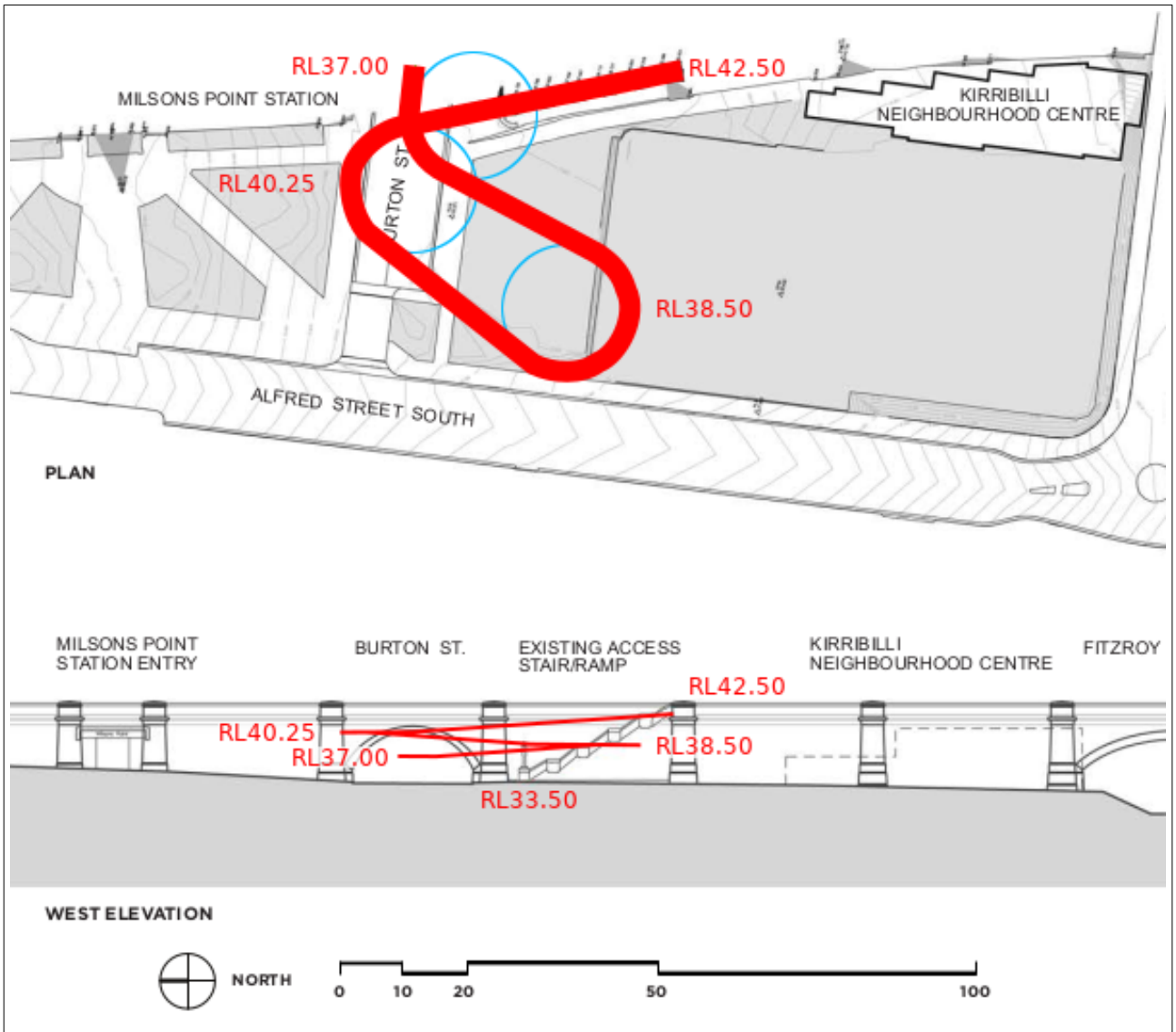
Sydney Harbour Bridge Cycleway Ramp Proposals

Alternative proposals for consideration by Transport for NSW:

- **Burton Street Tunnel elevated cycleway**
- **Kirribilli cycleway connection**
- **Ennis–Tramway elevated cycleway to North Sydney**
- (and a*n alternative alternative proposal*, the **Bradfield Highway cycleway**)

Version: **1.1**
Submitted by: **James Boyden** (jboy.cw@jboy.id.au), 27th of June, 2021
The latest version of this proposal is available at: https://jboy.id.au/burton



The **Western ramp** is the cornerstone of the **Burton Street Tunnel elevated cycleway** proposal.

This carefully-designed ramp from the Harbour Bridge cycleway satisfies several constraints, including:
(1) No ramps over the Milsons Point train station entrance gardens or Bradfield Park North.
(2) Minimal intrusion onto the green fields of Bradfield Park Central (the old bowls lawn).

This document proposes building new elevated cycleways to solve the current challenges of bicycle congestion & dangerous cycle ramps at the Northern end of the Harbour Bridge:

1. **Burton Street Tunnel elevated cycleway** in Milsons Point (map on Page 13)
2. **Ennis–Tramway elevated cycleway to North Sydney** (map on Page 15)

These two elevated cycleways will connect at a proposed **Kirribilli cycleway connection** on Ennis Rd, Kirribilli, a cul-de-sac that runs alongside the Cahill Expressway on the East. This is on the **opposite side of Milsons Point** to the Sydney Harbour Bridge cycleway, the existing ramp/stairs down to Burton St, and Bradfield Park North. There will be:

- **no cycleways obscuring the Milsons Point train station Western entrance**;
- **no cycle ramps landing in Bradfield Park North or the bowling green**.

These cycleways will be less disruptive of Milsons Point park-lands & community spaces than the Linear or Loop options. By carrying cyclists at an elevation, they will ensure that cyclists do not need to ride through pedestrian areas or community events like the Kirribilli Markets on Burton St. This is **safer for pedestrians** and **more convenient for cyclists**.

These two elevated cycleways will carry cyclists off the Sydney Harbour Bridge cycleway, through Burton Street Tunnel to Ennis Rd, and then to North Sydney via the unused North Sydney Tramway. The top priorities are: **safety**; **no congestion**; **easy for all abilities**. On these cycleways, cyclists will not need to queue at traffic lights or pedestrian crossings. They will not need to dodge pedestrians on shared paths, nor dodge speeding cars at the busy Lavender St round-about, nor pedal up-hill in front of buses on the Pacific Highway. These cycleways will provide a **safe, uninterrupted connection to North Sydney**.

This document will build a case, supported by maps & photos, for the proposed cycleways. It will show that the proposed elevated cycleways are both **feasible** and **preferable** to previous ramp options for cyclists & the Milsons Point community. These two cycleways will also make better use of under-utilised space in the Milsons Point / North Sydney area, such as the car-park under Cahill Expressway and the unused **North Sydney Tramway**.

Burton Street Tunnel (Western entrance) and the stairs/ramp from the Sydney Harbour Bridge cycleway.

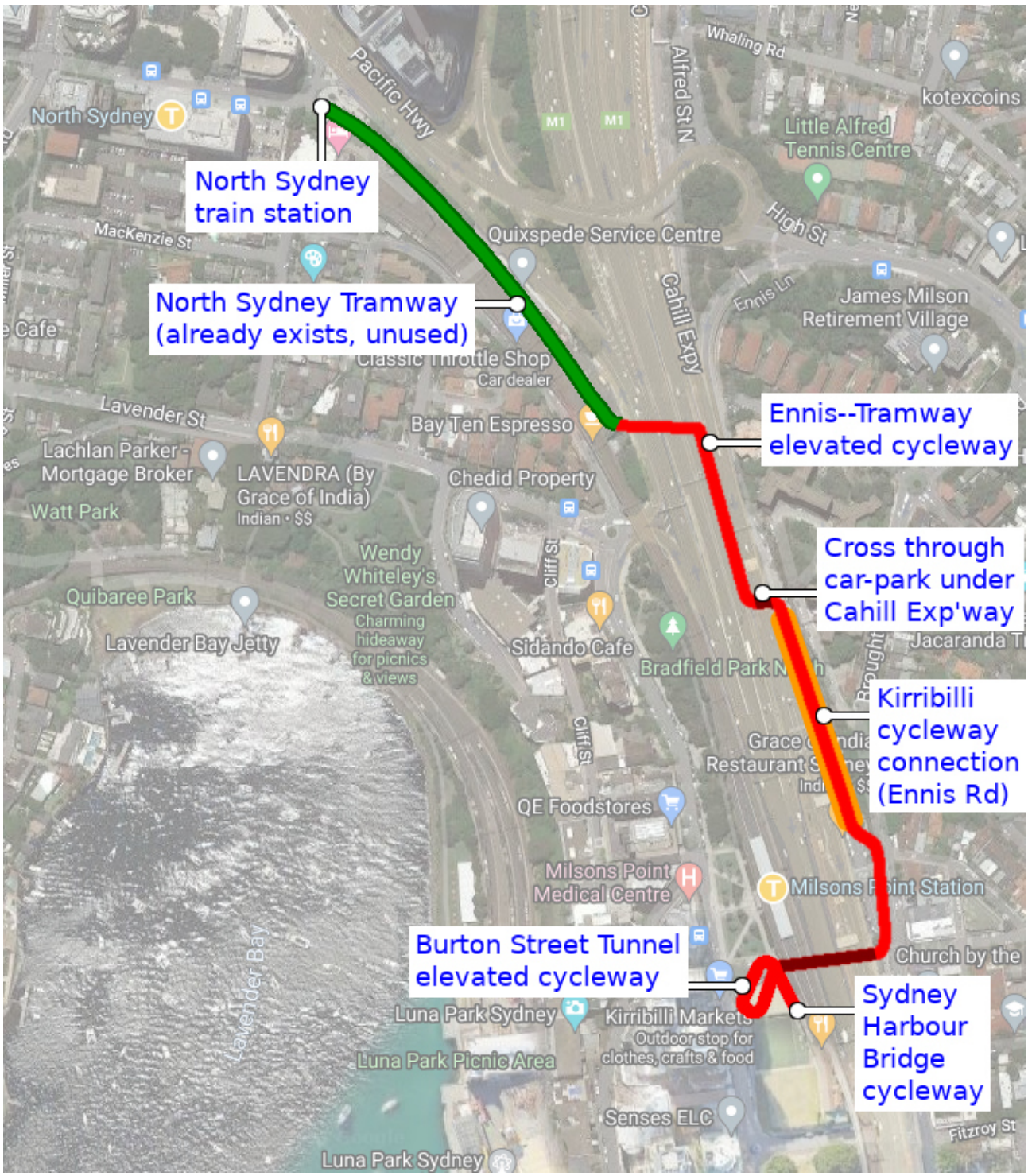
This document is a response to: *Sydney Harbour Bridge Cycleway – Northern access project | June 2021* from **Transport for NSW**: https://roads-waterways.transport.nsw.gov.au/projects/sydney-harbour-bridge/access-projects/cycleway-access-proposals.html → "Community updates" → "June 2021 project overview".

Comparison of all cycle ramp options

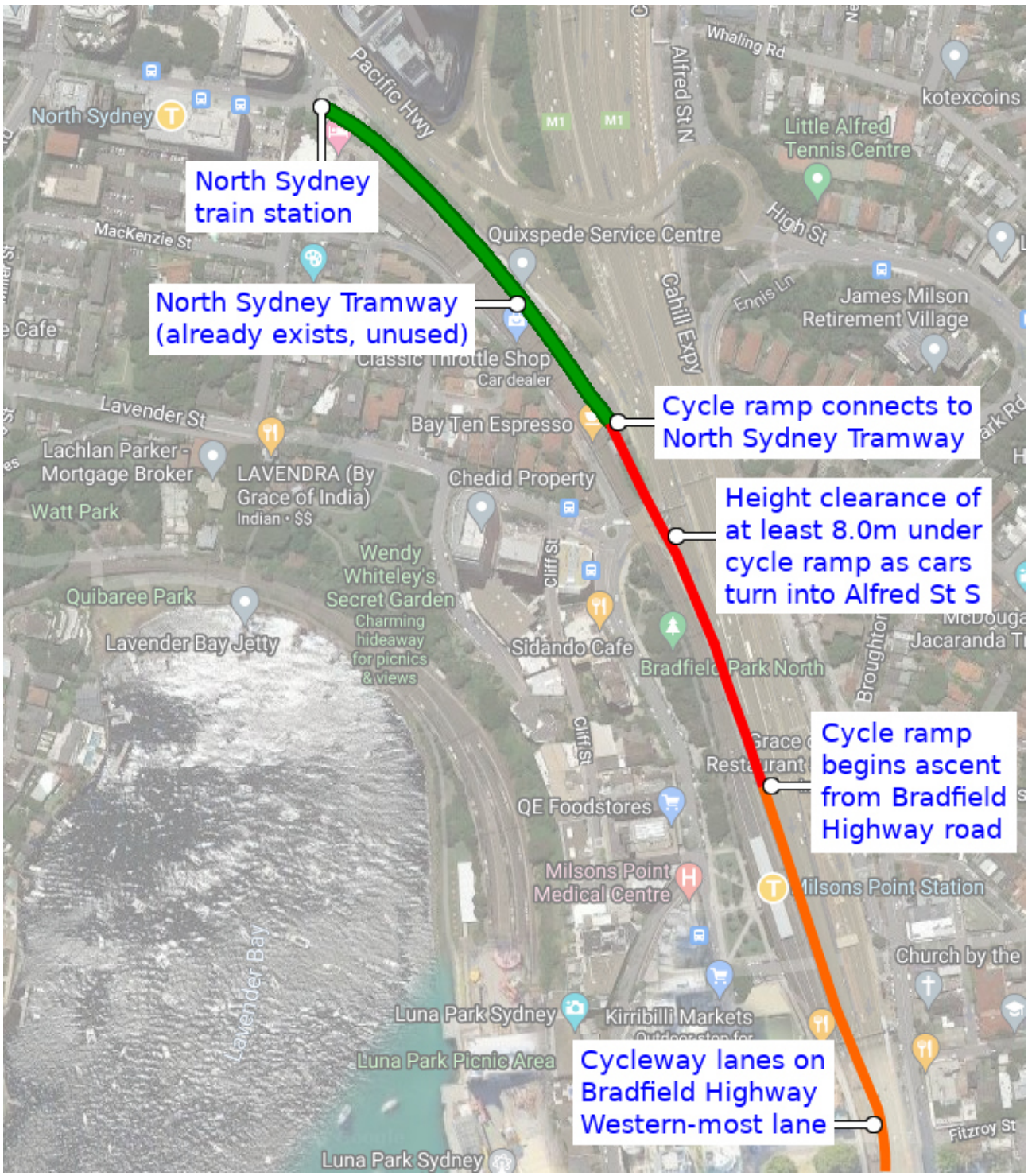
	This proposal (Burton Street Tunnel)	Linear ramp	Looped ramp	Lift to top of stairs	Current ramp/ stairs
Connects to Kent St cycleway: Bicycles travel over Harbour Bridge along Western side to CBD bike network	✓	✓	✓	✓	✓
High-throughput up & down: No bottlenecks on Harbour Bridge cycleway or Burton Street during ascent or descent	✓	✓	✓	✗	✗
Easier ascent for cyclists: No need to carry bicycle up 55 stairs or wheel bicycle up steep, narrow ramp	✓	✓	✓	✓	✗
Safe descent for fast cyclists: Safer descent for fast-moving cyclists (couriers & long-distance commuters)	✓	✓	✓	✗	✗
Safe for pedestrians on Burton Street: Avoids pedestrians near Burton Street & Milsons Point train station entrances	✓	✓	✗	✗	✗
No ramps in Bradfield Park North: No ramps through Bradfield Park North or in front of Milsons Point Western entrance	✓	✗	✓	✓	✓
Easy ramps for all ages & abilities: Ramp difficulty (Z score) < 0.25 [*Brief Dutch Design Manual* suggests ≤ 0.2]	✓	✓	✗	✗	✗
No congestion at road-crossings: Cyclists do not queue to cross roads at traffic lights or pedestrian crossings	✓	✗	✗	✗	✗
Safe to North Sydney: Avoids Lavender St round-about, avoids Middlemiss St, avoids Pacific Hwy up-hill	✓	✗	✗	✗	✗

The "**Z score**" is a measure of cycle ramp's difficulty, as defined in *Brief Dutch Design Manual for Bicycle and Pedestrian Bridges* (2015). A Z score is calculated as the ramp height (m) squared, divided by the ramp length (m). A higher Z score means a more difficult ramp. The *Brief Dutch Design Manual* suggests a maximum Z score of 0.2. This document evaluates ramp difficulty by both **gradient** (%) and **Z score**.

