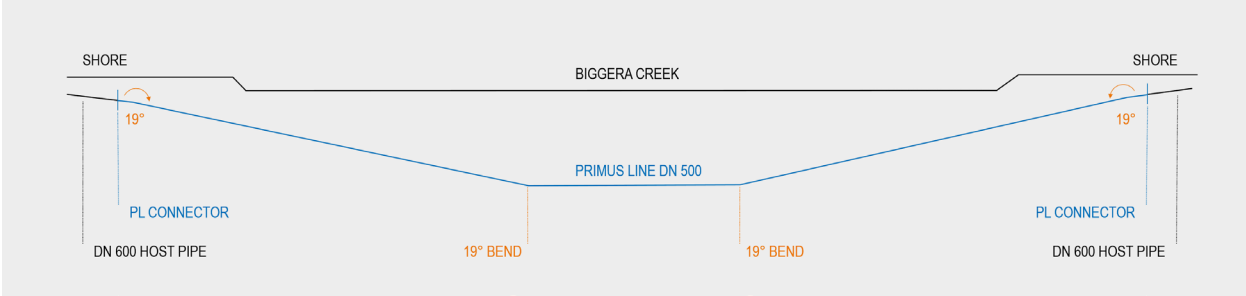

Figure 4. Long section graphic of Biggera Creek crossing showing vertical bends

3. THE PRIMUS LINE® SOLUTION

Interflow, who have been undertaking sewer relining works for the City for some time, was contacted for assistance in the development of solutions for the Eastern Force Main repair. Once it became evident that Primus Line was a likely solution, the City requested that Interflow help both facilitate the Primus Liner and installation equipment supply as well as installation of the Primus Line® system. Whilst this may sound straight forward, there were significant challenges associated with both the logistics of material supply as well as crew mobilisation and subsequent installation of the liner. These challenges included:

- Emergency response – the need to install the liner before any wet weather conditions were encountered.
- Construction Window (refer section 6 for further details) – the pipe was submerged most of the time and liner installation needed to be completed within a three hour window around low tide.

Emergency Response

Due to the high risks associated with a wet weather event and the need to return the main service as quickly as possible, an immediate response was required in order to install the Primus Liner® system. In the normal course of events, even where fittings and proprietry tools are available locally, sea freight of the liner would normally take eight to twelve weeks with air freight three to four weeks. Both options were unacceptable.

In order to facilitate an immediate installation, Interflow was able to draw upon its connections within both Sydney Water (SW) and Queensland Urban Utilities (QUU) to meet the tight time frame required for supply of materials and tools. SW had purchased 75m of DN500 Primus Liner, including the proprietary fittings which were in stock and unallocated. QUU had possession of the necessary proprietary tools required for installation of the system. Both SW and QUU agreed to support this emergency project by supplying these items subject to re-supply arrangements being met.

During this time the Primus Line Engineering team in Germany also reviewed technical data (drawings, flows, etc.) in relation to the project and confirmed that the main was suitable to be repaired with a Primus Line®.

Figure 5. Primus Liner from SW and Tools from QUU

From the time of first notification, Interflow received support from both SW and QUU to ensure supply of the liner, fittings and tools within three working days. During these three days, the City had placed orders with Primus to re supply materials that had been offered by SW and QUU.

The City was on its way to having the first sewerage pressure main repaired with the Primus Line® system in the Southern Hemisphere.

4. THE PRIMUS LINE® SYSTEM

Primus Line® Overview

The Primus line® system is a trenchless technology for the rehabilitation of pressure pipelines consisting of a flexible, high-presure liner and patented end fittings. The Primus Liner has the capacity to withstand the full maximum allowable operating pressure (MAOP) within a given pipeline subject to any de-rating that may be required due to bends. While possessing sufficient ring stiffness to be self-supporting when de-pressurised the liner has insufficient ring stiffness to withstand external dead and live loads in its own right.

