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Simpson Street Tunnel Rehabilitation and Lining Stage 1

Rohan D McKinnon [1*] and Luke Coughlan[2]

[1] *Senior Projects Engineer, Warrnambool City Council*
[2] *Manager Infrastructure Services, Warrnambool City Council*

[*] *Corresponding author. Email: rmckinnon@warrnambool.vic.gov.au*

ABSTRACT: The Simpson Street drainage tunnel in Warrnambool was built in the early 1970's as a Whitlam era RED Employment scheme and allows a large area of East Warrnambool to drain directly into the Hopkins River to the south. Council is now looking after a failed piece of critical drainage infrastructure. A video walk of the 700 metre long tunnel reveals that the tunnel is unlined for 384 meters and cut through limestone of varying quality and strength. In the unlined section, the tunnel is scouring out along weak seams in the limestone and getting wider as areas erode. The worst section of tunnel is located under the Geelong to Warrnambool rail line. The remaining 316 metre is lined with a steel multi plate culvert, which after 50 year in service has rusted out along the invert, what is occurring behind the steel culvert is uncertain. In 2006, Council engaged consultants to prepare an options paper for future works in the tunnel. The investigation identified the tunnel was undersized for the catchment it services and supercharging flows were a major risk of damaging or collapsing to the unlined tunnel sections. 5 options where investigated and the preferred solution was lining the tunnel with no capacity increase and diverting part of catchment from the tunnel to another outfall. In 2015, Council completed lining of 118m of tunnel with the Tunneline (cast in suit concrete liner) process. The next section of lining works is underway which will see a Glass Fibre Reinforced Pipe (GFRP) liner inserted to the tunnel via pipe jacking method, and the space around the liner grouted. In total, Council is investing $7,000,000 in tunnel rehabilitation works and storm water diversion works to alleviate problems created 50 years ago by poor planning and under investment in technical expertise.

1 Introduction

This report looks at the recent maintenance and rehabilitation of the Simpson Street Tunnel, Warrnambool since 2008.

The Simpson Street drainage tunnel is a major piece of drainage infrastructure that Warrnambool City Council owns and maintains.

The Simpson Street tunnel is one of 6 drainage tunnels that the Council is responsible for.

The tunnel was created to drain low-lying land in the Warrnambool East area and services a catchment of 147 Ha or just over 1% of the City by area. Figure 1 shows a plan of the tunnel.

2 Warrnambool

Warrnambool City is located on the Victorian south-west coastline, 265km from Melbourne, at the western end the Great Ocean Road and home to 34862 [1] residences.

Significant natural features include the estuaries of the Merri and Hopkins rivers and the expansive Lady Bay which in winter and spring is a nursery for southern right whales.

The municipality is also situated within Victoria's most productive farming region.

Prior to the arrival of Europeans, Warrnambool was home to a significant indigenous population. In 1918 Warrnambool was declared a city.

In recent years Warrnambool's population has grown rapidly. Warrnambool City Council is planning for our population to reach 50,000 by 2036.

Warrnambool is a major employment base with significant dairy and meat processing factories along with a range of industries which service agricultural enterprises.

Warrnambool generates a gross regional product of about $1.6 billion which accounts for over 20 per cent of the Great South Coast region's economic output despite the municipality covering less than one per cent of the region's total area.

Each year Warrnambool City Council manages operating budgets of between $70 million and $90 million, depending on the capital works projects being undertaken

3 Tunnel Inspection 2006

Consultants were engaged to undertake an engineering investigation and provide a report.

The first attempted inspection utilised a tractor mounted camera, with the intent to inspect the tunnel remotely via the tractor camera unit. The inspection was abandoned after just a few meters, the tractor unit was not able to negotiate the tunnel floor and bogged down.

The second inspection, was undertaken using hand held video and still cameras, this was more successful at getting results however entailed greater risk due to confined space to enter into a tunnel that had not been inspected on over a decade.

The results of the inspection were reported to Council, the overall assessment was a tunnel in poor condition.

The first reach from MH 2 to MH 3 was lined with 1200 mm dia galvanised steel multi-plate corrugated culverts. The invert of the culvert is rusted out and the flood of the tunnel is showing through. (See Figure 2). There is no information on the soil condition outside the culvert.