The dangers of the current route to North Sydney (Lavender St round-about and Pacific Highway up-hill) are detailed in section "**2.2. Danger on the existing bike network**".



The **proposed cycleways** connect from the Sydney Harbour Bridge cycleway to North Sydney train station. Proposed elevated cycleways are indicated in red; the proposed Kirribilli cycleway connection in orange; and the unused North Sydney Tramway in green.



There's also an *alternative alternative proposal*: the **Bradfield Highway cycleway** via North Sydney Tramway.

A Bradfield Highway cycleway would be simpler than the other cycleways proposed in this document, but it crucially requires Transport for NSW to convert the Western-most car lane of Bradfield Highway to a separated bicycle lane across the Sydney Harbour Bridge.

This alternative proposal is described in section "**3.6. Alternative: Bradfield Highway cycleway**".

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Part 1. Introduction

Cycling is a virtue (especially cycling to commute). It's good for the cyclist and good for the air we all breathe. It's not selfish to ride a bike and ask for safe, convenient routes. Cyclists deserve cycleways that are as safe & convenient as what motorists would expect of their roads.

The Harbour Bridge cycleway is the only North-South bicycle route across Sydney Harbour. It should be safe & convenient for cyclists of all ages and abilities.

However, for the safety of pedestrians and for the convenience of fast-moving commuter cyclists, **we should route bicycles around (or above) the dense pedestrian areas near Milsons Point train station entrances & Burton St**.

- **Especially** if the bottleneck of the Harbour Bridge cycleway stairs is removed...
- **Especially** if Harbour Bridge cycleway throughput doubles in coming decades...
- **Especially** because a large proportion of Milsons Point pedestrians are elderly local residents, school children, and tourists who are unfamiliar with the area.

Shared zones for pedestrians & bicycles won't work! They are not a viable solution.

Please note that I am **not** a leading urban design, architectural or heritage expert. I'm just a Milsons Point resident who's lived here for years.

1.1. Benefits of Burton Street Tunnel cycleway

This whole proposal follows from an appreciation of the benefits of an elevated cycleway through the Burton Street Tunnel, as an alternative to other options:

1. **Bicycles travel above the pedestrian areas** of Milsons Point train station.
2. Bicycles ascend & descend from the Harbour Bridge safely, but at high-throughput.
3. No bicycle ramps in front of the Milsons Point train station Western entrance.
4. No large, eye-catching, multi-level loops.
5. **No congestion at traffic lights or pedestrian crossings** as bicycles queue to cross Alfred St South or Lavender St.
6. **Bicycles avoid the dangerous Alfred St South / Lavender St round-about**, which combines a 4-way round-about with fast-moving (often speeding) traffic racing off Bradfield Hwy on a sharp left curve, with visibility obscured by bushes.
7. Bicycles avoid the narrow, curving, mixed car/bicycle traffic on Middlemiss St.
8. **Bicycles avoid the gauntlet of the Pacific Highway up-hill to North Sydney** (where they choose between pedalling up-hill in a road-lane with fast-moving buses; or dodging around trees, pedestrians, opposing cyclists on a tree-dotted footpath).

After these 8 major benefits, all the rest is icing on the cake. But there are more benefits to this proposed option, which will be described in detail in the coming pages.

Part 2. Problems of other options

2.1. The major failing of Looped & Lift options

A major failing of the Looped option and Lift option (see note below) is that they both drop cyclists off at the base of the Harbour Bridge cycleway stairs again. At this point, cyclists are back to dodging the dense pedestrian traffic of Burton St, the Alfred St South footpath, and the Milsons Point train station entrance plaza. **So the Looped & Lift options both immediately re-introduce congestion for cyclists and danger for pedestrians!**

> **Note:** The Lift option is **not** actually an option proposed by Transport for NSW in 2021. A lift has already been ruled out by Transport for NSW, because it would not remove the bottleneck at the current stairs/ramp, as noted on p.2 of the June 2021 project overview. A lift would also have a lower throughput than the current stairs/ramp, but would introduce a second bottleneck on the cycleway (at the upper entrance to the lift) as lift-exiting traffic merged with stair traffic, while the cyclists queuing to use the lift blocked the cycleway.
>
> However, the idea of a Lift option has taken on a life of its own in the community — despite the analysis by Transport for NSW that it would be worse than the Linear or Looped options on almost all relevant criteria — which is why we include it in our discussion.

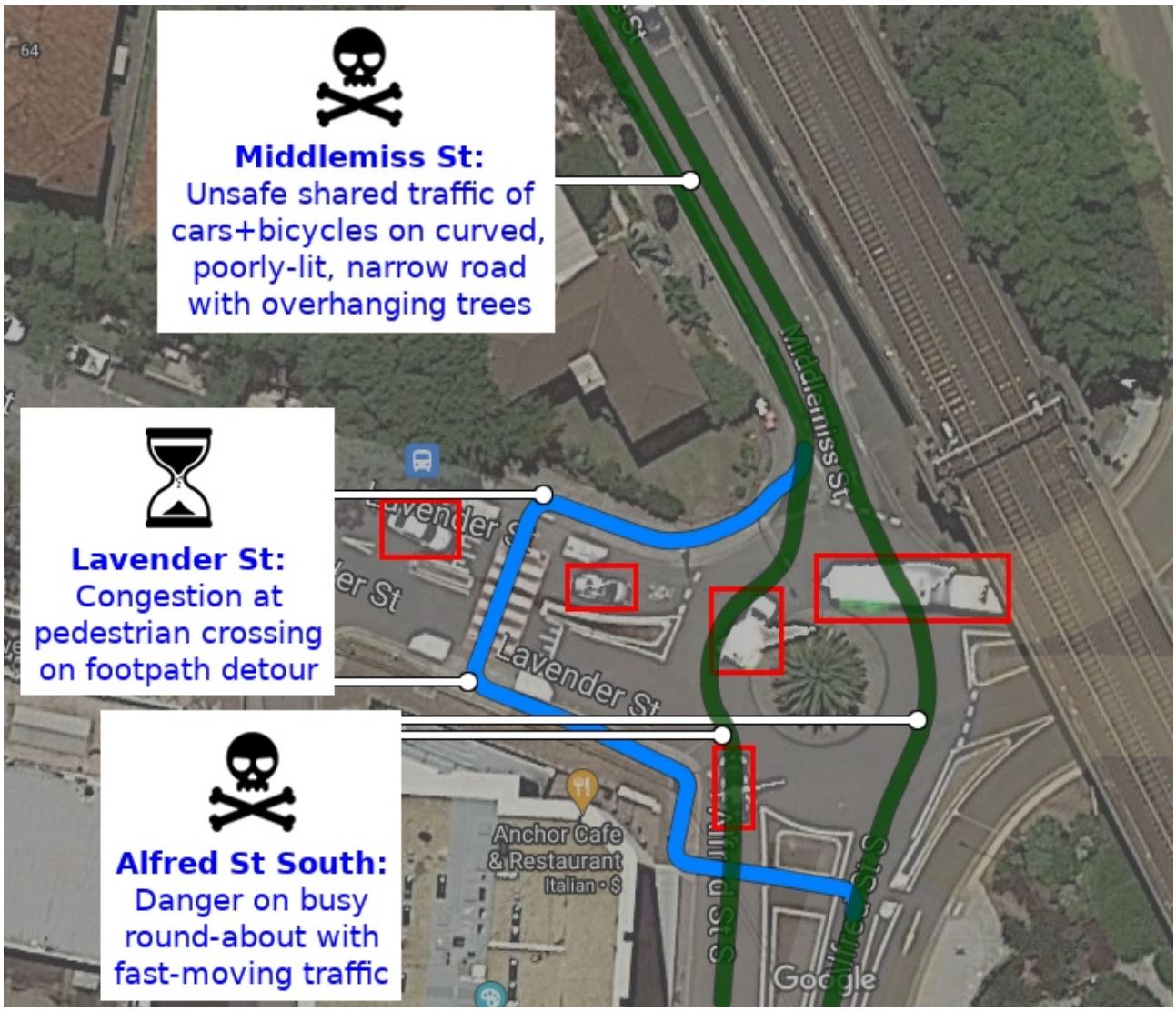
2.2. Danger on the "existing bike network"

There's **another major failing of all previous options** (Linear, Looped, and Lift), which seems to have escaped scrutiny to this point: They connect to the "existing bike network" at Middlemiss St, meaning a route to North Sydney via Middlemiss St and Pacific Highway. **The existing bike network route is dangerous to cyclists and pedestrians alike.**

Even aside from our central concern about cyclist safety on the steep ramp/stairs descent from the Harbour Bridge cycleway — even aside from our concern about pedestrian safety in the dense pedestrian areas around Burton St & the Milsons Point train station entrances — even aside from the contentious debate about ramps in front of the Western entrance to Milsons Point train station and landing in Bradfield Park North — the route to North Sydney is also a danger to cyclists (and sometimes also pedestrians).

A bicycle ramp doesn't simply drop cyclists off in Bradfield Park North and then suddenly they teleport to North Sydney station. To get to North Sydney, the existing bike network requires cyclists to:

1. Cross the busy Alfred St South / Lavender St / Middlemiss St **round-about** — either sharing the round-about lane with fast-moving buses, trucks, cars (often speeding off Bradfield Hwy); or queuing to cross at the pedestrian crossing on Lavender St.
2. Cycle along the curving, poorly-lit, mixed-traffic lane of **Middlemiss St**.
3. Cross under the train-line to Pacific Hwy through the **Arthur St tunnel**.
4. Cycle up-hill along **Pacific Hwy** — either sharing a lane with fast-moving buses; or dodging around trees, pedestrians, and opposing cyclists on the footpath.



At the Northern end of Alfred St South, the round-about with Lavender St & Middlemiss St is a danger for both cyclists and pedestrians: a busy single-lane round-about with a tight turn (and even a hairpin left-turn off Bradfield Hwy) that merges traffic from 4 directions.

The greatest danger is the fast-moving traffic turning off Bradfield Hwy. **Cars often speed through the round-about**, maintaining their Bradfield Hwy speed on the tight left-turn or even the hairpin left-turn. As cars approach the turn-off along Bradfield Hwy, **visibility of the round-about is completely obscured** by the concrete foundations of the train-line and by bushes planted under the tunnel arch.

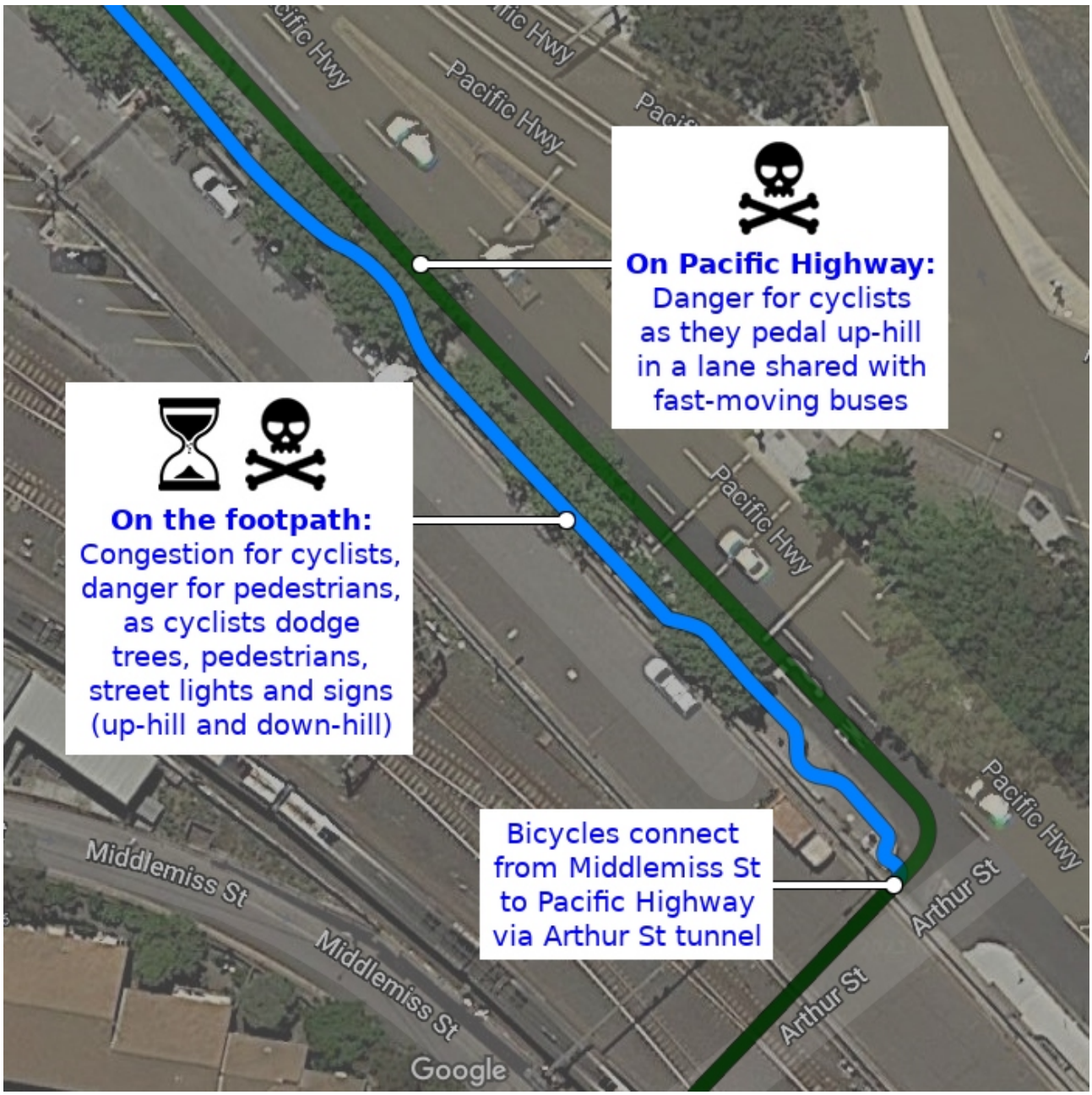
A safer alternative is to take a short detour via the pedestrian crossing on Lavender St. But the price of safety is congestion at the pedestrian crossing: bicycles queuing on both sides of the crossing; and road congestion due to increased usage of the crossing.

There's no way for cyclists to avoid this round-about completely unless they:

- Take a scenic, hilly detour via Cliff St, Lavender St, and Blues Point Rd — but this detour would still not resolve any of the other concerns about pedestrian safety & ramps in Bradfield Park North; or
- **Cross under the train-line through Burton Street Tunnel** (ahem).

