NORTHSIDE STORAGE TUNNEL – LANE COVE RIVER CROSSING FROM INVESTIGATION TO COMPLETION

Paran Moyes
Coffey Geosciences Pty Ltd

The Northside Storage Tunnel project is a system designed to collect and store sewage that presently enters Sydney Harbour from four major overflow points on the Northern Suburbs Ocean Outfall Sewer (NSOOS). The overflow of sewage during wet weather from the NSOOS is the main source of pollution for Sydney Harbour.

The Northside Storage Tunnel is a rock tunnel system comprising a 15.8 kilometre tunnel from Lane Cove River to North Head Sewage Treatment Plant and a 3.7 kilometre northern branch tunnel to Scotts Creek, Castle Cove. The crossing beneath Lane Cove River posed particular challenges in both the investigation and construction stages. This paper presents the investigation procedure, the geology encountered, the geological model developed, and the required design and subsequent construction.

1 INTRODUCTION

The Northern Suburbs Ocean Outfall Sewer (NSOOS) system is the main sewer collection system for the north shore of Sydney. At present, in times of heavy rainfall this system is inundated by more sewage and water than it was designed to carry. The majority of the excess enters the harbour at four of some twenty five overflow points. The Northside Storage Tunnel (NST) is designed to capture the flow from the four largest overflows. These overflows are located at Lane Cove River, Tunks Park, Northbridge, Scotts Creek in Castle Cove, and Quakers Hat Bay, Mosman. The captured sewer water drains to the east and is stored for later treatment and discharge from the North Head Sewerage Treatment Plant.

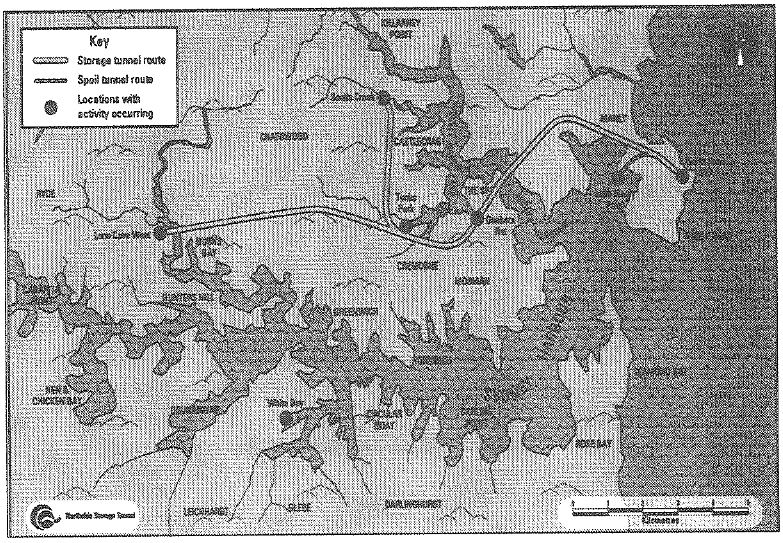

Figure 1 Northside Storage Tunnel Alignment (Sydney Water Web Site, 2000)

The NST is being constructed on an accelerated time frame to be ready before the Sydney 2000 Olympic Games. To facilitate this, the tunnel was designed with one construction methodology, whereby construction was undertaken entirely in hard rock. This required the vertical alignment of the tunnel being taken below the deep paleochannels at Lane Cove River, Middle Harbour and Manly and terminating at North Head with an invert level of RL –97.5m (AHD). The tunnel horizontal alignment essentially follows the existing NSOOS. (Parker et al 1998)

2 LANE COVE RIVER CROSSING

The Lane Cove River Crossing of the NST has involved tunnelling with a 3.8m diameter Tunnel Boring Machine (TBM). The tunnel was bored in a westward direction from the Tunks Park construction site. The tunnel passes beneath the river with an invert level of RL -43m and a horizontal alignment some 30m downstream of the existing NSOOS siphon tunnel (Coffey Report S10901/14-AG).

The Lane Cove River Drive of the NST was not always planned to cross beneath the river. At various stages during the initial phase of the project the tunnel was terminated at either the western or eastern shores of the Lane Cove River. The decision making process was influenced by the fact that the existing overflow is on the eastern shore and there was the possibility of future expansion of the NST to the western suburbs.

