



A Brief Overview of the Road Safety Approach in Singapore



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Executive Summary

This report introduces how the Safe System Approach works, with a focus on road infrastructure and road safety engineering best practices from one of the best performing countries in Southeast Asia and the Pacific, Singapore.

Singapore roads are not only considered the safest in the region, they rank among the safest globally. Road safety management rules and regulations implemented in the country have resulted in significant strides in managing the effects of collision factors related to roadway design, human behavior, and vehicle attributes. As a result, road safety statistics have shown that fatalities on the Singapore road network have been steadily declining over the past decade. This is leading to a desire on the part of neighboring countries to follow Singapore's example and learn from its experience.

In order to mitigate collisions attributed to vehicle inadequacies or defects, one of the measures taken in Singapore was to enforce a **strict vehicle import policy**. Vehicle imports are permissible from countries that have adopted and comply with recognized high vehicle safety standards. Vehicle safety compliance is particularly focused on 52 items specified by the Land Transport Authority (LTA). In addition to strict vehicle import standards, Singapore enforces a **strict vehicle quota system**, which regulates the number of vehicles on the road network. Additionally, vehicles are required to undergo frequent inspections. Cars between 3 and 10 years old are required to have a biennial inspection, and cars older than 10 years are required to undergo annual inspections. Furthermore, taxis are required to undergo inspections every six months.

Road safety education and driver education are core tenants of Singapore's roads safety strategy. Road safety education is predominately undertaken by the Singapore Traffic Police, but nongovernmental organizations such as the National Security Coordination Secretariat contribute significantly to road safety education in Singapore.

Ensuring that roads are safe and adequate for road users is vital, and Singapore implements a range of road safety management measures to ensure this is the case. Road safety audits, also known as Project Safety Reviews (PSR), have been implemented in Singapore since 1998. LTA guidelines specify that PSRs are required to be undertaken at the planning, design, construction, and completion stage of a project. PSRs are essential components of Singapore's road safety strategy.

Another key road safety measure used in Singapore is **speed cameras**. A network of 87 speed cameras is strategically positioned along the road network. Singapore uses four different types of speed cameras: fixed speed camera, police speed laser camera, mobile speed camera, and average speed camera. Data obtained from the Singapore Traffic Police show

that the number of speeding violations is in decline. The data have shown that the introduction of 20 speed cameras at 11 locations in 2014 has resulted in a steep decline in the number of violations. Further investigation would be required to know whether this decline is attributed solely to the speed cameras or to various contributing factors.

Speed management is essential, particularly in areas where vehicles and vulnerable road users come into contact. Traffic-calming measures can be a low cost and effective way of managing speeds in areas with a presence of vulnerable road users and can include physical measures such as road dividers or visual measures such as road markings. Certain areas in Singapore have been designated as “special zones”: Silver Zones and School Zones. Speed management techniques have been implemented in these areas because of the presence of vulnerable pedestrians such as elderly people and school children. Speed management and traffic-calming measures in School Zones and Silver Zones include lower speeds (40 kilometers per hour in school zones and 40 kilometers per hour when possible in silver zones), appropriate signage, assisted crossings and road safety features such as rumble strips.

At the same time, in order to prevent collisions at junctions due to vehicles running red lights, Singapore implements a **red-light camera (RLC) system**. Research has shown RLCs can be an effective way of preventing or reducing the impact of collisions. Singapore has a total of 240 RLCs across its road network.

As previously stated, Singapore roads are among the safest globally, but there is still room for improvement, particularly when it comes to pedestrian infrastructure. Pedestrians and cyclists account for approximately 16 percent of all road deaths in Southeast Asia. The number of collisions involving pedestrians in Singapore in 2018 was 1,036, and 25 percent were elderly pedestrians (who actually account for 62.5 percent of pedestrian fatalities). Although the pedestrian infrastructure in Singapore is considered good, there are plenty of examples of subpar pedestrian infrastructure across the country that could benefit from improvements.

Additionally, there have been recent strides by local authorities in Singapore to improve sustainability and accessibility by promoting sustainable modes of transport. Several improvement schemes have been implemented, and many more are planned to improve pedestrian and cyclist accessibility.