Rain, hail or shine, the Alfred St South / Lavender St round-about is busy with fast-moving traffic.

Middlemiss St is curved and poorly-lit at night (with street lights obscured by the trees).
Overhanging trees lean into the Northwards bicycle lane (painted green).
The Southwards bicycle lane is a narrow mixed-traffic car lane.



Halfway up Middlemiss St, bicycles cross under the train-line to Pacific Highway through the Arthur St tunnel. At this point, the existing bike network continues along Pacific Hwy, up the hill to North Sydney.

Bicycles must choose between:

- pedalling up-hill in a road-lane with fast-moving buses;
- dodging around trees, pedestrians, and opposing cyclists along a single footpath dotted with trees that obscure visibility.

There’s no way for cyclists to avoid this up-hill ride to Pacific Highway unless they:

- Take a scenic, hilly detour via Blues Point Rd; or
- **Cross through Burton Street Tunnel and travel along Ennis Rd**.

Both pedestrians & cyclists travel up-hill & down-hill on this footpath,
without any lane markings to indicate the up-hill or down-hill direction,
and with trees along the footpath obscuring visibility.

The fast-moving buses prefer to maintain momentum to reach the top of the hill.
A bus is almost as wide as the road-lane; there's no space for a bus to pass a bicycle.

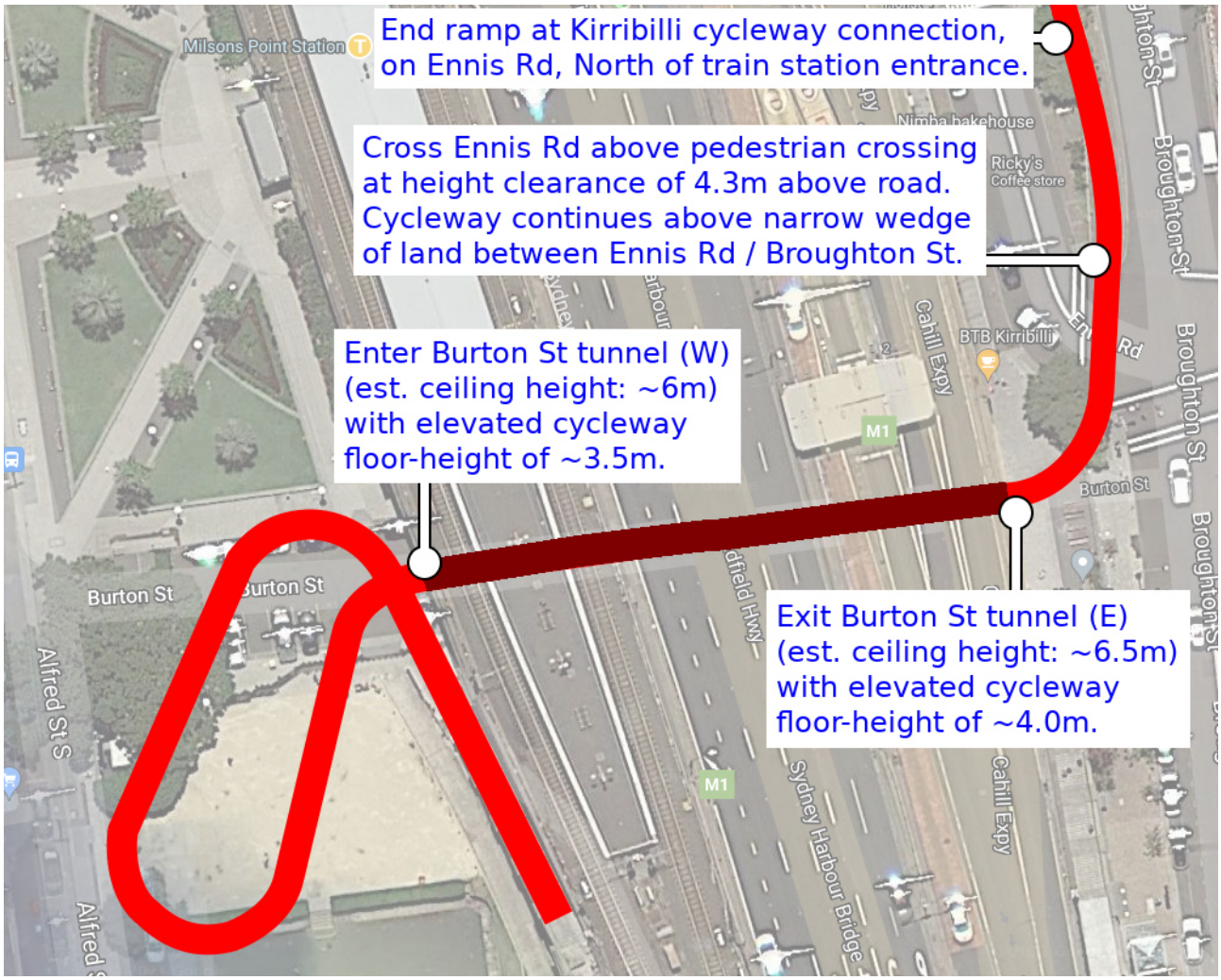
Part 3. Overview of proposals

There are 3 inter-connected components in this proposal:

1. **Burton Street Tunnel elevated cycleway** (map below)
2. **Ennis–Tramway elevated cycleway to North Sydney** (map on Page 15)
3. **Kirribilli cycleway connection** on Ennis Rd: a raised traffic island along Ennis Rd, where cyclists may safely enter or exit the fast-moving cycleways.

[There's also an *alternative proposal*, the **Bradfield Highway cycleway** (**section 3.6**).]

3.1. Map of Burton Street Tunnel cycleway



The Burton Street Tunnel elevated cycleway will consist of 5 sections:

1. Western ramp from Sydney Harbour Bridge cycleway to Burton Street Tunnel.
2. Enter Burton Street Tunnel (West) at 3.5m elevation above road-level.
3. Exit Burton Street Tunnel (East); cross over Ennis Rd at 4.3m height clearance.
4. Maintain height clearance of 4.3m (clearance for firetrucks) along Ennis Rd.
5. At Kirribilli cycleway connection, descend as a ramp to 1m above road-level.

3.2. Overview of Kirribilli cycleway connection

The proposed **Kirribilli cycleway connection** (on Ennis Rd) will allow cyclists to enter or exit the Burton Street Tunnel cycleway (South) or the Ennis–Tramway cycleway (North), travelling in either direction.

Ennis Rd is a long, flat, straight, quiet cul-de-sac that runs alongside the Cahill Expressway on the Eastern side. This is an ideal route for a North-South cycleway and an ideal stretch for cycle ramps to finally land at ground-level.

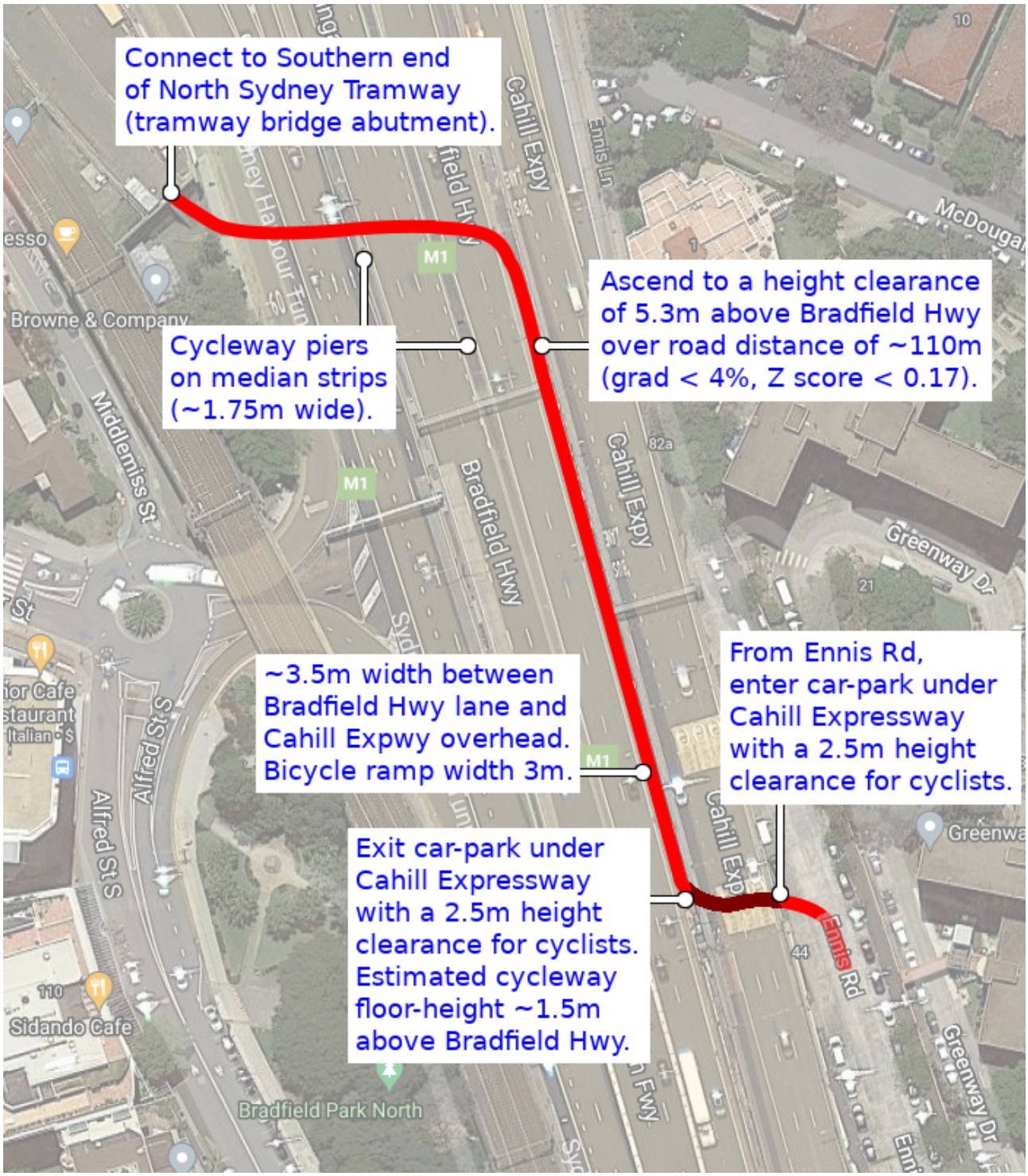
Ennis Rd is on the opposite side of Milsons Point to the Harbour Bridge cycleway and the existing stairs/ramp down to Burton St. It's also the opposite side to Bradfield Park North, Alfred St South, and all other proposals. This is how we avoid having cycle ramps land in Bradfield Park North or the Milsons Point bowling green.

A system of 4 inter-woven parallel bicycle lanes will allow cyclists travelling on Ennis Rd to gain speed and merge with the fast-moving stream of bicycles. This will enable cyclists to enter or exit the stream without interrupting the flow or risking a high-speed collision.

At the Kirribilli cycleway connection, the Burton Street Tunnel cycleway will connect to the Ennis–Tramway cycleway, to provide a safe, uninterrupted, separated cycleway from the Harbour Bridge cycleway to North Sydney train station.

Ennis Rd: the long, straight, quiet cul-de-sac where the **Kirribilli cycleway connection** will allow cyclists to enter or exit the Burton Street Tunnel cycleway (South) or the Ennis–Tramway cycleway (North), travelling in either direction.

3.3. Map of Ennis–Tramway cycleway



The Ennis–Tramway elevated cycleway will consist of 5 sections:

1. At Kirribilli cycleway connection, ascend as a ramp to a height clearance of 4.3m (the minimum clearance for firetrucks & garbage trucks to pass).
2. Curve left to enter under the ceiling of the car-park underneath Cahill Expressway; travel from East to West across the car-park; then curve right to emerge from under Cahill Expressway, directed North along the shoulder between Cahill Expressway & Bradfield Hwy (estimated width: 3.5m).
3. Following Bradfield Hwy Northwards, ascend as a ramp to height clearance of 5.3m above Bradfield Hwy road-level.
4. Curve left (to the West); cross over Bradfield Highway; **connect to the Southern end of the unused North Sydney Tramway** (at the tramway bridge abutment).
5. Continue Northwards along the unused Tramway to North Sydney train station.

3.4. Car-park under Cahill Expressway

At the Northern end of Ennis Rd, there's a car-park underneath the Cahill Expressway. The car-park is open-air on both sides, with a high ceiling. Bradfield Highway is directly on the other side; on the Bradfield Highway side, the ceiling has a 4m height clearance above Bradfield Highway road-level. The ceiling is highest at the Southern end of the car-park.

Crossing through the Southern end of this car-park would allow an elevated cycleway to pass under the Cahill Expressway, from Ennis Rd to Bradfield Highway, without impacting most of the car-park. Conveniently, the car-park is already operated by Transport for NSW.

A view through the car-park from the Ennis Rd side (at the Northern end of Ennis Rd).

3.5. Unused tramway to North Sydney

Let us not forget the unused North Sydney Tramway, which runs for 260 metres alongside the North Sydney train-line and Pacific Highway, all the way to North Sydney train station. It's a quarter of a kilometre of flat, sealed, multi-lane roadway that's currently only used as a mostly-empty car-park for Sydney Trains employees & contractors, and a storage area for trucks & trailers.

A view of the unused North Sydney Tramway from North Sydney train station.

[More about the North Sydney Tramway in section "**4.3.4. North Sydney Tramway**".]

Conveniently, it seems that North Sydney Council is already aware of the under-utilisation of the North Sydney Tramway. But they're planning to convert it into a park, as described on this North Sydney Council page titled *CBD Public Domain Strategy*:
https://www.northsydney.nsw.gov.au/Building_Development/North_Sydney_CBD/CBD_Public_Domain_Strategy

and in this April 2020 Media release:
https://www.northsydney.nsw.gov.au/files/assets/public/docs/1_council_meetings/news/media_releases/2020/mr07_-_north_sydney_cbd_public_domain_strategy.pdf

North Sydney Council: **Convert the North Sydney Tramway into a cycleway instead!**

3.6. Alternative: Bradfield Highway cycleway

Note: This is not one of the two "official" cycleways proposed in this document. It's an *alternative alternative cycleway proposal*, documented here for completeness.

This Bradfield Highway cycleway proposal builds upon the **same evidence & arguments** that have already been presented about the problems with options from Transport for NSW. It offers an **alternative alternative solution** to the problems described — alternative to both the Transport for NSW options and the previous proposals in this document.

This Bradfield Highway cycleway proposal is simpler than the other cycleway proposals in this document. But it crucially hinges upon **converting the Western-most car lane of Bradfield Highway to a separated bicycle lane** on the Sydney Harbour Bridge.

[**Note:** It's the **Western-most** car lane (closest to the train-lines) that we would want to convert; **not** the **Eastern-most** car lane (closest to the pedestrian walkway, on the Cahill Expressway), which seems to be the usual target for a bicycle-lane conversion request.]

Regardless of *which* Harbour Bridge car lane we would want to convert, Transport for NSW has never expressed much willingness to convert *any* Harbour Bridge car lanes to bicycle lanes. (But we wish they would...)