Figure 6. The Primus Line® system consists of a flexible, high-pressure liner and patented end fittings

Primus Line® Composition

Primus Line® has the following composition:

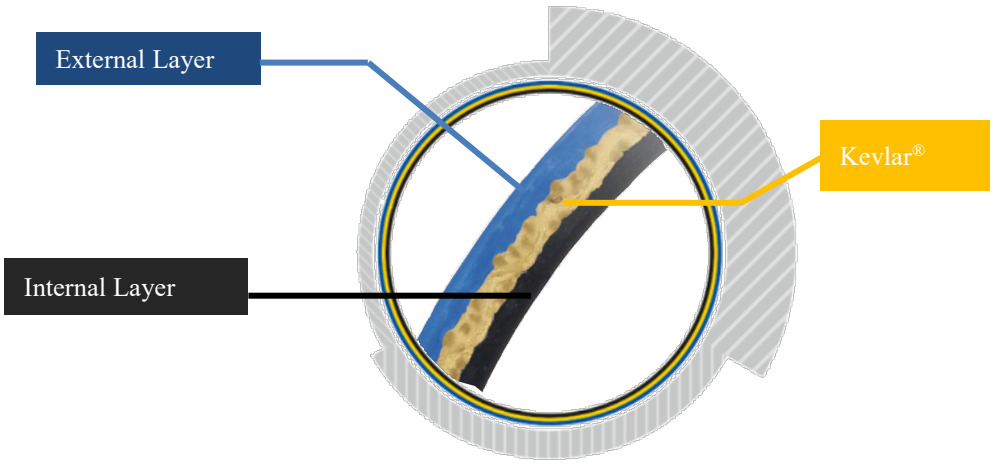

Figure 7. Primus Liner Composition

1. The external layer is an abrasion-resistant polyethylene sheath designed to provide protection for the fabric (Kevlar®) during installation.
2. The internal layer is a fluid specific coating based on either polyethylene (PE) or thermoplastic polyurethane (TPU).
3. The Kevlar® fabric is made up of seamless, woven aramid fibres as either a single-layer hybrid of Aramid and Polyester, or double layer design. This layer is designed to withstand the tensile longitudinal pulling forces during installation as well as the radial pipeline operating pressures during service.

Testing and Design Considerations

Primus Line® has carried out significant product testing in order to ensure the long-term, predictable and safe performance of the Primus Liner. This tesing includes, but is not limited to long-term regression (creep) testing, short term burst pressure testing, cyclic load testing, vacuum testing, abrasion resistance testing and potable water contact testing (including AS/NZS 4020:2005).

Liners are therefore pressure rated based on a 'lifetime factor' of 2.0 plus a factor of safety of 1.25. For example, a DN500 Primus Liner has a burst pressure of 40 bar (~4MPa or 400m hydrostatic pressure). Applying both the lifetime factor plus the factor of safety results in a pressure rating of 16 bar (~1.6MPa) before application of any de-rating factors. The pressure carrying capability increases as the diameter decreases due to constant wall thickness. The Primus Liner is manufactured in three configurations as low, medium and high pressure solutions.

A significant contribution to determining the pressure rating for the liner is the maximum bend configuration that the liner is required to negotiate. As the bend radius decreases and the bend angle increases the final pressure rating of the liner will decrease. For example, for a 1.5-D radius bend in a DN500 host pipe with minimum internal diameter of 470mm, the following pressure de-rating in Table 1 applies:

Table 1. Pressure de-rating by bend angle for DN500 Primus Liner

Bend Angle	MAOP[1] (bar)	STP[2] (bar)
0°	16	20
15°	14	17
30°	11	13
45°	9	11

[1] – MAOP = Maximum Allowable Operating Pressure
[2] – STP = Maximum Test Pressure

These de-ratings are based on the nominated host pipe internal diameter and bend radius taking into accout stress concentration factors these produce on the Primus Liner during service. These will alter and require re-calculation where the bend radius and host pipe internal diameter differ.