Abbreviations

BIGRS	Bloomberg Philanthropies' Initiative for Global Road Safety
COE	Certificate of Entitlement
GRSF	Global Road Safety Facility
LTA	Land Transport Authority
PSR	Project Safety Review
RLC	red-light camera
SRSC	Singapore Road Safety Council
TP	Singapore Traffic Police
WHO	World Health Organization
VIG	vehicle impact guardrail

1. Introduction

The World Health Organization (WHO) estimates that road injuries accounted for approximately 1.35 million deaths in 2016, ranking it 8th in the top 10 global causes of death (WHO 2018a). This global epidemic is not only fatal but comes with great economic consequences. Road collisions are estimated to cost around US\$518 billion, costing countries 1–2 percent of their annual GDP. If no intervention is taken, road traffic injuries are expected to become the fifth leading cause of death globally by 2030.

The World Bank gives road safety a critical consideration in its transport investment projects. Through its Global Road Safety Facility (GRSF), a partnership under the Bloomberg Philanthropies' leadership was formed with another nine international institutions, creating the Bloomberg Philanthropies' Initiative for Global Road Safety (BIGRS).

A World Bank (2017) study on the economic impact of road traffic injuries, undertaken under BIGRS, shows that over time, sharply reducing the number of road traffic injuries and deaths would enable the study's five selected countries to attain substantial increases in economic growth and national income, leading simultaneously to clear welfare gains. Reducing road traffic mortality and morbidity by 50 percent and sustaining it over a period of 24 years could, for example, generate an additional flow of income equivalent to 22.2 percent of 2014 GDP in Thailand and a 7.2 percent increase in the Philippines. This puts into perspective the magnitude of economic benefits that the countries may realize with sustained action if they were to achieve the United Nations Sustainable Development Goal targets on road safety.

The Bloomberg Philanthropies' BIGRS (2015–19) is the second phase of a \$125 million partnership program focused on reduction of road deaths and serious injuries in 10 selected cities and 5 countries in the developing world (figure 1.1). The following cities were selected through a competitive process: Accra, Addis Ababa, Bandung, Bangkok, Bogota, Fortaleza, Ho Chi Minh City, Mumbai, Sao Paulo, and Shanghai. Under the program, cities have been receiving funding support for full-time staff embedded in city agencies, comprehensive technical assistance from the collaborating organizations, training and capacity building for enforcement agency, and media and social awareness campaigns.

In addition, five countries were selected (China, India, Philippines, Tanzania, and Thailand) to receive support for national-level activities including legislative and policy implementation activities. Bloomberg has also requested the World Bank to carry out financial costing studies and assessment of high-risk roads in the five selected countries.

Figure 1.1 shows the locations of the BIGRS activities:

Figure 1.1. BIGRS (2015–19) Cities and Countries



Under BIGRS, the objective for the World Bank engagement is to:

- build road safety management capacity;
- improve road infrastructure safety; and
- leverage related road safety investment in countries where significant impact on lives saved can be achieved.

Working together with other BIGRS Safer Streets and Safer Mobility partners, EMBARQ - the World Resources Institute, Ross Centre for Sustainable Cities, and the National Association of City Transportation Officials' Global Designing Cities Initiative, the World Bank complements efforts in improving road infrastructure and mobility safety for the selected cities.

This report introduces how the Safe System Approach works, with a focus on road infrastructure and road safety engineering best practices from one of best performing countries in Southeast Asia and the Pacific, Singapore.

1.1. The Safe System Approach

The Safe System Approach advocates for a safe road system, better adapted to the physical tolerance of its users (Well et al. 2018; ITF 2016). The core principles of this approach are in line with well-known mid-1990s national strategies such as Sweden’s Vision Zero and the Netherlands’ Sustainable Safety approach (PIARC 2015). It was officially endorsed by the Australian Transport Council in 2004 and adopted by all Australian state and territory road authorities. The history of how the Safe System Approach was adopted and some of the rationale behind it is presented by Grzebieta, Mooren, and Job (2013).