3.6.1. Three sides of the triangle

A Bradfield Highway cycleway would be analogous to the **third side of a triangle** to connect three points on a map. In this case, the three corners of the triangle are:

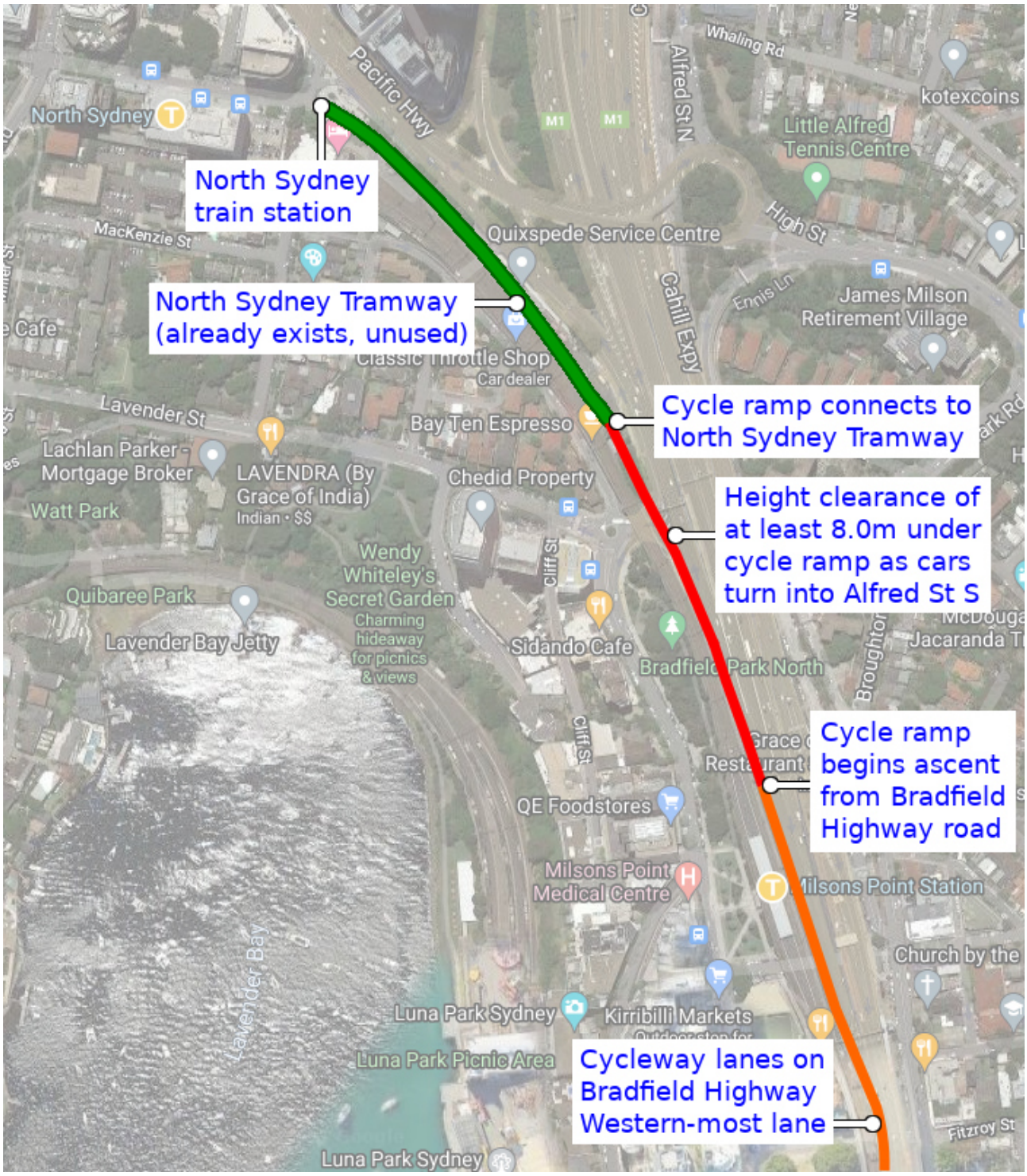
1. **Upper Fort St**, which connects to the Kent St bicycle network, the gateway to the CBD and the South Shore in general. It's on the Western side of Bradfield Highway.
2. **Ennis Rd,** the gateway to Milsons Point, Kirribilli, and the Northern shoreline of Sydney Harbour (for tourists, in particular). It's on the Eastern side of Bradfield Highway.
3. the Southern end of the **North Sydney Tramway**, which connects to North Sydney train station and the Pacific Highway, the gateway to the North Shore in general. It's on the Western side of Bradfield Highway. [More about North Sydney Tramway in section "**4.3.4. North Sydney Tramway**".]

We have already proposed two sides of the triangle:

1. **Burton Street Tunnel cycleway**, which connects Upper Fort St to Ennis Rd (via the Harbour Bridge cycleway); it crosses from West to East (under Bradfield Highway) through the Burton Street Tunnel.
2. **Ennis–Tramway cycleway**, which connects Ennis Rd to North Sydney Tramway; it crosses from East to West (under Cahill Expressway then over Bradfield Hwy).

A Bradfield Highway cycleway would connect **Upper Fort St** directly to the Southern end of the **North Sydney Tramway**, via Bradfield Highway over the Harbour Bridge.

3.6.2. Building a Bradfield Highway cycleway



A **Bradfield Highway cycleway** would provide a direct connection from the CBD to North Sydney.

A Bradfield Highway cycleway would be simpler than the other cycleways proposed in this document, but it crucially requires Transport for NSW to convert the Western-most car lane of Bradfield Highway to a separated bicycle lane across the Sydney Harbour Bridge.

A Bradfield Highway cycleway would actually be the simplest of the three sides: almost a straight line along Bradfield Highway (along the Western car lane); always on the Western side of Bradfield Highway, just like its Southern triangle corner (Upper Fort St) & Northern triangle corner (the Southern end of North Sydney Tramway).

The Western-most car lane of Bradfield Highway (now converted to separated cycle lanes) would connect to Upper Fort St & Kent St. [**Aside:** Surely this connection would also solve the *other* problem facing Transport for NSW — the "steep ramp between Upper Fort Street and Bradfield Highway outside the National Trust Building" — described as the "Southern access project" on p.8 of the June 2021 project overview?]

Then on the Northern descent from the Harbour Bridge, after Bradfield Highway crosses over Burton Street Tunnel, but before the turn-off to the Lavender St round-about, these cycle lanes along the Western-most lane of Bradfield Highway would become a cycle ramp ascending with minimal gradient to connect to the Southern end of North Sydney Tramway.

This would allow the **second**-Western-most lane of Bradfield Highway to be the car lane that turns left (West) to Alfred St South & the Lavender St round-about, passing under the ascending cycle ramp with a height clearance of at least 8.0 metres. Because Bradfield Highway is descending at the same time, the ramp would need only a moderate gradient.

3.6.3. Choosing two sides of the triangle

If Transport for NSW were to construct the Bradfield Highway cycleway, it would not be necessary to construct **both** of the other two cycleways — because only two sides of a triangle are needed to reach all three corners.

If only **one** of Burton Street Tunnel cycleway & Ennis–Tramway cycleway were constructed, then the Kirribilli cycleway connection on Ennis Rd could be constructed as just one longer, lower-gradient ramp ascending in just one direction.

In particular, if Bradfield Highway cycleway & Ennis–Tramway cycleway were constructed, there would be no need for the current Harbour Bridge cycleway along the Western side of the Harbour Bridge: Cyclists could just travel along the wider Bradfield Highway cycleway, directly to North Sydney train station, with minimal gradients and no sharp turns. Then the current Harbour Bridge cycleway could be converted to a second pedestrian walkway (just like the one on the Eastern side of the Harbour Bridge). Then the current ramp/stairs at the Northern end of the Harbour Bridge cycleway could simply be converted to stairs for pedestrians. So easy!

Or perhaps the current Harbour Bridge cycleway could be retained as a slower-moving scenic cycleway for families & tourists. In this scenario, it would make sense to install a multi-level Looped ramp over Bradfield Park South (on the Southern side of Fitzroy St), to route families & tourists directly to the shoreline of Sydney Harbour, thus by-passing the dense pedestrian areas of Milsons Point. This would be safer for Milsons Point pedestrians and more convenient for cyclists.

If only Transport for NSW would convert this Bradfield Highway car lane to a bicycle lane…

3.7. Disclaimer: What this proposal is & isn't

3.7.1. What this proposal is

This proposal is something like a **feasibility analysis** (by an **unqualified layman**).
It considers basic topography & geometry, including:

- estimated ceiling height of:
  - Burton Street Tunnel
  - the car-park under Cahill Expressway (at the Northern end of Ennis Rd)

- existing community usage of areas in Milsons Point & Kirribilli such as:
  - the bowling green & the clay area adjacent to Burton St
  - Burton St (the Kirribilli Markets)
  - the taxi-rank on Ennis Rd, outside the Eastern entrance to Milsons Point station

- cycleway geometry:
  - cycle path floor width
  - bend/curve radii
  - ramp gradient (ideally 5% or less) & ramp difficulty (Z score: ideally 0.2 or less)

- vertical clearance underneath elevated cycleways, with particular attention on:
  - pedestrian access that provides overhead clearance (and is not claustrophobic)
  - NSW firetruck access (as the largest emergency vehicle) to maintain emergency vehicle access along Ennis Rd (especially to the high-rise Greenway Apartments)

- width clearance for NSW firetrucks to work along Ennis Rd (avoiding "pinch points")

Several of the constraints are challenging (especially along Ennis Rd) and the solutions are a tight fit (in terms of valid parameter values). But this proposal demonstrates that (at least topographically & geometrically), **solutions exist**.

3.7.2. What this proposal isn't

This proposal does **not** attempt to address engineering considerations such as:

- construction materials
- physical supports (mechanics, distance, materials) for an elevated cycleway
- ramp surface (exposed concrete, paint type / colour, tiles, ...)
- outside surface (exposed concrete, paint type / colour, tiles, ...)
- any other aesthetic detailing
- what type of railings / fences to install, to prevent cyclists ever falling (or jumping) out of an elevated cycleway
- drainage, lighting, ...

3.7.3. Technical references

This proposal references measurements, diagrams, and photos from these documents:

- *Appendix D – Sydney Harbour Bridge Cycle Ramp Options Feasibility Study* (2012) by the Government Architect's Office of the NSW government; available at: https://www.rms.nsw.gov.au/documents/projects/sydney-inner/sydney-harbour-bridge/cycleway-access-proposals/shb-cycle-ramp-options-feasibility-study--2012.pdf

- *Brief Dutch Design Manual for Bicycle and Pedestrian Bridges* (2015) by ipv Delft; available at: https://ipvdelft.com/publications/ → https://ipvdelft.com/brief-dutch-design-manual/

- *Guide to Road Design Part 6A: Pedestrian and Cyclist Paths* (October 2009) by Austroads Inc.; available at: https://roads-waterways.transport.nsw.gov.au/business-industry/partners-suppliers/documents/austroads-supplements/roaddesign_part6a-agrd-paths-walking-cycling.pdf

- *Access for fire brigade vehicles and firefighters* (version 5, issued 4 October 2019) by the Fire Safety Branch of the Community Safety Directorate; available at: https://www.fire.nsw.gov.au/gallery/files/pdf/guidelines/vehicle_access.pdf

— “This is either madness, or brilliant.”
— “It’s remarkable how often those two traits coincide.”

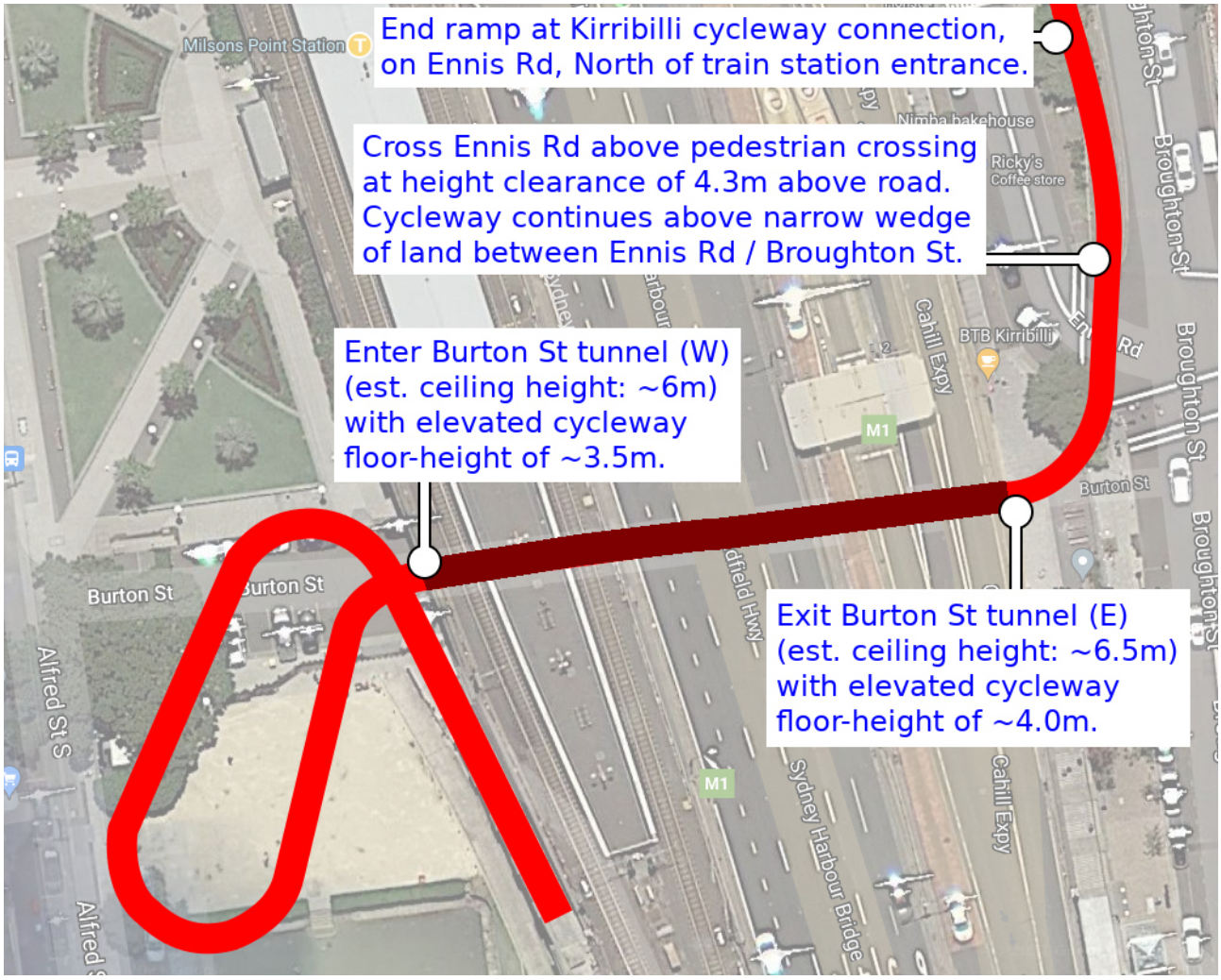
Pirates of the Caribbean: Curse of the Black Pearl (2003)

Artist impression of the Burton Street Tunnel elevated cycleway (passing through Burton Street Tunnel)

Part 4. Proposals in detail

Warning: Here be details.

4.1. Burton Street Tunnel elevated cycleway



The Burton Street Tunnel elevated cycleway will consist of 5 sections:

1. Western ramp from Sydney Harbour Bridge cycleway to Burton Street Tunnel.
2. Enter Burton Street Tunnel (West) at 3.5m elevation above road-level.
3. Exit Burton Street Tunnel (East); cross over Ennis Rd at 4.3m height clearance.
4. Maintain height clearance of 4.3m (clearance for firetrucks) along Ennis Rd.
5. At Kirribilli cycleway connection, descend as a ramp to 1m above road-level.