Primus Liner Classification

When considering how to classify the Primus Line® liner, it is worth noting that the Primus Line® system does not neatly fit either of the structural classifications defined in ISO 11295, subcommittee TC138/SC8, "Rehabilitation of Pipeline Systems", or the AWWA Manual M28. Both of these classifications employ qualitative measures to define lining systems – refer Figure 8 and Figure 9.

The main issue for Primus Line is that whilst it is generally classified as a semi-structural liner which is not designed to carry external loads when de-pressurised, it is capable of carring the pipe operating pressure for its service life. Based on the definitions, above, this would place the liner somewhere between a Class A & B as defined by ISO and somewhere between Class III & IV as defined by AWWA. On this basis, Primus Line is not adequately classified as simply being 'semi-structural'. Primus line has the capacity to be fully structural in its ability to withstand full internal pressure (MAOP). Where external loads are either not significant (e.g. above ground pipelines or shallow pipelines not subject to live loads) and/or where the host pipe is capable of resisting external loads for the duration of the service life (e.g. where pitting corrosion may be present but generalized corrosion is not), Primus Line can be considered to be a structural solution, as opposed to a semi or fully structural solution.

Liner characteristics	Class A	Class B	Class C	Class D
Can survive internally or externally induced (burst, bending or shear) failure of host pipe	✓	—	—	—
Long-term pressure rating ≥ maximum allowable operating pressure (MAOP)	✓	—	—	—
Inherent ring stiffness[a]	✓	✓	—[b]	—[b]
Long-term hole and gap spanning at MAOP	✓	✓[c]	✓	—
Provides internal barrier layer[d]	✓	✓	✓	✓

[a] The minimum requirement is for the liner to be self-supporting when pipe is depressurized.

[b] The liner relies on adhesion to the host pipe to be self-supporting when depressurized.

[c] The liner becomes sufficiently close-fit for radial transfer of internal pressure stress to the host pipe, either during installation or within a short period from initial application of operating pressure.

[d] The liner serves as barrier to the corrosion, abrasion and/or tuberculation/scaling of the host pipe and to the contamination of the pipe contents by the host pipe; it also generally reduces surface roughness for improved flow capacity.

Figure 9. ISO structural classifications for pressure pipe liners

LINER CHARACTERISTICS	NON-STRUCTURAL	SEMI-STRUCTURAL		FULLY STRUCTURAL
	CLASS I	CLASS II	CLASS III	CLASS IV
INTERNAL CORROSION BARRIER	YES	YES	YES	YES
BRIDGES HOLES/GAPS AT PIPE OPERATING PRESSURE	NO	YES	YES	YES
INHERENT RING STIFFNESS	NO (depends on adhesion)	NO (depends on adhesion)	YES*	YES*
LONG-TERM INDEPENDENT PRESSURE RATING ≥ PIPE OPERATING PRESSURE	NO	NO	NO	YES
SURVIVES "BURST" FAILURE OF HOST PIPE	NO	NO	NO	YES

Figure 8. AWWA structural classifications for pressure pipe liners

5. REQUIREMENTS FOR THE BIGGERA CREEK CROSSING

The Biggera Creek crossing had the following project-specific parameters:

Host Pipe Material	Mild Steel Cement Lined (MSCL) and Asbestos Cement
Transported Fluid	Residential waste water
Host pipe diameter	MSCL DN600 (635mm OD, 6mm WT,)
Operating pressure	5 bar (~50m head)
Length to be rehabilitated	68m

In addition to the above parameters, the pipeline section incorporated 2 x 20° horizontal bends and 4 x 19° vertical bends (see Figure 3 and Figure 4 in section 2).