In February 1999, a decision on whether to proceed with the crossing of the Lane Cove River had to be made. More information was required to make that decision and as a result an investigation was undertaken.

3 INVESTIGATION OF THE LANE COVE RIVER CROSSING

The investigation of the crossing of the Lane Cove River focused on the paleochannel structure and depth beneath the river sediments, and whether the bedrock had been subjected to stress relief and valley floor bulging. During the initial investigation phase (mid 1998), a borehole (NS20) was drilled on the eastern shore of the river in the vicinity of the existing NSOOS siphon, tunnel and overflow. The emphasis of the later investigation (early 1999), consisting of NS42 and NS43, was towards the centre and western side of the river.

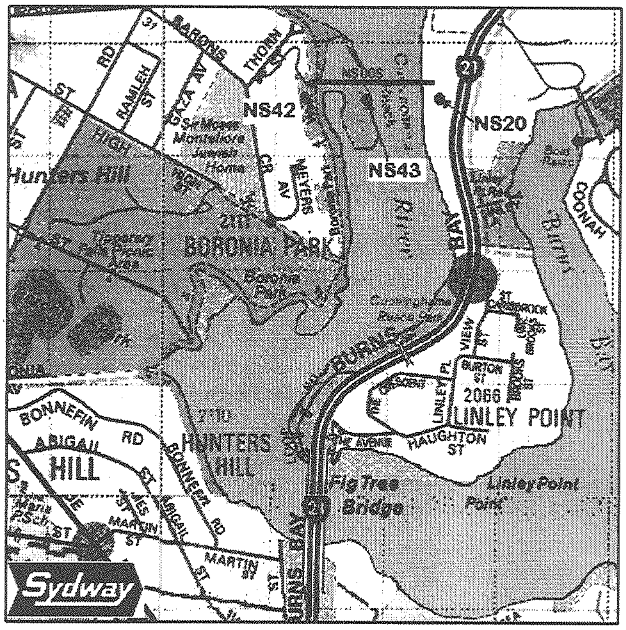

Figure 2 Location of the geotechnical investigations

Drilling work conducted for the NSOOS tunnel in 1928 had found the paleochannel to be located under a mangrove island on the western side of the Lane Cove River. In that investigation, 18 boreholes were drilled from the surface to the top of rock with three boreholes penetrating the rock. A cross section based on the 1928 investigation is shown in Figure 3 below.

In order to assess the accuracy of the 1928 borehole data and define the location and level of the bedrock paleochannel downstream for the proposed NST alignment, a series of three parallel seismic refraction lines were performed across the river. This data was used to locate an inclined borehole (NS43) drilled westwards towards the centre of the paleochannel, from the only accessible place on the mangrove island. Another borehole (NS42) was drilled vertically on the western shore at the site of the drop shaft and TBM arrival chamber.

Borehole NS42 was drilled using a truckmounted drilling rig. HQ-3 coring was commenced at the surface (RL 17.83m AHD) and terminated at 70.14m depth (RL –52.3m AHD).

Borehole NS43 was drilled using a Gemco HC10 drilling rig mounted on a Yanmar 8 wheel ATV, supplied and crewed by McDermott Drilling. The drilling rig was delivered to the site by barge. It was driven onto the mangrove mud flat, where it was jacked up onto a stable platform of wooden blocks above the high tide level.