The second reach from MH 3 to MH 4 is also lined with the galvanised steel multi-plate corrugated culverts, again the invert was rusted out and the floor shoring through. There were also two sections of multi-plate dislodged and protruding down into the flow, behind the dislodged section were shoring timber and loose rubble and rocks. (See Figure 3)

The third reach from MH 4 to MH 5 was lined with 30 metres of galvanised steel multi-plate corrugated culvert. After 30 metres the tunnel is general un-lined natural sandstone ground. There are isolated sections of sandstone block walls and blue stone block walls that had been constructed to control poor section of the tunnel.

Co-located in the section of tunnel is a 300mm diameter sewer, controlled and operated by Wannon Water. The sewer is encased in concrete and blue-stone 600mm wide and 600mm high encasement. (See Figure 4).

The length of this section of tunnel is easily measured but the width and height are a bit like measuring the width of the Isle of Skye.

The tunnel is nominal 1600mm high and 1200mm wide in an arch profile, however there is significant variability due to hard material not being removed at time of construction and area that had eroded due to the flow of water over time. Both vary considerably from the nominal dimensions.

Overhead, above this section of tunnel is the Geelong to Warrnambool rail line, some 15 metres above.

This section of tunnel was rated very poor and represented the highest risk of failure to Council and our community.

At MH 5 the sewer and stormwater tunnels split. The sewer continues south along Simpson Street and eventually converts from a tunnel to cut and cover sewer.

The stormwater tunnel changes direction leaving Simpson Street and crossing EJ King Park at 45 degrees to the river outfall.

The section of tunnel from MH 5 to outfall is mainly unlined. (See Figure 6). There were two sections of timber shoring and two sections of corrugated culverts of a different design to the upstream sections. The final outfall is a 900mm diameter flush joint concrete pipe.

The timber shoring had collapsed and was not supporting the roof, material had eroded from the roof leaving the shoring free standing in the tunnel. (See Figure 7). The collapsed shoring was partially blocking the flow in the tunnel reducing capacity.

All of the maintenance holes are circular shafts that are unlined. The shafts contained black iron ladders and support rings that were in very poor condition and unsafe for use by personnel.

3 Hydraulic capacity

The consultant also completed a hydrologic and hydraulic analysis of the tunnel.

The catchment in a 1 year ARI (rational method) storm event would produce runoff of 5.4 m^3/ sec. [4]

The hydraulic capacity of the tunnel at full tunnel flow was estimated between 3.3 to 2.4 m^3/sec. [4]

"The full pipe capacity of the tunnel is exceeded in the calculated 1 year return interval suggesting that the tunnel will be flowing under pressure for minor storm events and the likelihood of regular upstream flooding is high" [4]

4 Strategy

The consultants had suggested some long term solutions to increase the strength and structural stability of the tunnel. These options would significantly increase the longevity of the tunnel and its stormwater conveyance. The options suggested are:-

1. **Do Nothing**

   The risk of failure remains and significant works will be required at a future stage. If a tunnel failure occurs, then Council could be exposed to major rectification costs in the Simpson Street area.

2. **Simpson Street Tunnel Partial Re-Sleeving and Total Catchment Upgrade - $5.5m**

   This provides a longer term solution and can be carried out in 2 stages, as the re-sleeving component is only part of the total solution. Stage 1 is to partially re-sleeve the tunnel between MH 4 and 5, which has an estimated cost of $1 million. This option requires the creation of a wetlands / retarding basin to protect downstream flooding in the Russell's Creek catchment. The re-sleeving of the tunnel will not increase the capacity and minor flooding will be experienced at approximate 2 year intervals; however it will rejuvenate the tunnel asset and ensure that low flows are discharged. This will protect the integrity of properties in the Simpson Street area from experiencing damp and swampy conditions.

3. **Simpson Street Tunnel Re-Sleeving and New Tunnel Alignment - $8.7m+**

   This option increases the flow capacity by duplicating a new tunnel at 1.5m diameter pipe parallel to the existing tunnel and re-sleeving the existing tunnel with a smaller diameter pipe. The works must be carried out in one stage and there are a significant number of unknown factors when digging which could increase the price significantly. This option does not improve any drainage networks upstream from the tunnel, and the existing catchment infrastructure may need to be upgraded and this cost has not been included in the proposal.

4. **Larger Diameter Tunnel along Alignment of Existing - $10.6m+**

   The works must be carried out in one stage and there are a significant number of unknown factors when digging which could increase the price significantly. This option does not improve any drainage networks upstream from the tunnel, and the existing catchment infrastructure may need to be upgraded and this cost has not been included in the proposal.