Pressure Capacity

Given the nature of the bends and the actual internal diameter (>600mm), it was determined that a DN500 medium pressure Primus Liner would be rated with a MAOP = 13.5 bar and STP = 16.9 bar. With an operating pressure of 5 bar, the Primus Line® system therefore had sufficient capacity for the project specific parameters.

Host Pipe Condition

Determining the exact nature of the failure, including its actual location, had challenges that could not be resolved in the timeframe available prior to rehabilitating the section of the rising main. However it was determined,via injection of compressed air, that the failure within the creek bed was localised. On this basis, with internal pressure fully borne by the Primus Liner, it was determined that there was an acceptably high probability that the host pipe had sufficient capacity to withstand the minor external loads for its remaining required service life.

6. INSTALLATION

In addition to the challenges faced with the supply of the materials, there was a tight time frame for the installation of the liner. It was one thing to obtain the necessary equipment and materials, another thing entirely to install the the liner promptly and without incident.

Gaining access to both ends of the pipeline was difficult and heavily constrained due to the need to maintain pedestrian access around the construction site. The site was also congested, particularly on the southen side of the creek, with presence of a Trunk Water Water Main, stormwater drainage, a significant tree and a bridge abutment in the same corridor as the Eastern Force Main. In addition, with only 75m of Primus Line available from SW, the location of the cut in points to the main was critical.

Figure 10. Southen end of the Eastern Force Main – the need to maintain pedestrian access around the site was critical

The City was able to mobilise the services of the civil contractor, NTS to ensure all enabling works were carried out in preparation for the liner installation. During these enabling works, a CCTV inspection (with an inclination meter) of the main was also undertaken to ensure there were no potential issues that would cause damage to the Primus Liner during installation. This was only partially effective as visibility was lost at the tidal water level within the pipe.

These works included, but were not limited to:

- Construction of launch and receival pits.
- Removal of a section of the AC host pipe connecting to the concrete encased MSCL pipe section.
- Jetrodding (cleaning and insertion of a pull through rope) of the main prior to the installation of the liner.
- Attachment of backing flanges to the host pipe to facilitate liner installation.

Within a week of the failure of the Eastern Force Main, all enabling works were completed by NTS, materials and tools had been supplied and were on site. On Monday 26 November 2018, the liner had arrived from SW and Interflow had mobilized their specialist crew to site ready to commence installation.

The plan was to commence with pigging the line, however the DN600 pig was sized to fit the larger ID of the AC main, not the smaller ID of the MSCL main. Without this final clean and a complete CCTV inspection, the risks during installation were high. Interflow and the City assessed the risk and, due to the nature of the installation with the flexible Primus Line and the assumed localized nature of the pipe defect, opted to move forward without the benefit of pigging.

Figure 11. The pre-folded Primus Liner is winched and guided into place

Once the pre-folded Primus Liner was winched into place, pressurisation was required to break the restraining wrap which were installed at the factory, and to inflate the liner to its full diameter ready for attachment of the proprietry flanged connectors.

The issue now was the rapidly rising water table as the tide came in. There was only a three hour window from low tide to the water table covering the pipe obvert. The very narrow working window meant the installation of the connectors was required to be staged from one shift to the next to accommodate the 12 hourly tidal cycles. At the end of the first shift only one connector was fully installed and bolted together. The other connector was only partially installed and it was thought that the work that had been done would be sufficient to stabalise the work until the commencement of the next shift. The down side was that as the tide came in, the partially prepared connector was subject to significant hydrostatic force which had the net effect of de-stabilising the liner within the connector, which required rectification. The team not only managed an innovative and successful repair, but the entire Primus Line installation, which commenced at 4.00am on the Tuesday morning, was completed by Wednesday night after four separate shifts.

