CASE STUDY

CityLink Groundwater Management

wetrocks

Aquifer

A layer of soil or rock with relatively higher porosity and permeability than surrounding layers. This enables usable quantities of water to be extracted from it.

Fault zone

A area of rock that has been broken up due to stress, resulting in one block of rock being displaced from the other. They are often associated with higher permeability than the surrounding rock

Watertable

Water table is the upper surface of groundwater in the aquifers.

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About CityLink

CityLink is a series of toll-roads that connect major freeways radiating outward from the centre of Melbourne. It involved the upgrading of significant stretches of existing freeways, the construction of new roads including a bridge over the Yarra River, viaducts and two road tunnels. The latter are beneath residential areas, the Yarra River, the botanical gardens and sports facilities where surface construction would be either impossible or unacceptable.

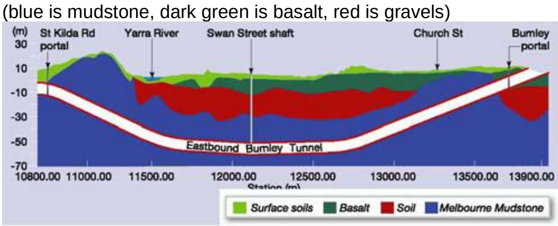
The westbound Domain tunnel is approximately 1.6km long and is shallow. The east-bound Burnley tunnel is 3.4km long part of which is deep beneath the Yarra River. The tunnels each accommodate three traffic lanes.

The construction of the Burnley Tunnel required the engineering management of significant groundwater issues. These issues included the need to modify the design during construction, to overcome post-construction issues, and requires ongoing active management today.

Geology and Aquifers – Burnley Tunnel

The Burnley Tunnel is primarily excavated through Mudstones and some Basalt (Figure 1). Overlying the mudstones is a thick sequence of gravels (Moray Street gravels) and basalt that are directly in connection with the Yarra River.

FIGURE 1. GEOLOGY OF THE BURNLEY TUNNEL
(blue is mudstone, dark green is basalt, red is gravels)

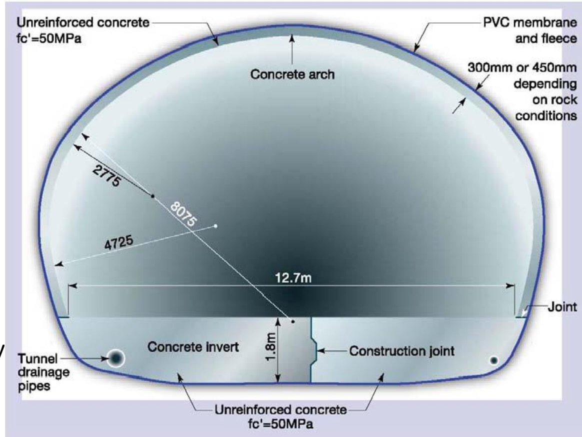


The "Melbourne Mudstones" within which much of the tunnel is constructed is made of folded and faulted thin beds of mudstone and sandstone. The Moray Street gravels comprise sands and gravels and form the major aquifer. The basalt is also a significant aquifer, and importantly both aquifers are connected (that is the groundwater water can move freely between the aquifers). Another significant feature of the area is that surface soils are derived from the basalts shrink and swell depending on how much water is within them. Further detail on the geology is provided in Figure A1 (attached).

Groundwater implications for design and construction

Design of tunnels requires lots of detailed geological studies to understand the materials that the tunnel will be excavated through and how those materials behave. The behavior of the material and the groundwater within it impacts the design of the tunnel. A challenge for design beneath suburbs and other infrastructure is getting access to sites to get that information! The initial design of the tunnel was based on assumptions of how much groundwater would flow into the tunnel, and how much pressure it would apply on the tunnel walls (Figure 2).

FIGURE 2. DESIGN OF THE BURNLEY TUNNEL



As construction of the tunnel continued, significantly more groundwater was entering the tunnel than the design had allowed for. More significantly, the pressure this water was applying was "shifting" the massive concrete slabs that formed the base of the tunnel. This required significant redesign as the project was being constructed, delaying the project significantly.