5. **Simpson Street Tunnel Back Filling and New Tunnel Alignment - $10.4m+**

   The works must be carried out in one stage and there are a significant number of unknown factors when digging; factors which could increase the price significantly. This option does not improve any drainage networks upstream from the tunnel, and the existing catchment infrastructure may need to be upgraded and this cost has not been included in the proposal.

Preferred Option

Option 2 was the preferred work method and is expected to slightly reduce the capacity of the existing tunnel whilst improving the level of service for the balance of the catchment and therefore obtaining a higher level of flood protection than currently exists.

It includes partial tunnel re-sleeving stage 1, proposed diversion drains, proposed relief drains, proposed channel upgrading and also proposed wetlands within the confines of the Warrnambool Racing Club grounds stage 2.

Council also implemented a number of short term strategies to mitigate the risk of tunnel failure:

- Increase the frequency of inspections of the tunnel.
- Undertake works to clear rubble and fallen timber.
- Undertake works to improve access to the tunnel by replacing rusted black iron access ladders.
- Repair the dislodged multi-plate culvert sections. (See Figure 9)

Stage 1 works

In 2015 Council engaged a Contractor to under and Design and Construct contract to line the most critical section of the tunnel from MH 5 toward the existing multi-plate culvert south of MH 4.

The chosen process for lining the tunnel was "Tunneline"®. It consisted of building a steel form-work in the tunnel with a 100mm clear annuls all-round the form-work. The gap is filled with concrete pumped into the form by port at the overt of the form works.

The concrete mix used in this process was a high strength concrete with Dramix fibre reinforcement.

To accommodate the sewer in this section of tunnel a modified ovoid profile was used. (See Figure 10). The modified profile maintained the invert of the tunnel near the original level and maximized the water way area.

An alternative install a 900 diameter circular profile was investigated, however this profile would have raised the tunnel invert 300 to 400mm to provide protection of the sewer, it was not accepted as a solution.

Figures 11-15 show the Tunneline works from excavation to finished liner.

The Contractor used a tunnel gauge to identify an area of rock that needed to be removed from the tunnel to maintain the Tunneline thickness.

The forms were setup in 10 metre sections and a bulkhead established at the upstream end to contain the concrete, the downstream end contained by the previous Tunneline works.

The annuls between the tunnel and the forms were filled with concrete supplied from a concrete pump located at the surface.

Once the concrete was poured the forms were tapped to remove air bubbles at the surface of the forms.

The first 118 metres of tunnel from MH 5 toward MH 4 was lined using the Tunneline process. An early break in the weather in April 2016 put a stop to works in the tunnel, with rainfall every few days interrupting works.

Following the abandonment of works in April 2016, no common ground could be reached between the Contractor and Council to restart works.

The Tunneline contract was mutually abandoned in 2017 due to frustration of both parties.

Stage 1 – Second lining contract

In late 2017, Council tendered again for tunnel lining works for the remaining section from the end of the Tunneline to MH 4.

During the Tunneline works a large void over the first 30 metres of multi-plate culvert was discovered downstream of MH 4. (See Figures 16-17). The demolition of the culvert and replacement with liner was included in the works.

The selected liner treatment for this section of works was a Glass Fibre Reinforced Polymer (GFRP) liner. The liner again follows the modified ovoid profile as show in Figure 18.

The liner was constructed in 4 parts, the base, the side walls and the arch roof. Each section is connected by a deep tongue and grove joint 60 mm deep. (See Figure 19).

Access to install the GFRP section was provided by removing the cover slab on MH 4. (See Figure 20).

Again the tunnel was excavated to ensure a consistent clearance from the GFPS profile. Figure 21 shows the tunnel following excavation ready to accept the GFRP liner.

The liners section were assembled in place in the tunnel, a 60 mm deep tongue and groove joint between each panel provides the connection, the joint is filled with selastic sealant. Figure 22-23 show the units being placed.

Figure 25 shows the inside of the tunnel before grouting, the inside surface of the GFRP pipes is smooth, there is some roughness at the joints, but a much improved product over the unlined tunnel.

A very high slump grout 290mm slump was used to fill the annuls between the liner and the GFRP pipe. The grout had a high fly ash content, to slow hydration and achieve the high slump value. The strength of the grout is in the order of 2 to 10 mpa.

The GFRP liner was installed between January and April 2019, over a 4 month period.

Table of cost

Item	Description	Amount

		(Ex gst)
1	Project management and supervision of works	$150,000
2	Tunneline works	$530,000
3	GFRP lining works	$1,285,000
Total		$1,965,000

Cost per meter $9500 / meter to tunnel treated.