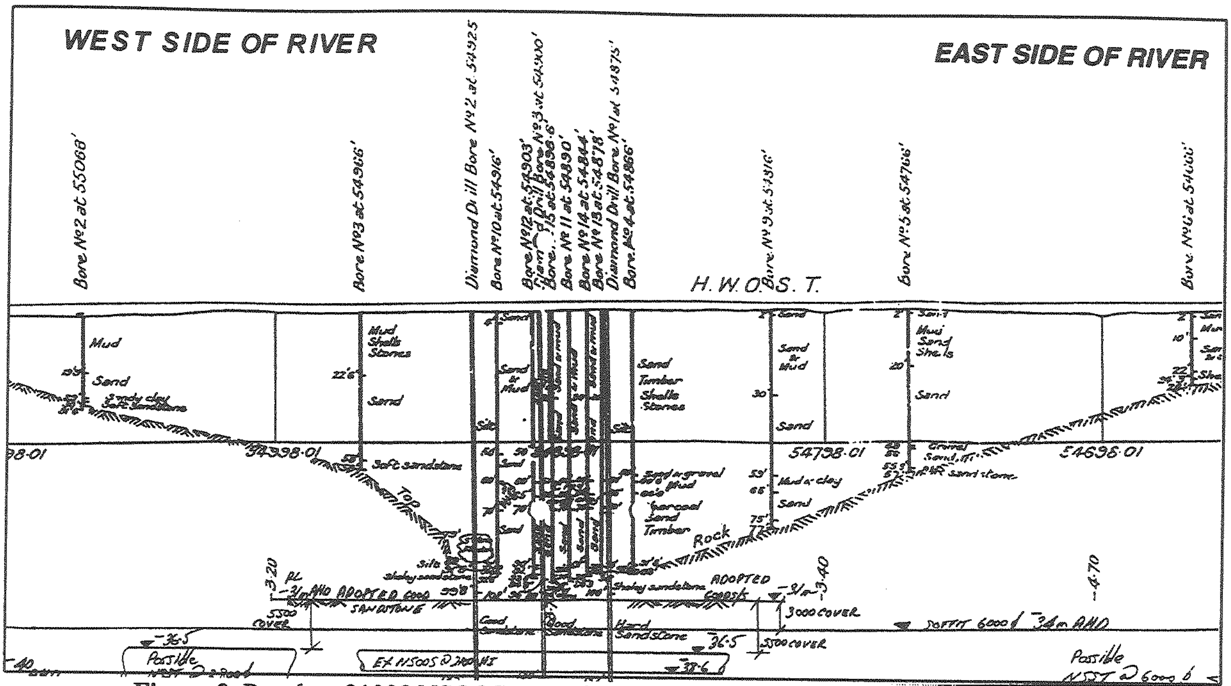

Figure 3 Results of 1928 NSOOS geotechnical investigation (Dept of Public Works Archives)

The NQ-3 sized borehole was angled at 60 degrees above the horizontal. The sandstone was intersected at an inclined depth of 26.56m (RL -22.5 m AHD). Water pressure testing (packer testing) was performed at six metre intervals. The borehole was terminated at an inclined depth of 65.33m (RL –56.1m AHD).

The major geological features intersected by borehole NS43 included:

A 1.67m no core zone. This was part of a three metre thick, extremely weathered, laminate band. This occurred at RL –27.5 to –30.5m AHD.

Low angle defects such as clay seams and parts occurred with defect spacings of 50 to 500mm from RL –23.3 to –36m AHD.

Intense low angle shearing and fracturing, with subvertical jointing and high rock mass permeability was evident between –33.4 to –36m AHD.

The geophysical investigation was extended to include surface to borehole tomographic imaging out from borehole NS43. This seismic work indicated that there was a sub horizontal zone of rock from RL – 30 to –36m AHD that had a lower seismic velocity than surrounding rock. A lower seismic velocity is indicative of fractured rock where major stress relief has occurred. The lower seismic velocity zone was correlated with the low angled shear features and high permeability zone in NS43 to represent a zone of stress relief beneath the paleochannel. The plot of the surface to borehole tomography is shown in Figure 4 below.

Subsequently a recommendation was made that the tunnel vertical alignment at Lane Cove River be lowered one tunnel diameter, so that the tunnel profile was below this feature. The lowered tunnel alignment provided a rock cover of about 11m.

Geological correlation between the three Lane Cove River boreholes (NS20, NS42 and NS43) was difficult due to the the 170m spacing between holes. However, a 3m thick siltstone unit was correlated between the three boreholes suggesting no significant vertical displacements in the geology beneath the river.

