The $1.86 billion Forrestfield-Airport Link is jointly funded by the Australian and Western Australian governments and will deliver a new rail service to the eastern suburbs of Perth – with three new stations at Redcliffe, Airport Central and Forrestfield.

The rail link forms part of the METRONET vision to create liveable communities connected by world class public transport. The line will spur off the existing Midland Line near Bayswater Station and run to Forrestfield through twin-bored tunnels.

In April 2016 the Public Transport Authority awarded the design, construct and maintenance contract to Salini Impregilo – NRW Joint Venture.

First trains will operate on the new line in the second half of 2021.

The Forrestfield-Airport Link will travel through 8km of twin-bored tunnels and at its deepest point will be 26m below ground level. Entry and exit points to and from the tunnels will be provided via stations at Redcliffe and Airport Central, as well as tunnel portals at Bayswater and Forrestfield.

Given the length of the tunnels, additional infrastructure is required to provide safe egress between the two tunnels and to ground level in the event of an emergency.

Twelve tunnel-to-tunnel cross passages and three tunnel-to-egress shaft cross passages will be constructed along the Forrestfield-Airport Link alignment.

What is an emergency egress shaft?
An emergency egress shaft (EES) provides access from the tunnels to ground level via stairs and lifts.

Its layout is designed in conjunction with the Department of Fire and Emergency Services to ensure functionality during an emergency situation.

It takes up to six months to build each EES and another six months to build the supporting ground level infrastructure.

What is a cross passage?
A cross passage is a short concrete tunnel which provides a link between two main tunnels, or a link between a tunnel and an EES. Cross passages can be used by passengers in the unlikely event of an emergency, or by employees for operational maintenance purposes.

It takes up to three months to build each cross passage, which are up to 10 metres long and five metres high (around three metres high after final lining installation).
Once the tunnel boring machines (TBMs) have tunnelled past a cross passage site, equipment is used underground to excavate between the two tunnels. While excavating, a quick-setting form of concrete called shotcrete, which is strengthened with steel fibres, is sprayed onto the excavated soil and steel lattice supports. Further layers of shotcrete and concrete are then added to make the surface watertight. This creates a permanent structure approximately one metre thick.

Stages of work include:

- installation of steel supports within the tunnels
- excavation and temporary support of the excavation
- waterproofing and reinforcement works within the excavated area
- formwork and concreting (final lining).

Following an incident at the project’s first tunnel-to-tunnel cross passage, where silt and groundwater entered the site during excavation, the cross passage construction methodology has been reviewed.

Additional measures will be implemented during construction of the remaining cross passages.

**Changes to the methodology include (but are not limited to):**

- extensive contact grouting around the exterior of the tunnels near the cross passages as required
- additional grouting inside the jet grout block as required
- installing additional bolts in the tunnel rings adjacent to cross passage construction to connect the segments of each ring
- minimising the use of mechanical excavation tools
- installing circular steel ribs on tunnel rings adjacent to the cross passages in both tunnels (depending on the site’s soil formation).

A number of additional contingency measures will be in place should future water ingress occur. This includes having dry shotcrete, foam and cementitious grout available as well as subcontractors with water inflow control expertise on call.
Cross passages

Ground improvement works

Before construction started in late 2016, a series of geotechnical investigations were undertaken along the project’s route. These investigations provided insight into the ground conditions, water levels and soil types at the cross passage sites.

Two ground improvement methods - jet grouting and ground freezing - have been, or will be, undertaken at 11 of the 15 cross passage/EES sites to improve ground conditions and stabilise soils in preparation for cross passage excavation works.

The remaining four sites can be excavated without additional ground improvement as they are located within naturally-stable geology, such as the Osborne formation.

Ground freezing

Within Perth Airport’s airside environment, where restricted land access makes jet grouting impractical, three cross passages will be constructed using a ground freezing technique.

Ground freezing involves placing pipes underground and freezing the soil. Frozen soil can be as hard as concrete and therefore stabilises the ground during excavation.

The process involves drilling (from within the tunnels) a series of holes around the perimeter of the proposed excavation area and installing pipes into them. A brine solution (non-toxic, calcium chloride salty water) is then circulated through the pipes to freeze the surrounding ground, forming a waterproof, rock-like mass.

The brine solution for the ground freezing process will be piped to the three cross passage sites via the Airport West EES.

It takes approximately six weeks to freeze the soil around each site before excavation can commence. The freezing will be maintained until the excavation is completed, approximately two months later. Once the cross passage is constructed and the freezing is turned off, the soil will return to normal temperature.

Jet grouting

Jet grouting is a method used to improve ground stability before the tunnel boring machines arrive at a cross passage site.

Drilling equipment injects a grout and water mixture (slurry) at high pressure into the soil being treated. This creates overlapping columns of high-strength material. The tunnel boring machines then bore through the overlapping columns.

Additional grouting is conducted from within the tunnels and tested to ensure it meets the required strength and permeability before the cross passage is excavated.

Given the type of equipment required for jet grouting, a temporary construction site is established at ground level.

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Below: example of the ground freezing method

Below: example of the jet grouting process

Cross Passage Dundas
There will be three EES along the Forrestfield-Airport Link alignment:

- Wright Crescent, Bayswater
- Airport West, within Perth Airport Estate (T3/T4 precinct)
- Abernethy Road, Forrestfield

Cross passages link the tunnels to an EES, where a lift and staircase lead to ground level. These are much shorter than the tunnel-to-tunnel cross passages, at about two metres on each side of the shaft. Two out of three tunnel-to-egress shaft cross passages will be constructed using the jet grouting technique, the third one is located in naturally-stable geology.

The EES vary in depth between 23m and 34m below ground. A plant room, located at ground level adjacent to the shafts, stores fire and emergency response equipment, as well as hydraulic, mechanical, electrical and communications services which are required for tunnel operations.

Construction method

Diaphragm walls (d-walls) are the main component of the construction process for underground structures, including egress shafts.

A large claw-like machine is used to remove spoil, before a steel cage is lowered into the ground and concrete is poured. This process continues until all walls of the EES are built.

The ground water level is then temporarily lowered to allow for the excavation of the shaft and the installation of the concrete base to seal the structure.

The d-wall method has also been used to build the dive structures at Bayswater and Forrestfield, and the underground stations at Redcliffe and Airport Central.

After the shaft has been excavated and sealed, the above-ground structure is constructed. This involves:

- installation of electrical containments, hydraulic services, sewerage and stormwater drainage
- driveway construction and asphalt sealing
- ground slab construction
- building installation (structural steel, tilt-up panels, roof)
- fit out of the shaft and building.