4.1.1. Distances: land-surveys, estimates, recommendations

Burton Street Tunnel (Western entrance) and the stairs/ramp from the Sydney Harbour Bridge cycleway.

The following measurements were obtained from land-survey schematics in the document *Appendix D – Sydney Harbour Bridge Cycle Ramp Options Feasibility Study* (2012), prepared by the Government Architect's Office of the NSW government; available at: https://www.rms.nsw.gov.au/documents/projects/sydney-inner/sydney-harbour-bridge/cycleway-access-proposals/shb-cycle-ramp-options-feasibility-study--2012.pdf :

Horizontal distances (approx):

- Harbour Bridge cycleway stairs/ramp: 24m
- Base of stairs/ramp to Burton Street Tunnel (Western entrance): 8m
- Top of stairs/ramp to Burton Street Tunnel (Western entrance): 32m
- Ground-level width of Burton Street Tunnel (Western entrance): 20m
- Top of stairs/ramp to middle of Burton Street roadway: 42m

Vertical distances:

- Harbour Bridge cycleway stairs/ramp: 9m (RL42.50 – RL33.50)

The "Z score" is a measure of a ramp's difficulty, as defined in *Brief Dutch Design Manual for Bicycle and Pedestrian Bridges* (2015); available at: https://ipvdelft.com/publications/ → https://ipvdelft.com/brief-dutch-design-manual/

The Z score is calculated as the height of the ramp (m) squared, divided by its length (m). A higher Z score means a more difficult ramp. The *Brief Dutch Design Manual* suggests a maximum Z score of 0.2.

The above measurements mean the Harbour Bridge cycleway ramp has a steep gradient of ~37.5%, and an extremely high Z score of 3.375. But that's why we're here...

The intention of this elevated cycleway is to transport cyclists above the pedestrians, for the convenience of cyclists and the safety of pedestrians. An additional benefit of an elevated cycleway is that there is less vertical distance that needs to be spanned by a ramp down from the Harbour Bridge.

Our North-travelling elevated cycleway must turn to the right (East) to enter the Burton Street Tunnel. We need our cycleway to be low enough, not just to enter the tunnel, but to provide sufficient overhead clearance for cyclists. This proposal will maintain a **minimum height clearance of 2.5m** above the cycleway floor at all times.

This minimum overhead clearance of 2.5m for cyclists (a "cyclist operating envelope" height of 2.2m + "overhead clearance minimum" of 0.3m) for cyclists is recommended in the document *Guide to Road Design Part 6A: Pedestrian and Cyclist Paths* (October 2009) by Austroads Inc.; available at:
https://roads-waterways.transport.nsw.gov.au/business-industry/partners-suppliers/documents/austroads-supplements/roaddesign_part6a-agrd-paths-walking-cycling.pdf

Specifically in the diagrams:

- *Figure 4.6: Bicycle operating space*
- *Figure 4.7: Clearances between cyclist envelope and potential path hazards*

in section *4.2.2: Cyclist Operating Space and Clearances* (pp. 34–35).

The document *Appendix D – Sydney Harbour Bridge Cycle Ramp Options Feasibility Study* (2012), does not provide direct measurements of the Burton Street Tunnel arch height. By comparing the above measurements with photos the same document, I've estimated that the Burton Street Tunnel has a maximum arch height of ~6.0m (Western entrance) and ~6.5m (Eastern entrance).

To maintain the 2.5m height clearance, this implies a 3.5m cycle-path floor elevation as the cycleway enters the Burton Street Tunnel (Western entrance) and a 4.0m cycle-path floor elevation at the Eastern exit. We want the cycleway to be as elevated as possible as it enters the tunnel, for two reasons:

1. Maximise the elevation above pedestrians on the ground.
2. Minimise the vertical distance that the cycleway needs to descend from the 9m elevation of the Harbour Bridge cycleway.

A 3.5m cycleway elevation implies that the cycleway must descend 5.5m from the 9m elevation of the Harbour Bridge cycleway. But from the top of the current stairs/ramp to the middle of Burton Street roadway is only 42m. This would mean a steep gradient of 13% and a too-high Z score of 0.72. So the shortest path of descent from the top of the current stairs/ramp is not feasible.

Besides, a ramp descending along the shortest path would follow along the concrete wall of the Harbour Bridge foundation in a straight line. But a larger "turning circle" is needed to turn into the Burton Street Tunnel: a turning radius of at least 10m is recommended. (The multi-level Looped option also has a 10m turning radius.)

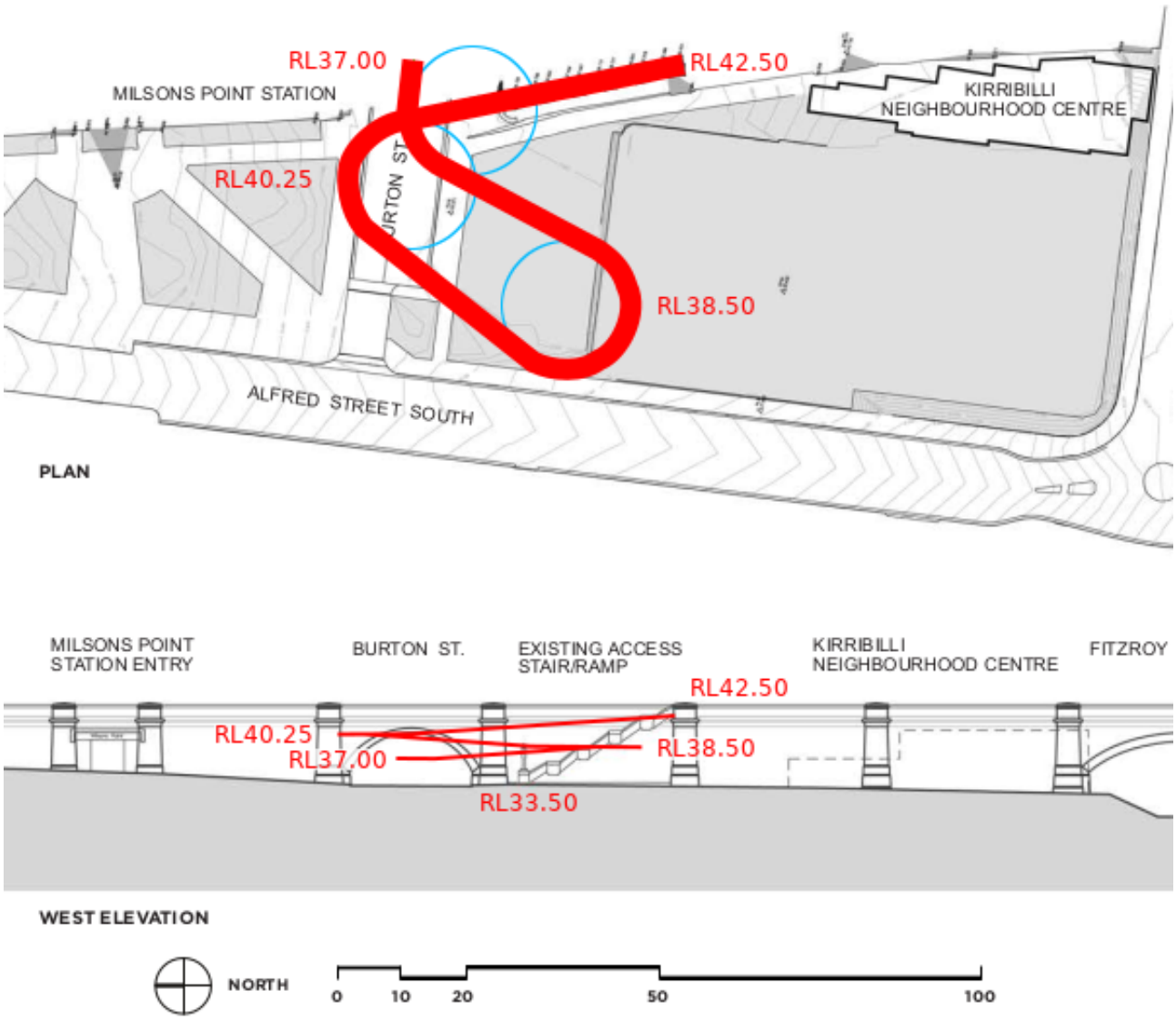
So for the elevated cycleway to enter Burton Street Tunnel, a hook or loop is necessary in the cycle path.

4.1.2. Western ramp to Burton Street Tunnel

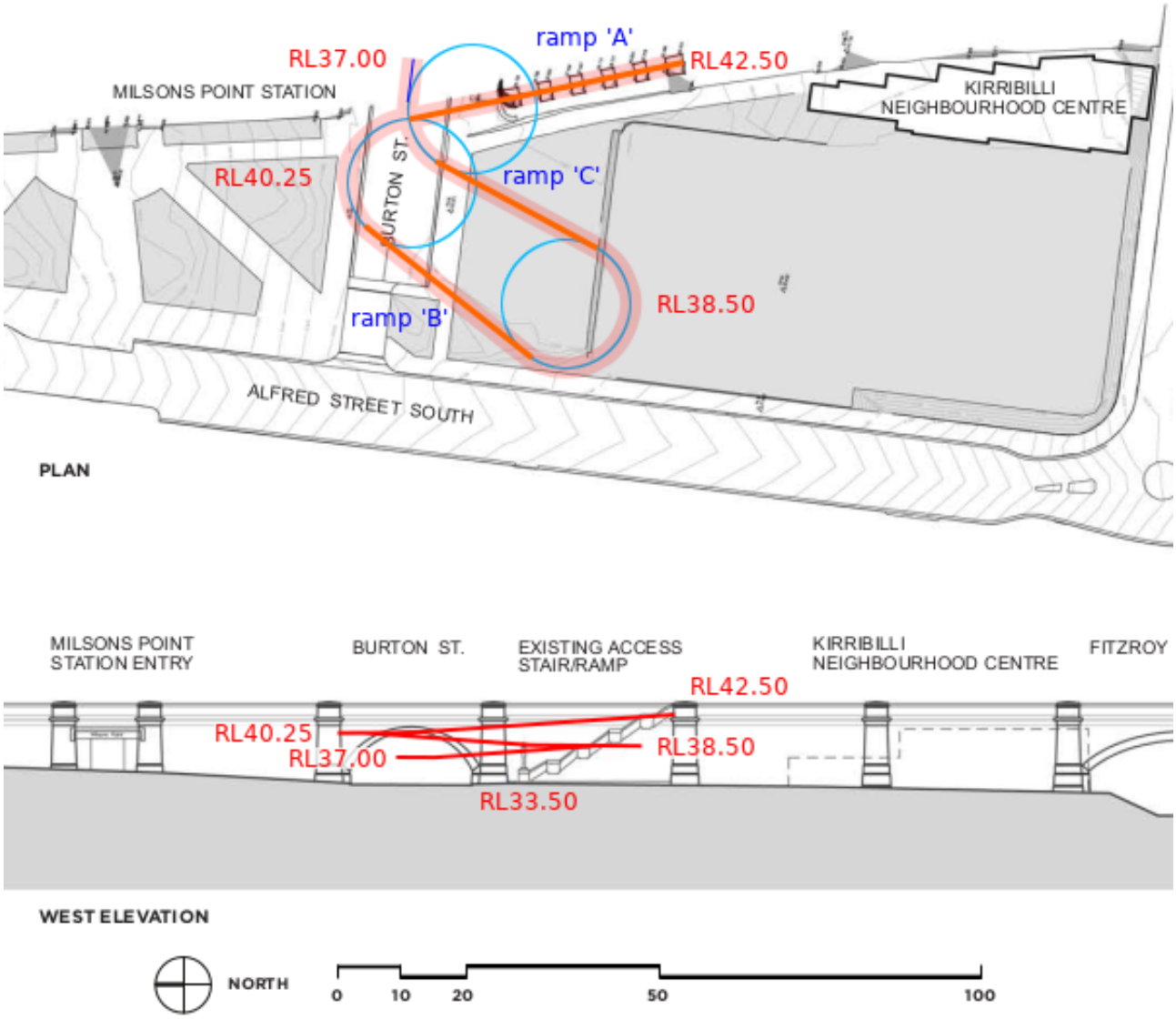
The Western ramp has been carefully designed to satisfy the following constraints:

1. Ramp gradient & Z score within acceptable limits.
2. No cycleway in front of the Western entrance to Milsons Point train station.
3. No cycleway over the gardens outside this Western entrance.
4. No cycleway through Bradfield Park North (like the Linear option).
5. No cycleway on the Alfred St South footpath.
6. No cycleway through the “5G” antenna on the corner of Burton St & Alfred St South.
7. No multi-level ramp loops (like the Looped option).
8. No destruction of the old bowling club building (like the Looped option).
9. Minimal intrusion onto the green fields of Bradfield Park Central (the bowls lawn).
10. Connect to Harbour Bridge cycleway at or near the top of the current stairs/ramp.

I experimented with many ramp designs. Only this design satisfied all constraints:



This Milsons Point land-survey plan was obtained from
Appendix D – Sydney Harbour Bridge Cycle Ramp Options Feasibility Study (2012).



The Western ramp design consists of:

- 3 straight ramps (indicated by the orange lines; labelled ‘A’, ‘B’, ‘C’),
- joined by 3 flat curves of radius 10 metres (indicated by the light-blue circles).

The following table provides per-ramp distances, gradients, Z scores of each straight ramp:

Ramp	Upper RL	Lower RL	Vertical	Horizontal	Gradient	Z score
	(m)	(m)	(m)	(m)	(%)	
A	RL42.50	RL40.25	2.25	44	5.1	0.12
B	RL40.25	RL38.50	1.75	34	5.1	0.09
C	RL38.50	RL37.00	1.5	29	5.2	0.08

Overall vertical distance = 5.5m; overall horizontal distance (including curves) = ~170m.
Overall ramp gradient = ~3.2%; overall ramp Z score = ~0.18.

Note that the highest ramp (‘A’) passes over the final flat curve into Burton Street Tunnel at an elevation difference of 3.25m (1.75m + 1.5m). This should ensure sufficient height clearance for bicycles on the final flat curve into Burton Street Tunnel.

Per-ramp gradients of 5.1% are slightly in excess of our target upper limit of 5%, but still within an acceptable range for limited-length distances.

If necessary to decrease the gradients, the ramp design could be modified to relocate the upper end-point of the highest ramp ‘A’ (which connects to the Harbour Bridge cycleway at the top of the current stairs/ramp) Southwards along the Harbour Bridge cycleway, to connect further South. This would provide more horizontal ramp distance, over which to distribute the gradients of all 3 straight ramps proportionally.

Because the Western ramp includes 3 tight curves of radius 10 metres, it should have a cycle-path floor width of 3.6m to match the width of the Looped option.

The Western ramp would have just 2 straight ramps passing over the clay-surfaced community area next to the current stairs/ramp from the Harbour Bridge Cycleway.

The height clearances of the ramps would range from 3.0m – 6.25m above ground-level, still sufficient height clearance for community events such as the Kirribilli Markets.

4.1.3. Through Burton Street Tunnel

A Burton Street Tunnel elevated cycleway offers benefits for pedestrians & local residents:

- Fast-moving bicycles are routed away from the dense pedestrian areas of Burton St and the plaza outside the Western entrance to Milsons Point train station.
- Fast-moving bicycles are separated from pedestrians within Burton Street Tunnel. Pedestrians can continue to use Burton Street Tunnel as a thoroughfare.
- Milsons Point residents can continue to use Burton Street Tunnel as an under-cover plaza for community events such as the Kirribilli Markets.