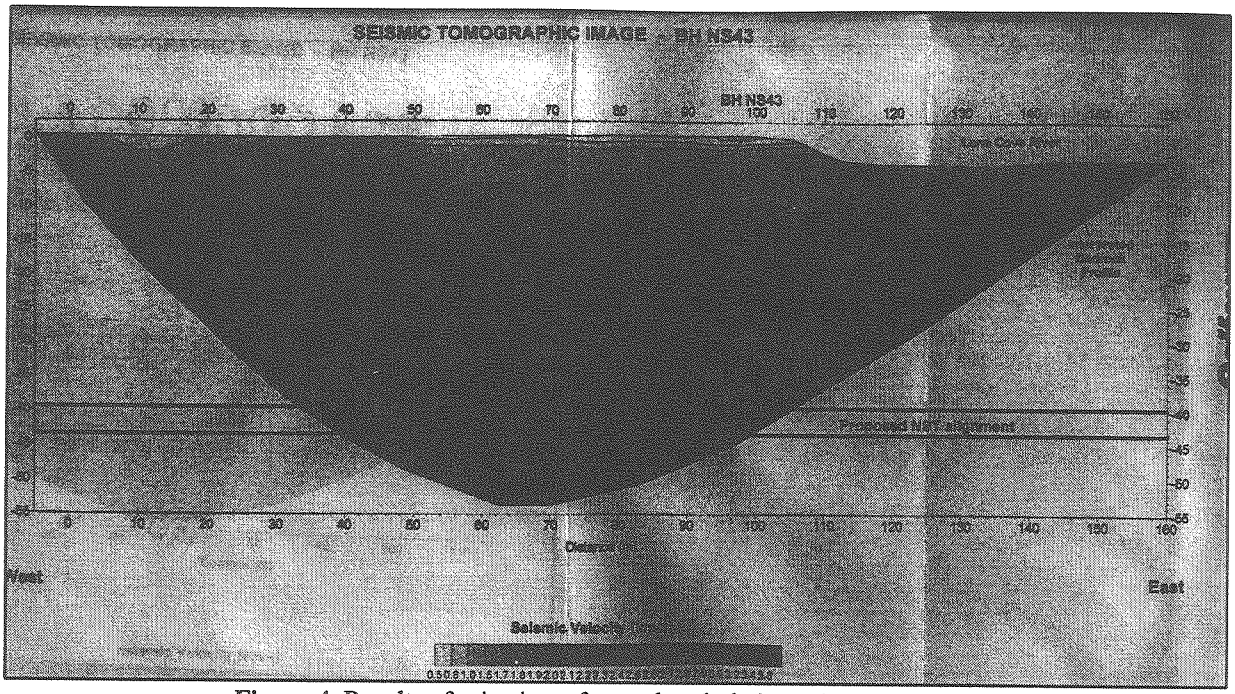

Figure 4 Results of seismic surface to borehole investigation for NS43

4 CONSTRUCTING THE TUNNEL

The Tunks Park to Lane Cove Drive of the NST was excavated using a 3.8 m diameter Wirth TBM. The majority of the tunnel was excavated through massive and cross bedded sandstone. Roof support was designed as rows of four rockbolts of between 1.8 and 2.4m length. The tunnel reinforcement was designed without a central rockbolt in the crown because the TBM's central beam did not allow the drilling of a vertical hole for rockbolt installation. Due to the occurrence of stress induced spalling in the roof and/or where shale interbeds were evident, steel mesh was installed prior to the four rockbolts.

The tunnel geology between boreholes NS20 and NS43 consisted of sandstone with interbeds of laminite and shale lenses that were found to be laterally quite variable. Subsequently, correlating the structure between the boreholes was quite difficult. The following figure (Figure 5) illustrates the geology encountered by the tunnel and possible correlations of features found in the boreholes.

At chainage 6445 m from Tunks Park and beneath the Lane Cove River water inflow caused problems with the removal of muck from the tunnel face. This was revealed to be emanating from a low angle shear zone (thrust fault). Rock cover at this point was approximately 40m and the tunnel was 120m from the deepest part of the paleochannel. The thrust fault was encountered beneath the channel of the Lane Cove River and not beneath the paleochannel, which had been the target of the geotechnical and geophysical investigation. This shear zone, up to one metre thick, manifested itself as a seam of clay and crushed rock. The shear zone rose up the sidewalls of the tunnel over a distance of approximately 20m, from the knee to the tunnel crown. At this point a large amount of spalling occurred in the shoulders and the crown. Significant water inflow still occurred. The unexpected tunnelling conditions resulted in the adoption of a probe and grout procedure being instigated to alleviate the water inflow problems and improve conditions for the TBM. Tunnel progress was impeded for two weeks. The tunnel support provided in this section included steel sets, steel straps, dowels and rockbolts. Timber blocking and timber cribbing were also required as the roof of the tunnel opened up to a span of five metres due to rock fallout.