Groundwater was playing a more significant role than expected because of four major fault zones within the mudstone. The fault zones were acting like "pipes" bringing large volumes of water from the overlying Moray Street Gravels (and Yarra River!) into the tunnel. As the water "drained" into the tunnels, it lowered the level of groundwater near the surface (the watertable).

The lowering of the watertable created further problems for management. As the surface clays dried out, they compacted or shrunk. This is because the water in the clays helps to carry the weight of the overlying clay and soils. When the support of the water is removed, the clays compress. This meant the land surface began to sink. This is called subsidence. If sufficient subsidence occurs, it can change the way water moves in drains, crack building foundations and walls and breakup road and other paved surfaces.

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Permeability

Permeability is a measure of how well connected the pores in soil and rock are. Generally groundwater flows through gaps between particles of soil and rock. How well it flows depends on how many gaps there are (porosity) and how well connected the gaps are (permeability). If you were just wearing a T-shirt in the rain it would be considered **permeable** because you would get wet. Your raincoat would be considered **impermeable.**

Clogging

Particles either within water or the precipitation of chemicals when waters of different temperature or chemistry block the openings that let the injected water out of the injection pipe.

Finding Solutions

In order to prevent the tunnel slabs from moving, a series of rock bolts and anchors were constructed. This involved drilling through the floor of the tunnel and cementing long steel rods or cables into the surrounding rock, and applying tension to hold the slabs in place (Figure 3, 4).

FIGURE 3: ONE OF THE ROCK BOLT DESIGNS

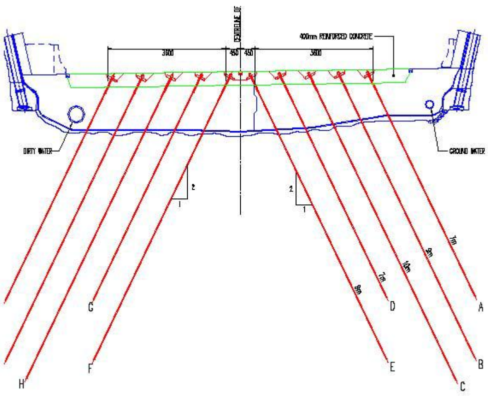

FIGURE 4: ROCK BOLTS INSTALLED

Even with the slabs stabilized, 60 litres of water was entering the tunnel every second. To reduce this flow of water, the rock around the tunnel was "grouted". This is where a hole is drilled into the rock, and cement is pumped into all the cracks within the rock under very high pressure. This reduces the permeability of the rock, reducing flow (See Figure A2). Even today, between 200 and 300ML of groundwater is pumped from the tunnels each year.

To manage the watertable and associated subsidence, water was pumped back into the aquifer. Initially, drinking water was used. In 2002/03 215ML of drinking water was pumped into the ground to maintain the watertable. By 2003/04 this had reduced to 45ML/year as a treatment plant was constructed that treated groundwater from the tunnels sufficiently to pump back into the aquifers. Treatment was needed, because the groundwater collected in the tunnels had natural salts that caused clogging of the bores used to inject the water. Today up to 200ML a year of treated groundwater is reinjected into the aquifers to maintain the watertable.

Consequences of Groundwater Issues

As a result of not fully understanding the groundwater conditions in the design and construction phase, the owner of the tunnel sought compensation from the designers and builders of the tunnel. $157M in compensation was paid. However, even after it opened, there were significant leaks of up to 5L/s that required the tunnel to be shut down for extended periods. This caused further significant losses from operation, and additional repair and maintenance costs.

In addition, the construction of the water treatment plant, and the continued operation of an aquifer reinjection system add significantly to the operating costs. The treatment plant alone cost $1.1M and has an annual operating cost of $0.17M.