The elevated cycleway will maintain the 2.5m height clearance for cyclists as it passes through Burton Street Tunnel. This will maximise the elevation above Burton Street Tunnel pedestrians & the Kirribilli markets underneath).

We should note that due to the curved tunnel ceiling, perhaps the 2.5m height clearance for cyclists should be measured above the mid-line or even outer edge of each cycle lane, rather than above the mid-line of the cycleway as a whole. Regardless, a minimum height clearance of 2.3m is approx 7 feet 6 inches (almost 2 feet taller than the Australian height average) in case a cyclist needs to walk their bicycle on-foot for some reason.

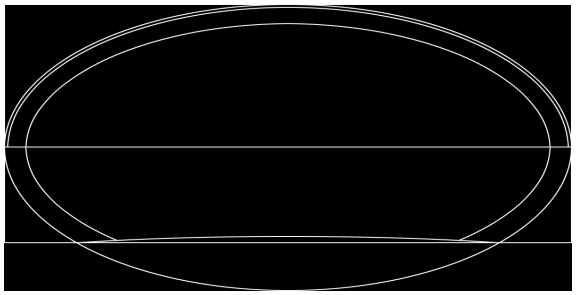
Burton Street Tunnel is currently lit by fluorescent lights hanging from the ceiling. There are two sets of lights: one set shining upwards (to light the curved ceiling of the tunnel) and one set shining downwards (to shine directly onto the activities in the tunnel).

These fluorescent lights must be removed to make way for the elevated cycleway. They were installed relatively recently (within the last 15 years, I think), so there's surely no way they can be considered "heritage". Outward-facing lighting can be attached to both sides of the elevated cycleway to light the tunnel. These outward-facing lights can be installed to shine upwards (to light the curved ceiling) and downwards.

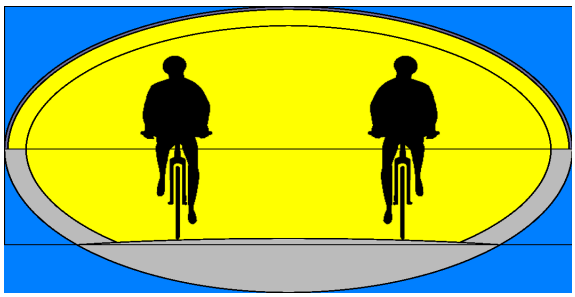
4.1.4. Ellipse cross-section for cycleway through tunnel

[**Note:** This is the only time I break my "no aesthetic design" rule.]

To best fit the shape (structurally) & design (aesthetically) of the arched ceiling of Burton Street Tunnel, perhaps the cross-section of the elevated cycleway should approximately resemble an ellipse (a widened circle). For example:



Schematic of ellipse cross-section
with an ellipse width:height ratio of 16:9
(total height = 3m; total width = 5.33m;
floor thickness = 0.5m; 2.5m interior height;
minimum concrete thickness = 0.2m)



Cross-section of ellipse construction,
coloured to indicate concrete (grey),
inside cycleway (yellow), outside (sky blue),
optional overhead metal grill (blue-grey)

The upper half of the ellipse should allow air-circulation into/out-of the cycleway.

It's interesting to note that the hanging enclosure of the tunnel's current lighting also has an ellipse cross-section. So it seems that the designers of the lighting enclosure might have arrived at the same conclusion about the suitability of an ellipse cross-section.

A view of the Eastern entrance of Burton Street Tunnel.
The ellipse cross-section of the hanging lighting enclosure can be observed.

4.1.5. Cross over Ennis Road at traffic lights

Where should the cycleway go when it emerges from the Eastern exit of Burton Street Tunnel? We don't want to simply drop cyclists back into the dense pedestrian traffic along Broughton St (particularly the tourists walking from Milsons Point train station to the stairs up to the Harbour Bridge Eastern walkway). That would simply be moving the problem of bicycle congestion, and the danger of pedestrian collisions, from one side of Burton Street Tunnel to the other.

This is another reason why the cycleway remains elevated for the full length of Burton Street Tunnel, rather than descending as a ramp to ground-level.

Instead, the cycleway will curve to the left (North) with a turning radius of 10m, travelling Northwards along Ennis Rd, towards North Sydney via the proposed **Kirribilli cycleway connection**.

An elevation of 4.0 metres as the cycleway emerges from the Eastern exit of Burton Street Tunnel allows the cycleway to rise quickly to an height clearance of 4.3 metres or higher before it reaches Ennis Rd, over an estimated distance of at least 15m on its 10m radius. A height clearance of 4.3 metres would enable the cycleway to "arch over" Ennis Rd (at the existing pedestrian crossing and intersection with Broughton St) without interrupting car & truck traffic along Ennis Rd (especially garbage trucks & firetrucks).

A view along Ennis Rd at the intersection with Broughton St.
Broughton St runs parallel to Ennis Rd for a short distance, visible on the right edge of the photo.

After the elevated cycleway crosses over Ennis Rd, it will continue Northwards above the narrow wedge of land between Ennis Rd & Broughton St.

Along Ennis Rd, there are:

- restaurants
- a bakery
- the Eastern entrance to Milsons Point train station
- an Australia Post office
- and at the far-Northern end, the high-rise Greenway Apartments.

Besides regular car traffic, we want to ensure that Ennis Rd is still accessible to:

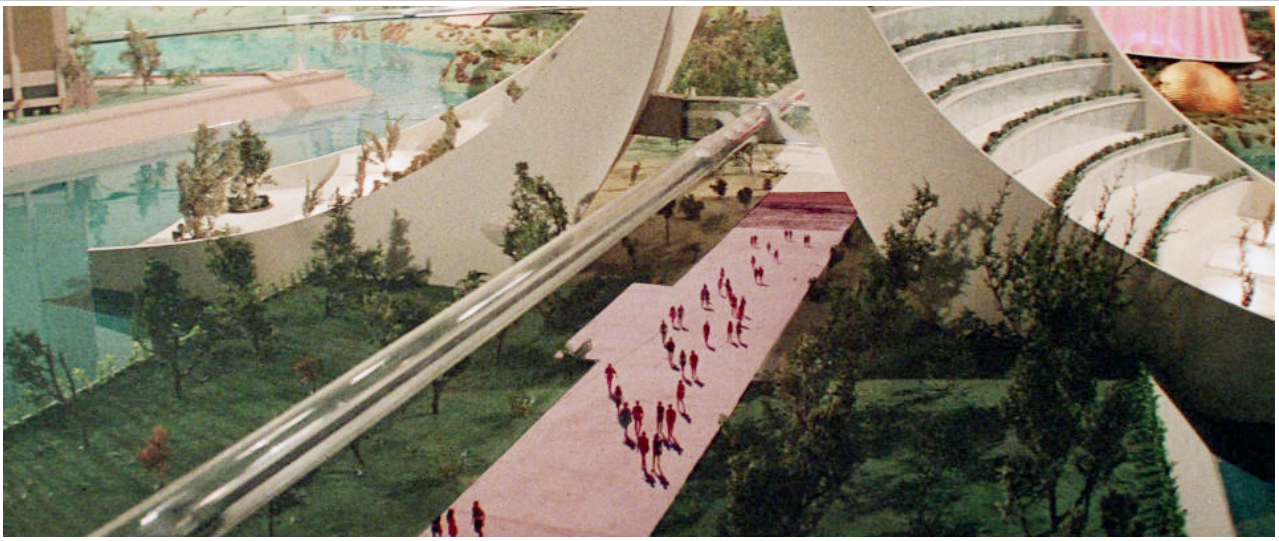
- delivery trucks
- Australia Post trucks
- garbage trucks
- ambulances & firetrucks

According to the document *Access for fire brigade vehicles and firefighters* (version 5, issued 4 October 2019) by the Fire Safety Branch of the Community Safety Directorate; available at: https://www.fire.nsw.gov.au/gallery/files/pdf/guidelines/vehicle_access.pdf , NSW firetrucks have a height of 3.7m, requiring a minimum height clearance of 4.0m to consider a carriageway accessible.

[I haven't been able to find comparable numbers for garbage trucks — perhaps because different collection companies use different trucks? I have found that some garbage trucks have a height of 4.1m; but no numbers for required minimum height clearance.]

The elevated cycleway should cross over Ennis Rd at a minimum height clearance of 4.3m.

After the cycleway has crossed over Ennis Rd at the intersection with Broughton St, it will travel Northwards, along the narrow wedge of land between Ennis Rd & Broughton St, to the proposed **Kirribilli cycleway connection**.



Logan's Run (1976)
Copyright © Metro-Goldwyn-Mayer, Inc.

Artist impression of the Burton Street Tunnel elevated cycleway (above Milsons Point pedestrian areas)

4.2. Kirribilli cycleway connection

Ennis Road is a long, straight, quiet cul-de-sac that runs alongside the Cahill Expressway on the Eastern side. This is an ideal route for a North-South cycleway and an ideal stretch for cycle ramps to finally land at ground-level.

Ennis Rd is on the opposite side of Milsons Point to the Harbour Bridge cycleway and the existing stairs/ramp down to Burton St. It's also the opposite side to Bradfield Park North, Alfred St South, and all other cycle ramp proposals. Ennis Rd is how we avoid cycle ramps landing in Bradfield Park North or the Milsons Point bowling green.

There is minimal car traffic along Ennis Rd, aside from parking cars and a taxi-rank outside the Eastern entrance to Milsons Point train station.

Ennis Rd is 4 car-lanes wide, with a footpath on either side, for a total width of ~17.5m:

- 2 lanes of car traffic
- with a lane of car-parking (or taxi-rank) on either side
- and a footpath on either side of that.

Each footpath is approx 2.5m wide. This implies that each car lane is ~3.125m wide.

Ennis Rd is a long, straight, quiet cul-de-sac.

4.2.1. The need for a Kirribilli cycleway connection

The Burton Street Tunnel elevated cycleway will carry fast-moving cyclists safely down from the Harbour Bridge cycleway to a smooth landing on Ennis Rd. But once the cyclists have landed on Ennis Rd, where should they go?

As we've already noted, Ennis Rd is a long, straight, quiet cul-de-sac. This is ideal as a landing-stretch for cycle ramps, but it doesn't provide any exit at its Northern end — for either cars or bicycles. [Ennis Lane is a pedestrian walkway that continues from the Northern end of Ennis Rd, but unfortunately it's too narrow to serve as a cycleway, as we will explain in section "**4.3.5. Ruling out Ennis Lane**".]

We don't want the landed cyclists to simply turn around and ride back to the Southern end of Ennis Rd. Aside from the inconvenience (and likelihood of collisions) of two opposing streams of fast-moving bicycles attempting to U-turn past each other (in a road that's only 17.5 metres wide), routing two streams of fast-moving bicycles back through the dense pedestrian areas outside of Milsons Point train station & Burton Street Tunnel would defeat much of what the Burton Street Tunnel elevated cycleway accomplished in the first place.

The answer, of course, is for North Shore commuter cyclists to continue Northwards to North Sydney train station along the proposed **Ennis–Tramway elevated cycleway**.

The proposed **Kirribilli cycleway connection** will connect the Burton Street Tunnel elevated cycleway to the Ennis–Tramway elevated cycleway, providing an uninterrupted cycleway from the Harbour Bridge cycleway all the way to North Sydney train station.

The Kirribilli cycleway connection will also allow cyclists to:

- Enter/exit the Burton Street Tunnel cycleway (enter from the Northern end to travel South along the cycleway; or travel from the South and exit at the Northern end).
- Enter/exit the Ennis–Tramway cycleway (same again, but all directions reversed).

The Kirribilli cycleway connection will be constructed as a **7.5m-wide, elongated, raised traffic island with rounded ends**, on Ennis Rd. It will **replace the current Ennis Rd round-about** (located 85m Northwards along Ennis Rd of the Milsons Point train station pedestrian crossing) to enable cars to turn around. Construction of this raised traffic island **will require road-traffic modifications along Ennis Rd**.

The elevated cycleways will connect on this traffic island, both descending to 1m above ground-level to connect in a smooth arc.

A system of 4 inter-woven parallel bicycle lanes will allow cyclists travelling on Ennis Rd to gain speed and merge with the fast-moving stream of bicycles. This will enable cyclists to enter or exit the stream without interrupting the flow or risking a high-speed collision.

An **island of length 130m** along Ennis Rd seems to offer the best outcome. This length minimises the Z scores of the cycleway ramps, while still allowing for pedestrian footpaths on both sides of the road at the North & South ends, plus car parking & a taxi-rank near the train station entrance.

4.2.2. Dimensions of road modifications on Ennis Road

I've set the following self-imposed requirements for any traffic modifications on Ennis Rd:

- Maintain emergency vehicle access (especially firetrucks) to Greenway Apartments.
- Maintain the taxi-rank near the Eastern entrance to Milsons Point train station.
- Maintain 2 car-lanes, and a round-about or similar traffic island for turning around.
- Maintain car-parking outside the restaurants & Australia Post Office along Ennis St (including for deliveries and pick-ups).
- Maintain pedestrian access to Broughton St pedestrian staircase & the taxi-rank.
- Maintain pedestrian access along the full length of Ennis Rd on the Western side (to access the Australia Post office, the Transport for NSW offices, and the high-rise Greenway Apartments at the Northern end).

To ensure that firetrucks can pass, there must be at least one car lane with a horizontal clearance of 4.5m and a vertical clearance of at least 4.0m, stretching the full length of Ennis Rd. This lane is necessary to allow firetrucks to service the full length of Ennis Rd.

In addition, we want the car lanes in both directions to have a vertical clearance of at least 4.3m (for garbage trucks), and a horizontal clearance of at least 3.2m. A width of greater than 3.2m but less than 4.5m is called a "pinch point": A firetruck is able to negotiate past a pinch point, but cannot stop at that location to fight a fire.