5 Conclusion

Both the Tunneline and GFRP liners have addressed the poor condition of this unlined tunnel section. The risk of erosion and tunnel collapse has been greatly reduced in the treated section.

The liners have resulted in some loss of total cross section of the tunnel, but both Tunneline and the GFRP liner have reduced the roughness and improved the hydraulic efficiently of the tunnel.

The number of snag points for rubbish / rags in the tunnel have been significantly reduced.

The total investment in tunnel rehabilitation to date has been in the order of $2 million, this has allowed Council to treat 205 metres out of the 700 metre of tunnel.

There still remains 300 metres of multi-plate culvert that needs treatment for a rusting invert and 200 metres of tunnel form MH 5 to the outfall that is unlined and needs treatment.

From a community perspective, there is very little to show on the surface for 8 months of works underground, but our community in the East Warrnambool area now have a reduced risk of flooding from tunnel failure.

2.2 Figures and Tables

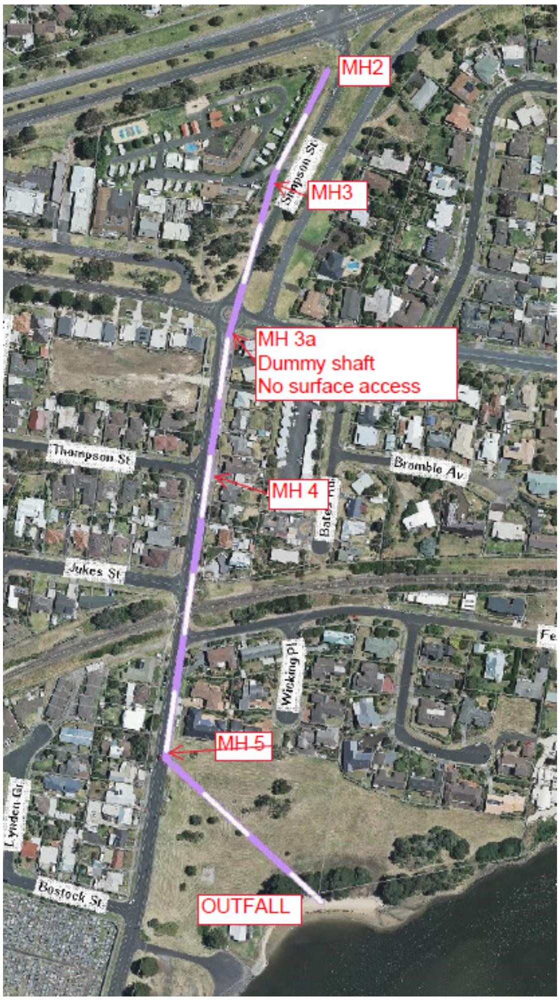

Figure 1: Plan of tunnel

Figure 2: Reach 1 galvanised steel multi plate culverts, not rusted floor. [2]

Figure 3: Dislodged section of multi-plate. [2]

Figure 4: Tunnel between MH 4 and 5 looking upstream with sewer encasement on left [2]

Figure 5: MH 4 to MH 5 section of sandstone wall, looking upstream [2]

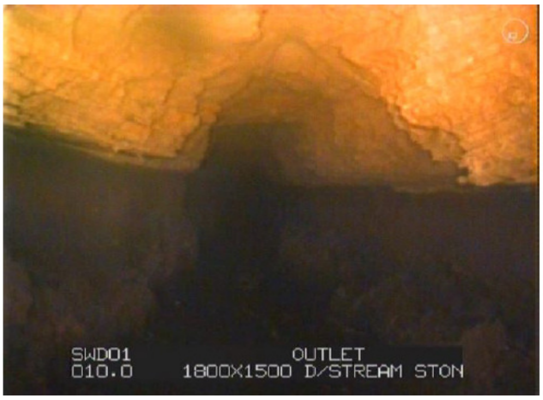

Figure 6: Downstream of MH 5 showing different stratum [2]

Figure 7: Downstream MH 5 collapsed timber shoring

Figure 8: Figure 8 corrugated pipe downstream MH 5


Figure 9: Repair Multi plate culvert, stainless steel plate with construction foam