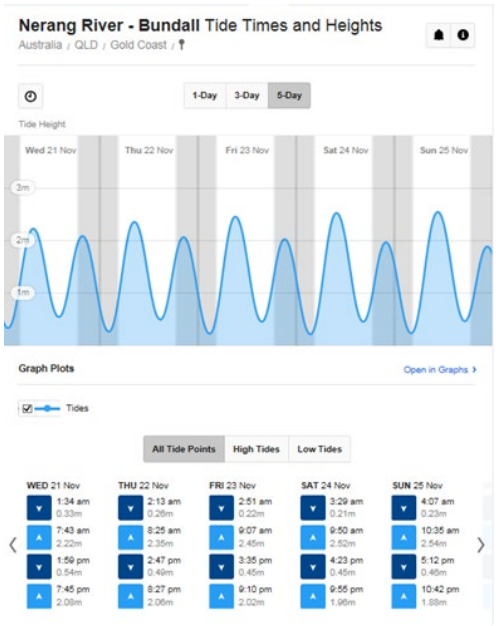

Figure 12. The incoming tide had a major impact on the available work window

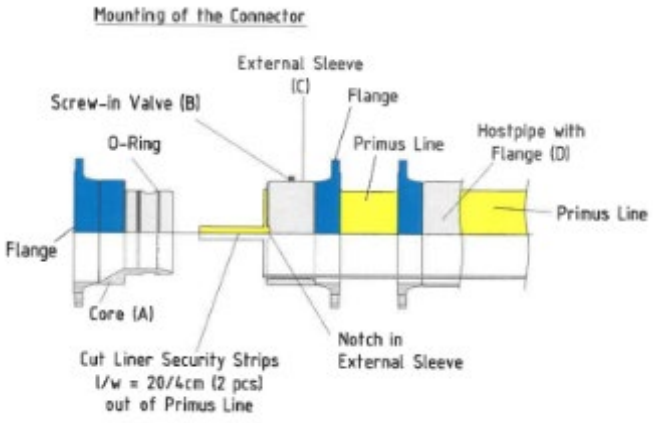

Figure 14. Primus Liner connector details

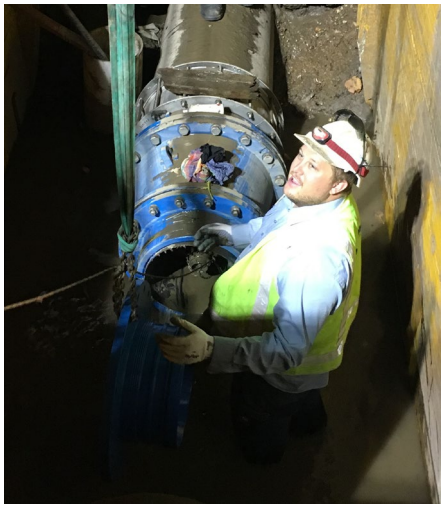

Figure 13. Key to the success of the operation was innovation in the face of adversity

The City and NTS completed all close out activities including the supply and installation of spool pieces between the Primus Line® fittings and AC pipe and thrust blocks, pressure testing, installation of air/vacuum relief valves and full site restoration following installation of the liner.

The main was ready to be placed back into service witin two weeks of the initial failure. Fortunately no significant rainfall occurred on the Gold Coast during this time and no significant issues were recorded on the Western Force Main during the diversion.

7. CONCLUDING REMARKS

It is often said that in chaos one will often find opportunity. In the case of the failure of the Eastern Force Main on the Gold Coast, a DN600 main which conveys the sewage from approximately 200,000 customers, the event enabled the Southern Hemisphere's first installation of Primus Line® within a pressure sewerage main.

The works were completed within two weeks and was only possible by the generous support of Queensland Urban Utilities, Sydney Water, Inteflow and NTS. The main, which failed in November 2018 was returned to service well before the Christmas tourist peak period on the Gold Coast.

A video showcasing this project can be found at https://youtu.be/swlUdyY1tlU

The City'sWater and Waste team are currently working with Primus Line and Interflow on a range of other opportunities to reline "difficult to get at" water and sewerage mains throughout the Gold Coast.