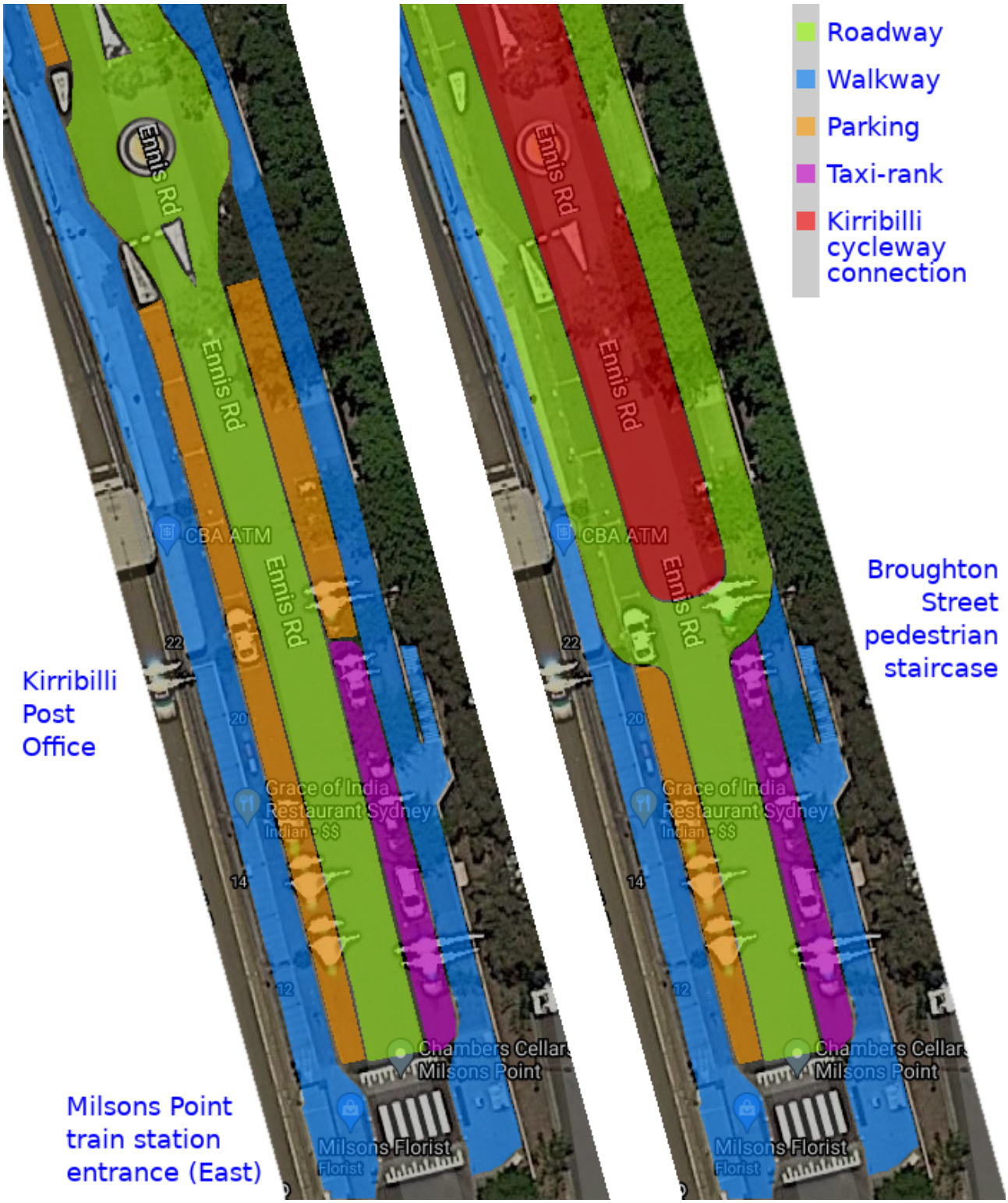
This would mean that both firetrucks & garbage trucks can negotiate the car lanes in both directions; and one of the car lanes can be used by firetrucks to stop and fight fires.

Thus, for the length of the Kirribilli cycleway connection, the 17.5m-wide Ennis Rd would be re-apportioned as:

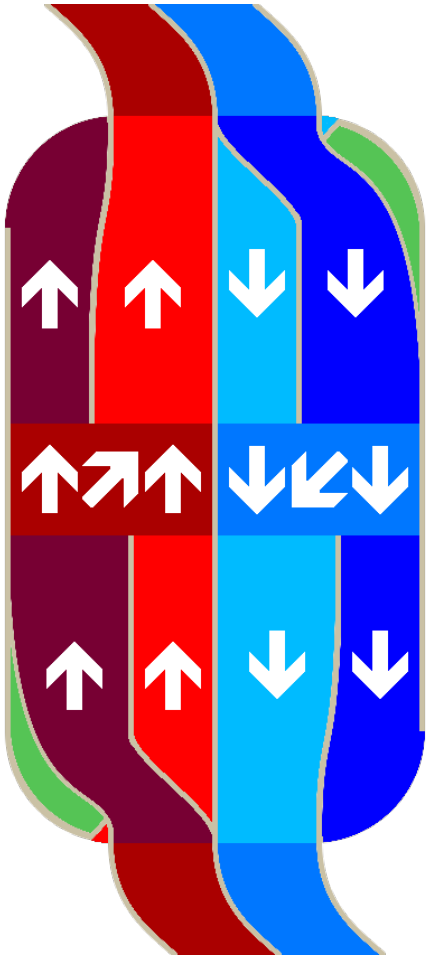
- 2.0m: footpath along the Western side of Ennis Rd
- 4.5m: "wider car lane" for firetruck access to Ennis Rd restaurants, offices, etc.
- 7.5m: raised traffic island for Kirribilli cycleway connection
- 3.5m: "pinch-point car lane" for firetruck negotiation along Eastern side of Ennis Rd

The traffic island must end at least 5m before the red footbridge over Greenway Drive that connects Ennis Rd to the Greenway Apartments. This will allow pedestrian access to the red footbridge (on the Eastern side of Ennis Rd) from the footpath (on the Western side of Ennis Rd), with 5m of road-length along Ennis Rd for vehicles to turn around the Northern end of the traffic island like a round-about.

4.2.3. Current usage vs. proposed usage of Ennis Road



4.2.4. The 6 paths through Kirribilli cycleway connection

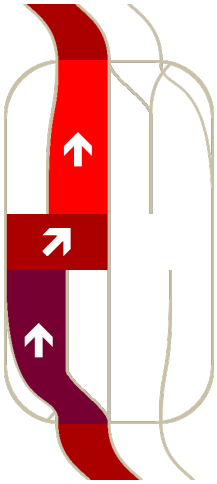


Top-down view of Kirribilli cycleway connection.

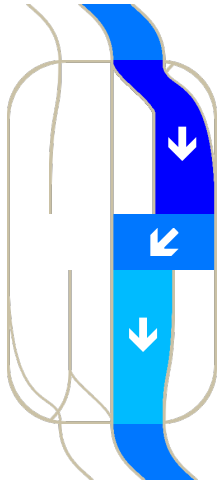
Width on Ennis Rd: 7.5 m
Length along Ennis Rd: 130 m
Lane width: 1.4–2.1 m (excl. barriers / median strips)

Cycleway ramps will have a height clearance of 4.3 m above road-level when they reach the traffic island. Cyclists may enter or exit the connection at road-level. The connection has 8 ramps to merge the flows. A system of 4 inter-woven parallel bike lanes allows cyclists to merge or diverge, so that they may safely enter or exit the fast-moving stream of bicycles.

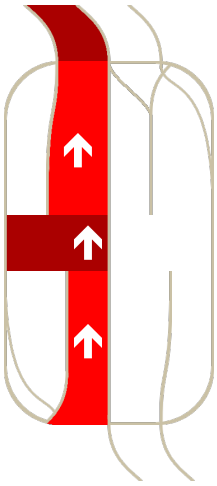
Red-coloured lanes travel Northwards; blue-coloured lanes travel Southwards. Lighter reds & blues are ascending ramps; darker reds & blues are descending ramps. Lanes are separated by barriers or median strips (coloured grey-brown in diagram), width 0.1 m.



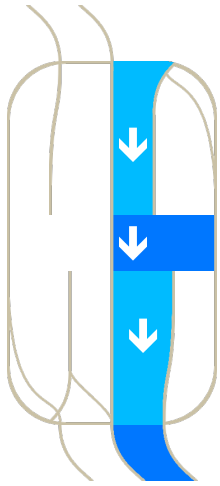
Travelling North, connect cycleways



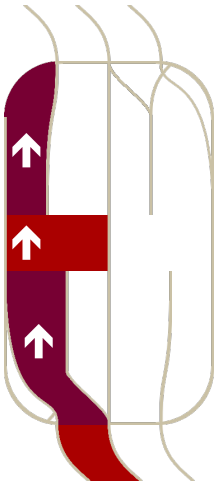
Travelling South, connect cycleways



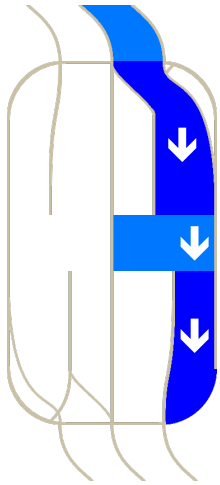
Travelling North, enter cycleway from road



Travelling South, enter cycleway from road



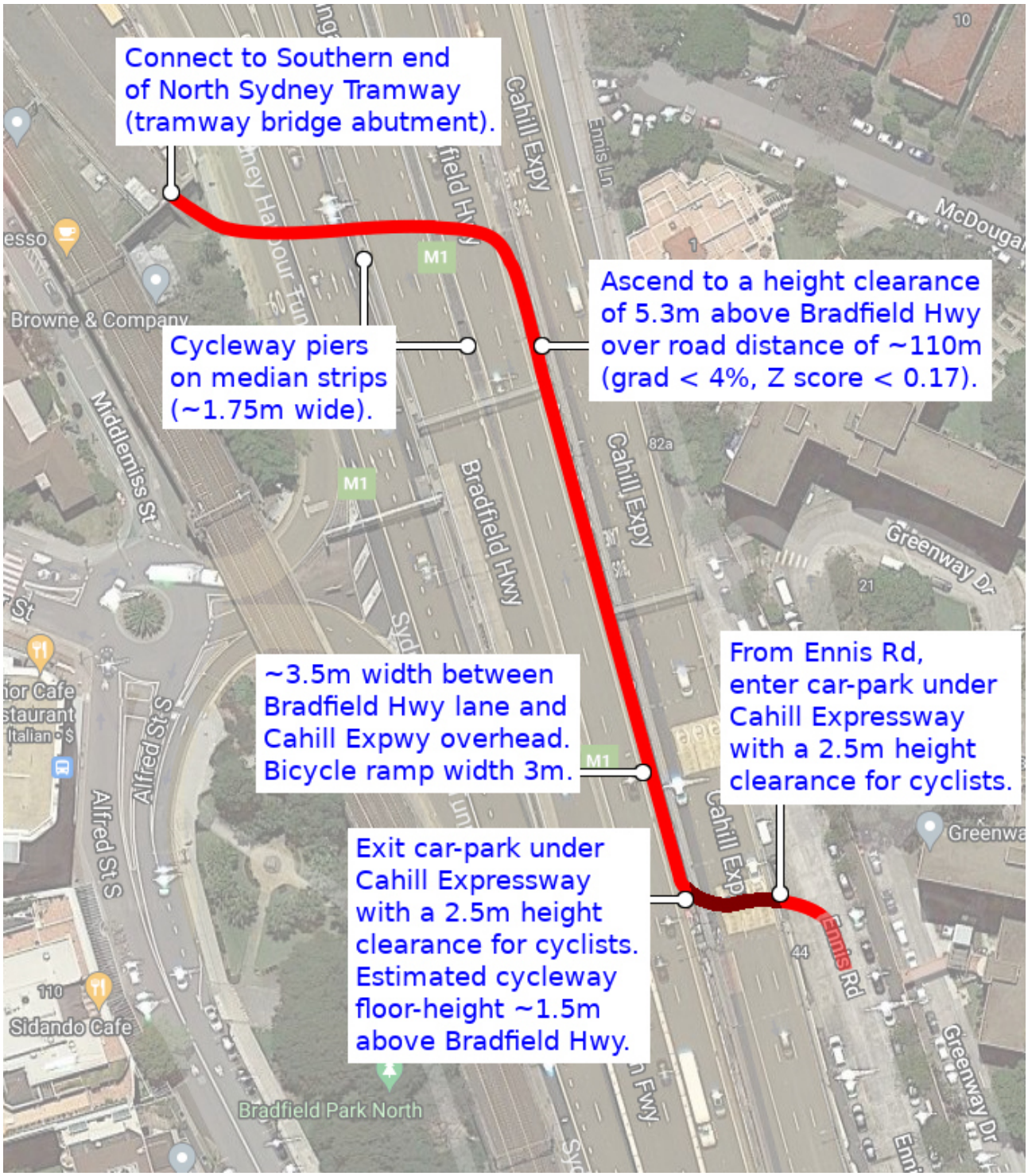
Travelling North, exit cycleway to road



Travelling South, exit cycleway to road

Artist impression of the Kirribilli cycleway connection.
Sardines are also high in Omega-3 fatty acids and low in mercury. Eat a sardine today!

4.3 Ennis–Tramway elevated cycleway



The proposed **Ennis–Tramway elevated cycleway** will consist of 5 sections:

1. At Kirribilli cycleway connection, ascend as a ramp from 1m above road-level to a height clearance of 4.3m (clearance for firetrucks) along 65m of Ennis Rd.
2. Curve left to duck underneath the ceiling of Cahill Expressway car-park with 2.5m clearance for cyclists; diagonally through car-park (width 13.5m); then curve right, to emerge from under Cahill Expressway (approx 1.5m above Bradfield Hwy road), directed North along the shoulder between Cahill Expressway and Bradfield Hwy.
3. Follow the 3.5m-wide shoulder of Bradfield Hwy Northwards. Ascend as a ramp to a clearance of 5.3m above Bradfield Hwy road-level. This exceeds the clearances of 4.9m & 5.1m indicated on the "Low Clearance" signs on the High St overpass (325m to the North). Assume height-delta of 4.3m; assume distance of 110m along Bradfield Hwy; this is < 4% gradient, and Z score < 0.17.
4. Curve left (West), to cross Bradfield Highway diagonally North-West at a minimum height clearance of 5.3m. Connect to the South-Eastern end of the Tramway (70m North of the Alfred St South / Lavender St round-about). Estimated distance = 55m.
5. Bicycle lanes along the length of the Tramway, ending at North Sydney train station.

4.3.1. Cycleway connection through the car-park under Cahill

At the Northern end of Ennis Rd, there's a car-park underneath the Cahill Expressway. The car-park is open-air on both sides, with a high ceiling. Bradfield Highway is directly on the other side; on the Bradfield Highway side, the ceiling has a 4m height clearance above Bradfield Highway road-level. The ceiling is highest at the Southern end of the car-park.

Crossing through the Southern end of this car-park would allow an elevated cycleway to pass under the Cahill Expressway, from Ennis Rd to Bradfield Highway, without impacting most of the car-park. Conveniently, the car-park is already operated by Transport for NSW.

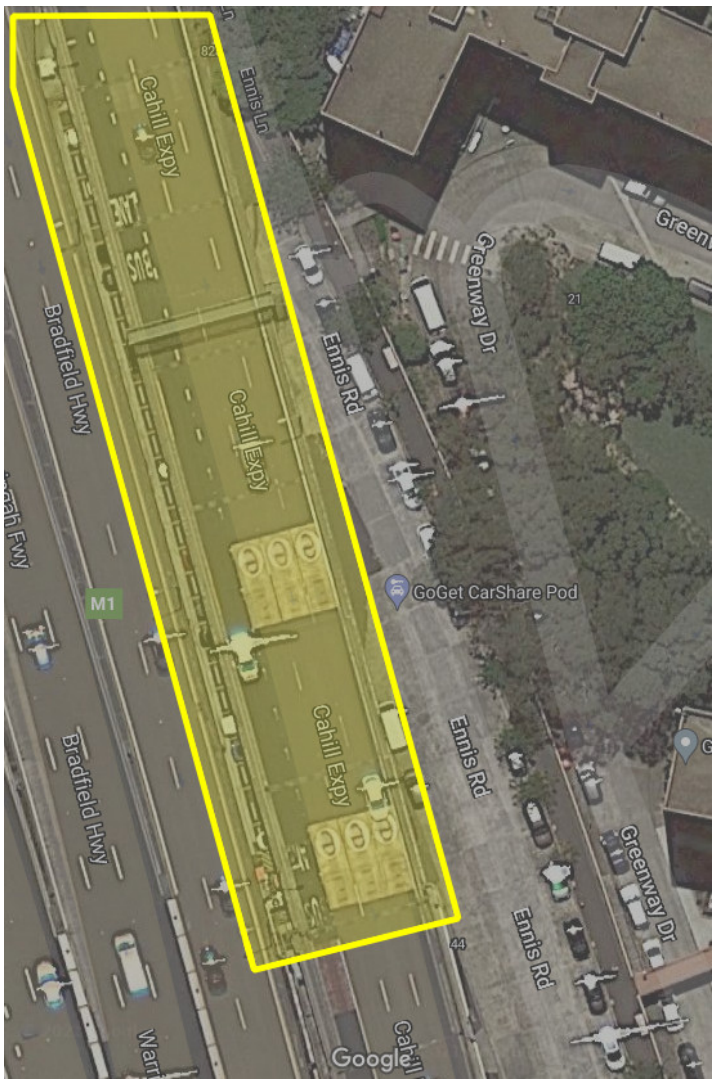
A view through the car-park from the Ennis Rd side (at the Northern end of Ennis Rd).