Going further

Have a think about tunnels or other built infrastructure that may have needed groundwater management during construction or operation? Find out if you are right (the internet is a good place to start, but you may have to go and visit!)

Sources used in the Case Study

Australasian Tunnelling Society: Melbourne Citylink (http://www.ats.org.au/index.php?option=com_content&task=view&id=160&Itemid=4)

Pells Sullivan Meynink Pty Ltd (PSM), 2005: REMEDIAL WORKS FOR THE BURNLEY TUNNEL, MELBOURNE

Transurban, 2011: Sustainability Report

Note: This information sheet is wholly or in part from existing information. For more details, readers are referred to the source information sites.

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Figure A1: DETAIL OF THE GEOLOGY OF THE BURNLEY TUNNEL

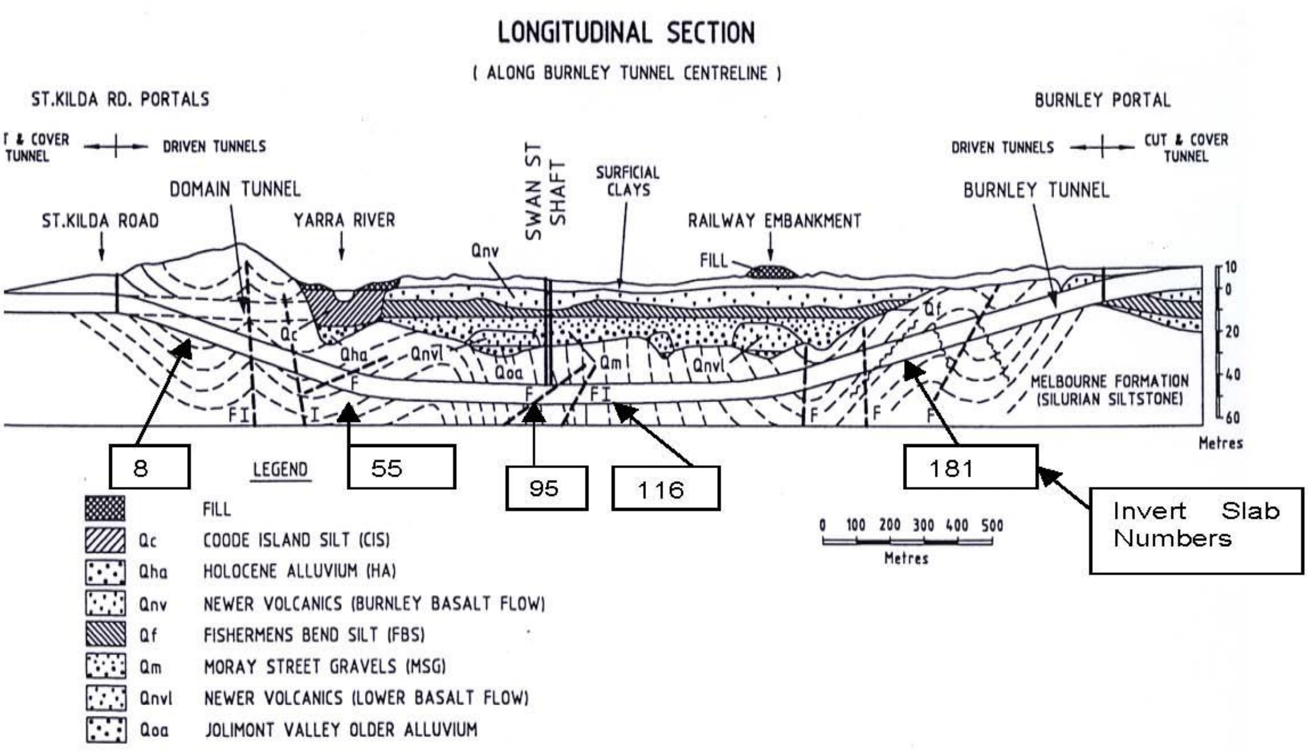

Figure A2: GROUNDWATER RECOVERY IN RESPONSE TO GROUTING