Tunnelling conditions improved as the shear zone rose above the crown of the tunnel. However, the feature was assessed to trend parallel to the crown of the tunnel for approximately 30 metres. Significant water inflow occurred as rockbolt and dowel holes penetrated the feature.

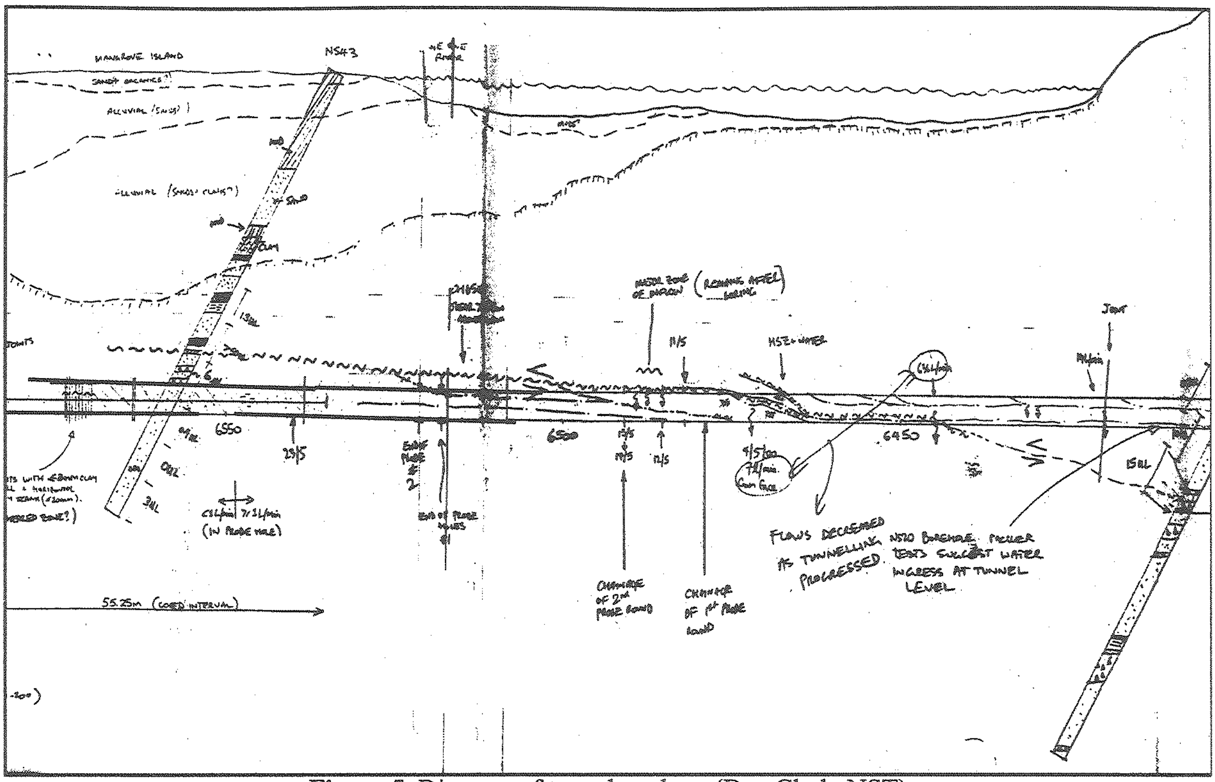

Figure 5 Diagram of tunnel geology (Dan Clark, NST)

5 CONCLUSION

The geotechnical investigation at Lane Cove River involved targeted drilling and seismic tomographic imaging that identified a stress relief feature below the paleochannel which resulted in a recommendation to lower the tunnel horizon. During tunnelling a low angled thrust fault feature was intersected some 120m from the paleochannel floor and this feature caused some tunnelling and support difficulties. While both boreholes NS20 and NS43 intersected shear features, which can be correlated to the tunnel feature, the shear zone was outside the area of the targeted investigations. The geophysics profile did illustrate the extent of the shear zone closer to the paleochannel but did not provide the complete picture of the feature intersecting the tunnel horizon further to the east.

6 REFERENCES

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