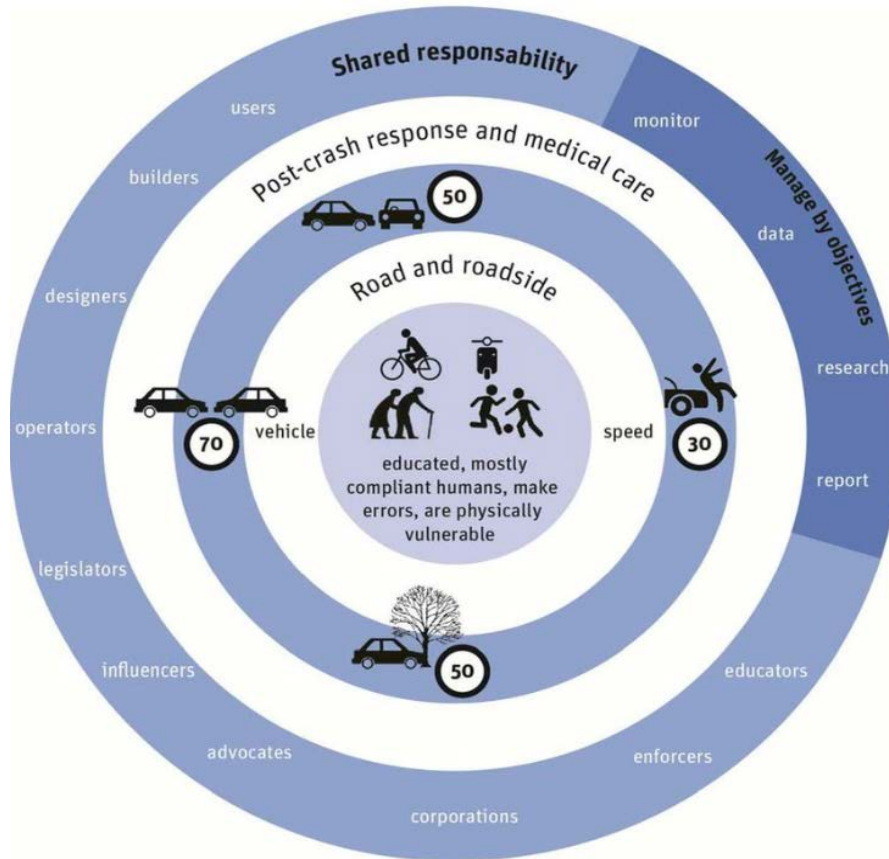
The main highlight of the Safe System Approach is that while it recognizes the need for responsible road user behavior, it also accepts that human error is inevitable. It therefore aims to create a road transport system that makes allowance for errors and minimizes the consequences—in particular, the risk of death or serious injury.

Obviously, the Safe System Approach does not absolve road users from complying with road laws. On the contrary, the Safe System Approach works at its optimum when road users comply with road laws. In other words, the Safe System Approach should be considered as a holistic graded safety system. For fully compliant road users, the Safe System Approach should guarantee maximum protection against death and serious injury. Road users should not expect to die or be seriously injured if, through no fault of their own, they find themselves involved in a crash or collision. However, the system should also assist with reducing the risk of a fatality or serious injury for a noncompliant road user who is involved in a crash.

In a nutshell, by taking a total view of the combined factors involved in road safety, the Safe System Approach encourages a better understanding of the interaction between the key elements of the road system: road users, roads and roadsides, vehicles and travel speeds (see Figure 1.2). It has three core components:

1. *Safe roads and roadsides*: a transport system designed to make a collision survivable through a combination of design and maintenance of roads and roadsides
2. *Safe vehicles*: the design of vehicles and their safety equipment to include protective systems including electronic stability control, air cushions, and so forth
3. *Safe speeds*: a speed limit reflecting the road safety risk to the road users and sending them the right messages

Figure 1.2. Conceptualization of the Safe System Approach



Source: ITF 2016.

It is essential that vehicles travel at speeds that suit the function and the level of safety of the road to ensure that crash forces are kept below the limits that cause death or serious injury. This requires the setting of appropriate speed limits supplemented by effective enforcement and education, together with self-explaining infrastructure that would send all road users the right signals on how to use the road.

1.2. Evidence-based measures

Evidence-based measures involve looking at a crash, casualty, and any other available data to be sure what road safety issue needs to be addressed. It further involves research and evaluation reports to check whether the type of intervention being considered is likely to be effective. Evidence-based practice originated in medicine, but it has been translated to several policy areas, including road safety.