4.3.2. From the car-park along the Bradfield Highway shoulder

A view of the car-park from the Western side, looking across Pacific Highway & Bradfield Highway.

A conveniently-placed coach (height: 3.8m) allows us to estimate a 4 metre height clearance on the Bradfield Highway side.

The cycleway would exit the car-park with a 2.5m overhead height clearance for cyclists. This would mean an estimated floor-height of approx 1.5m above Bradfield Highway. Follow the 3.5m-wide shoulder of Bradfield Highway Northwards, between the Bradfield Highway car-lanes on the West and the overhead edge of Cahill Expressway on the East.



The physical extent of the car-park under Cahill Expressway is indicated by the yellow rectangle.

If you look closely at the West (left) boundary of the yellow rectangle, you can observe the tips of the parked cars protruding from under the edge of Cahill Expressway.

Estimated length of car-park: 90m along shoulder between Bradfield Hwy & Cahill Expressway.

Estimated width between the Bradfield Highway car-lanes and the overhead edge of Cahill Expressway: 3.5m.

Half of this 3.5m width is due to the Bradfield Highway road shoulder, while the other half of the width is due to the narrow strip of uncovered car-park along its West (left) edge.

There is a horizontal gap of approx 3.5 metres between Bradfield Highway & Cahill Expressway on the Western side of the car-park under Cahill Expressway.

The cycleway would ascend to a minimum height clearance of 5.3m above Bradfield Highway, along a road distance of approx 110 metres. This would be a gradient of less than 4% and a Z score of less than 0.17.

4.3.3. Crossing over Bradfield Highway & Pacific Highway

Once the cycleway has reached a height clearance of 5.3m, it can curve left (to the West) to cross over Bradfield Highway to the South-Eastern end of the North Sydney Tramway.

The Bradfield Highway median strips are approx 1.75m wide.
Each median strip should be wide enough for a sturdy pier to support an elevated cycleway.

A sign on the overpass warns “LOW CLEARANCE / 4.9m”.
So (for traffic from the North, at least) we really only need to exceed a clearance of 4.9m...

4.3.4. North Sydney Tramway

Until 1958, North Sydney had several tram-lines, part of the Sydney tram network.

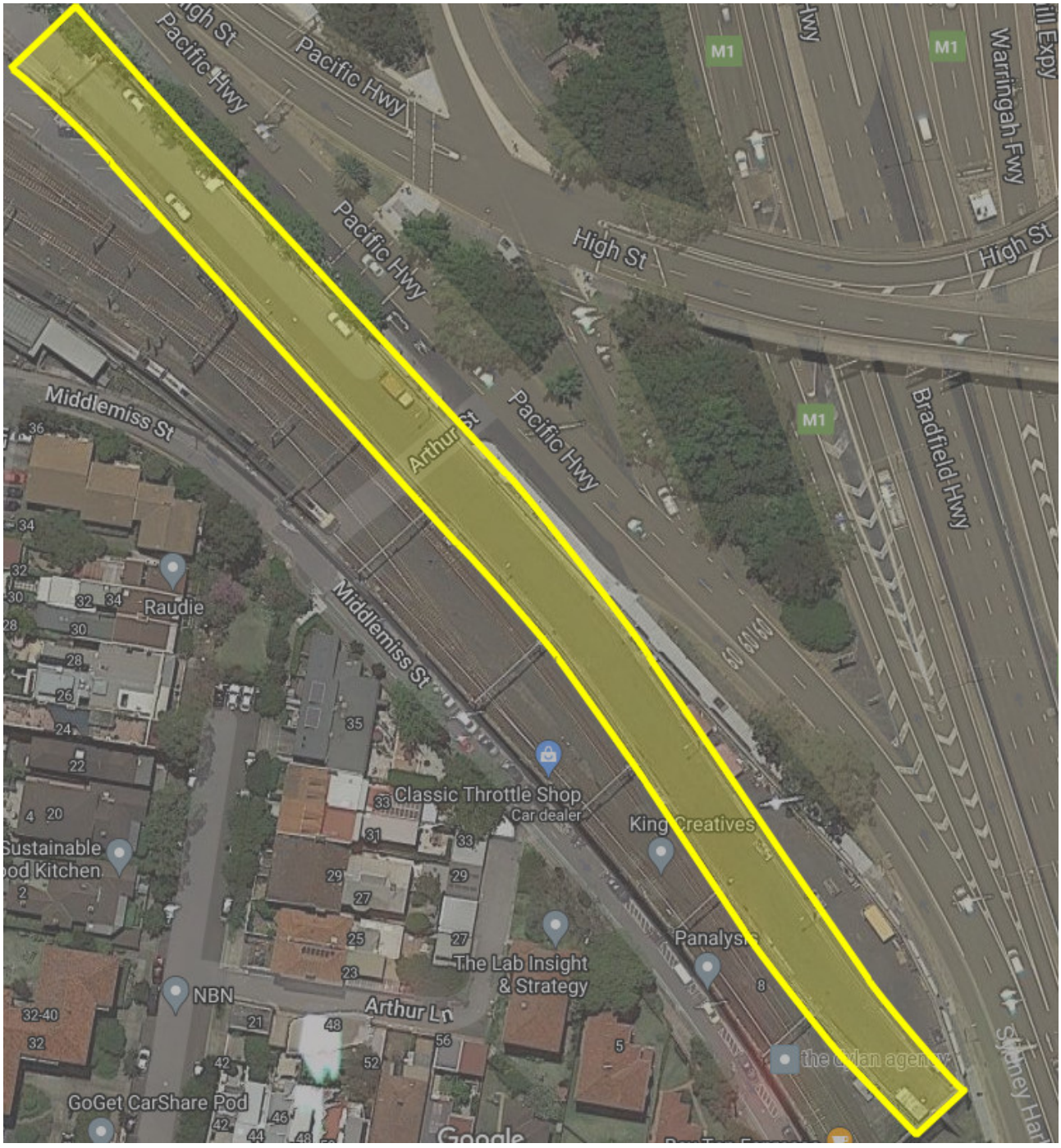
From https://www.visitsydneyaustralia.com.au/lost-tramways.html — photo attribution unspecified, but it appears to be a colour-corrected adaptation of https://www.flickr.com/photos/intervene/3850965655 , uploaded by Flickr user lindsaybridge under an Attribution 2.0 Generic (CC BY 2.0) Creative Commons license.

1958 photo of a tram crossing over Pacific Highway on the North Sydney Tramway bridge.

You may recognise the following present-day landmarks in the photo above:

- The North Sydney Tramway bridge crosses diagonally over Pacific Hwy, towards Milsons Point tramway station (now Cahill Expressway) in the bottom-left corner.
- A red train is travelling on the North Sydney train-line towards Milsons Point station.
- On the left edge of the photo, there is a tunnel arch underneath the train line, from Pacific Hwy through to Alfred St South & Lavender St.
- The Pacific Hwy curves around the tramway foundations towards North Sydney.
- The tramway continues Northwards all the way to North Sydney train station.

In 1958, the lower North Shore tram network was shut down. Most of the tram tracks have been removed. The Milsons Point tram station has been converted to Cahill Expressway. Ennis Rd is cut off from Pacific Highway by the Cahill Expressway. And the tramway bridge over Pacific Highway has been demolished. **But the elevated North Sydney Tramway to North Sydney train station remains intact** (without its tram tracks).



The physical extent of the North Sydney Tramway is indicated by the yellow highlight.

The North Sydney Tramway runs alongside North Sydney train-line (at the same elevation), between the train-line along its South-West side, and Pacific Hwy along its North-East side.

The North Sydney Tramway is 260m of flat, sealed, almost-straight, multi-lane roadway, stretching from the old tramway bridge abutment that remains at its South-Eastern end (70m North of the Alfred St South / Lavender St round-about) to North Sydney train station.

It would be perfect as a cycleway, with dedicated bicycle lanes running its length.

As has been noted already, the North Sydney Tramway is a quarter of a kilometre of flat, sealed, multi-lane roadway that’s currently only used as a mostly-empty car-park for Sydney Trains employees & contractors, and a storage area for trucks & trailers.

After crossing over Bradfield Highway & Pacific Highway, the elevated cycleway would connect to the South-Eastern end of North Sydney Tramway, at the old bridge abutment. Dedicated cycle lanes along the North Sydney Tramway could carry cyclists, conveniently & safely, **all the way to North Sydney train station**.

View of the old tramway bridge abutment at the South-Eastern end of the North Sydney Tramway (looking North-West from the Pacific Highway footpath). The tramway is on top.

View of the old tramway bridge abutment, looking West from across Bradfield Highway & Pacific Highway.

4.3.5. Ruling out Ennis Lane

Ennis Lane is a narrow pedestrian walkway that runs along the concrete foundation of Cahill Expressway for ~150m. It connects from the Northern end of Ennis Rd to High St. On a map, Ennis Lane looks like it would be the perfect next step from the Northern end of Ennis Rd, providing a cycleway connection from Ennis Rd to North Sydney (via High St).

Unfortunately, on closer inspection, **Ennis Lane is too narrow and sharply-curved** to be a high-throughput cycleway. It's certainly not wide enough for separated bicycle lanes and a pedestrian path. In at least two places, the width is physically constrained by fences or even exterior building walls of adjacent apartment blocks.

Even more unfortunately, it would presumably not be possible to widen Ennis Lane, with the concrete walls of the ascending Cahill Expressway on one side and apartment blocks on the other, without demolishing at least one apartment block. And a significant length of Ennis Lane would likely be inaccessible to large construction machinery.

Cyclists must dismount and walk their bicycles along Ennis Lane,
a narrow walkway between the concrete foundations of Cahill Expressway and some apartment blocks.

Part 5. Attributions & notes

5.1. Attributions for maps and icons

- The Milsons Point land-survey plan was obtained from the document *Appendix D – Sydney Harbour Bridge Cycle Ramp Options Feasibility Study* (2012) by the Government Architect's Office of the NSW government; available at: https://www.rms.nsw.gov.au/documents/projects/sydney-inner/sydney-harbour-bridge/cycleway-access-proposals/shb-cycle-ramp-options-feasibility-study--2012.pdf

- All other maps from Google Maps: https://www.google.com.au/maps
  Thank you, Google Maps. This proposal would not have been possible without the high-resolution maps & satellite imagery that you provide.

"Skull and Crossbones" icon by Andrew Cameron, GB:
https://thenounproject.com/term/skull-and-crossbones/1190285/
The icon is licensed as Creative Commons CCBY:
https://creativecommons.org/licenses/by/3.0/us/legalcode

"hourglass" icon by mark newman:
https://thenounproject.com/term/hourglass/269439/
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5.2. Notes

5.2.1. Ease of uphill travel for bicycles

From *Guide to Road Design Part 6A: Pedestrian and Cyclist Paths* (October 2009) by Austroads Inc.; available at: https://roads-waterways.transport.nsw.gov.au/business-industry/partners-suppliers/documents/austroads-supplements/roaddesign_part6a-agrd-paths-walking-cycling.pdf :

> Figure 7.1 shows the maximum lengths of uphill gradient acceptable to cyclists. The figure is based on a review of the ease of uphill travel (Andrew O'Brien & Associates 1996).
>
> In using the figure designers should understand that:
>
> - Above 3% the acceptable length reduces rapidly and it is considered this is the desirable maximum gradient for use on paths. However, in practice there are cases where it is not feasible to achieve a 3% maximum and the designer has no choice but to adopt a steeper gradient.
> - In cases where 3% cannot be achieved consideration should be given to limiting gradient to a maximum of about 5% and providing short flatter sections (say 20 m long) at regular intervals to give cyclists travelling both uphill and downhill some relief from the gradient.
>
> It is sometimes difficult to achieve these gradients where a path follows a river and a connection between paths must be achieved in the vicinity of a steep escarpment. It should also be noted that a long, uphill grade preceded by a downgrade is more acceptable than one preceded by a flat or slightly rising grade.

A sampling of points on the "Desirable" curve in *Figure 7.1: Desirable uphill gradients for ease of cycling*:

Gradient (%)	Length of gradient (m)
2	> 200
3	150
4	105
5	75
6	55
7	35
8	25

5.2.2. Height clearance for NSW firetrucks

From https://www.fire.nsw.gov.au/gallery/files/pdf/guidelines/vehicle_access.pdf :

> 7.5 Overhead clearance
>
> 7.5.1 The carriageway is to have a minimum overhead clearance height of 4 m for general fire appliance access or 4.5 m for specialist fire appliance access (see Figure 10).

5.2.3. Maximum height of vehicles on NSW roads

From https://roadsafety.transport.nsw.gov.au/stayingsafe/heavy-vehicles/overheight.html :

> In NSW, any heavy vehicle that is higher than 4.3m must comply with restricted travel conditions and use an approved road network. NSW has more bridges and tunnels with low clearances of less than 4.6m than any other state in Australia. Vehicles higher than 4.3m must not travel under or through them.

From https://roads-waterways.transport.nsw.gov.au/business-industry/heavy-vehicles/road-access/restricted-access-vehicles/4-6m-high.html :

> 4.6m high vehicles
>
> The allowable height limit for general access vehicles in the Road Transport (Vehicle Registration) Regulation 2017 is 4.3 metres. However, some vehicles are permitted to operate at a height that does not exceed 4.6 metres according to the 4.6 Metre High Vehicle Route Notice 2013.

From https://www.nhvr.gov.au/road-access/mass-dimension-and-loading/general-mass-and-dimension-limits :

> National Heavy Vehicle Regulator
>
> Height
>
> The height limit for heavy vehicles is 4.3 metres unless it is a:
>
> - vehicle built to carry cattle, horses, pigs or sheep - 4.6 metres
> - vehicle built with at least 2 decks for carrying vehicles - 4.6 metres
> - double-decker bus - 4.4 metres

5.2.4. Width clearance for NSW firetrucks

From https://www.fire.nsw.gov.au/gallery/files/pdf/guidelines/vehicle_access.pdf :

> 7.1 Carriageway width
>
> 7.1.1 A carriageway is to be wide enough to allow easy negotiating by the fire appliance and provide room around the vehicle to allow firefighters to exit and work with equipment.
>
> 7.1.2 Along any straight carriageway section, the minimum width is 4.5 m for general fire appliance access, or 6 m for specialist fire appliance access (see Figure 3).

and:

> 7.3 Constricted access (i.e. pinch point)
>
> 7.3.1 Constricted access is any narrow pinch point around an immovable object (e.g. building, structure, bridge, bollard, pylon, gate, vehicle barrier, traffic control device, utility pole, drain, fence, tree etc.) that provides less than 4.5 m width.
>
> Note: A pinch point has insufficient width for firefighters to exit the fire appliance and work with equipment. A fire appliance is not able to stop at any pinch point.
>
> 7.3.2 The carriageway is not to have any constricted access providing less than 3.2 m width (see Figure 8).
>
> Note: A fire appliance is unable to negotiate past a pinch point less than 3.2 m wide.