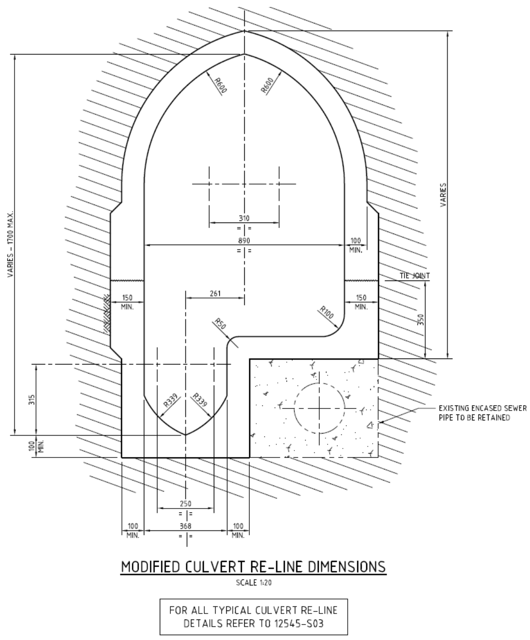

Figure 10: Tunneline profile

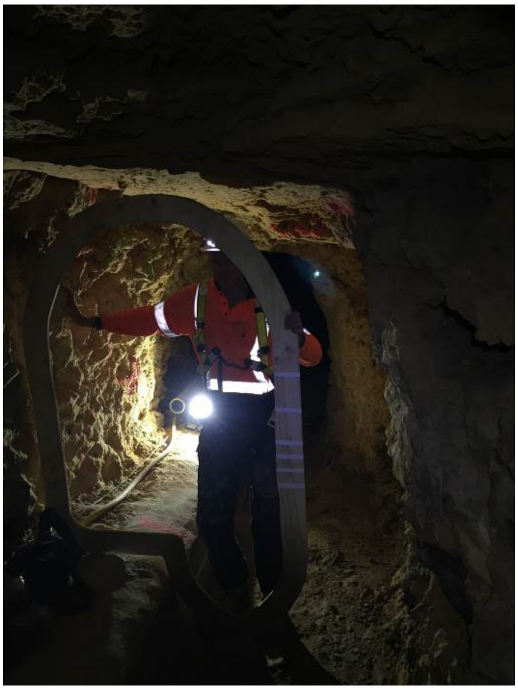

Figure 11: Preparation for Tunneline profile, tunnel gauge

Figure 12: Tunnel excavated to size for Tunneline

Figure 13: Tunneline form work with concrete hose in place

Figure 14: Tapping forms to remove air bubbles with hammer

Figure 15: Tunneline after form striped

Figure 16: Entrance to void over multi-plate culvert

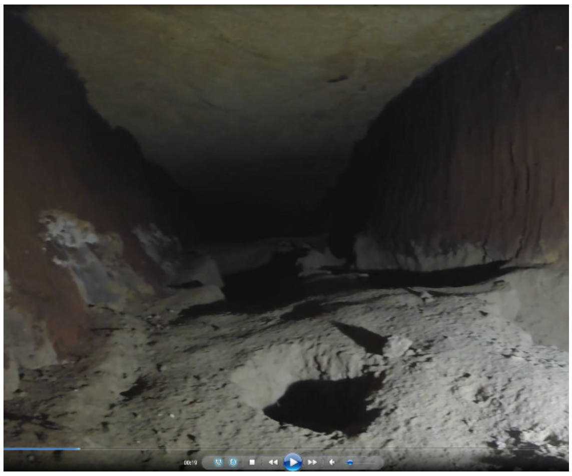

Figure 17: Void over multi-plate Culvert.

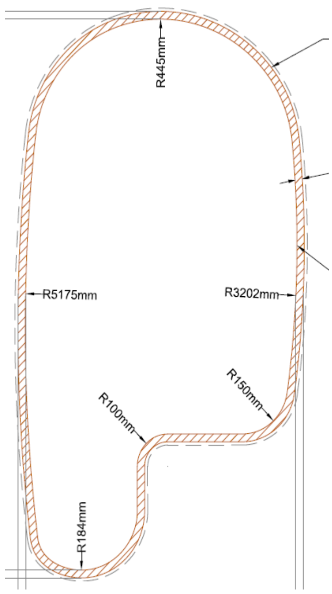

Figure 18: GFRP liner modified ovoid profile

Figure 19: GFRP liner units awaiting installation

Figure 20: MH 4 20 meter deep, cover slab removed to provide access to tunnel

Figure 21: Tunnel downstream of MH 4, note sewer exposed

Figure 22: GFRP section being lowered into tunnel

Figure 23: GFRP section being assembled

Figure 25: Grout hose in place

Figure 24: GFRP liner ready for grouting

Figure 26: Grout 290 mm slump being pumped into tunnel

Acknowledgements

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References

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