Evidence-based practice can help to ensure that both new and existing interventions are successful, as they have been proven to work in a similar context, and also maximize efficiency in times of budget cuts.

The main evidence-based interventions in road safety can be divided into four main groups:

1. *Safer road users*: informing and educating users about safe use of the road, and taking action against those who do not comply with the rules
2. *Safer roads*: designing, constructing, and maintaining roads and roadsides to reduce the risk of crashes and minimize the severity of injury if a crash occurs
3. *Safer vehicles*: designing and maintaining vehicles to minimize the risk of crashes and the severity of injury to motor vehicle occupants, pedestrians, and cyclists if a crash occurs
4. *Safer speeds*: setting speed limits taking into account the level of risk on the road network and the benefits of lower speeds in minimizing the incidence and severity of injury in the event of a crash, together with the corresponding self-explaining infrastructure and enforcement

According to Wegman et al. (2017), three subjects are key in this new approach of evidence-based and data-driven road safety management: ex post and ex ante evaluation of both individual interventions and intervention packages in road safety strategies, and transferability (external validity) of the research results.

1.3. Road safety in the ASEAN context

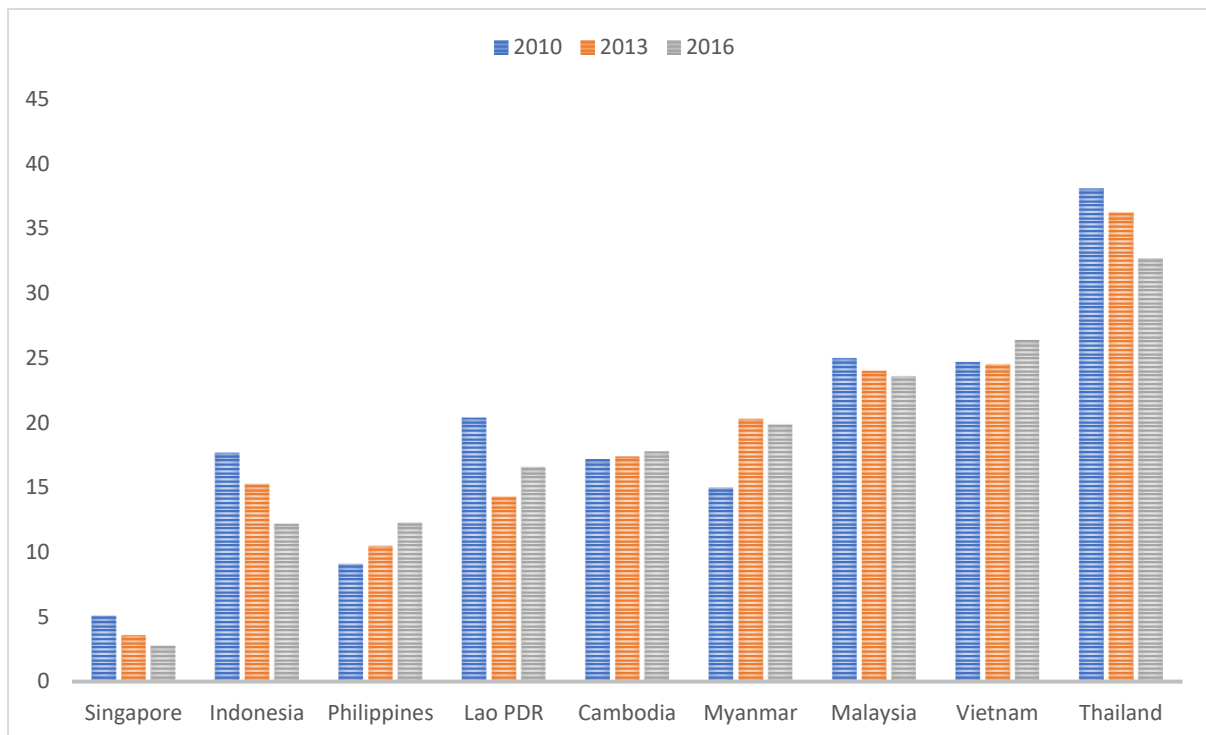
It is estimated that vulnerable road users such as pedestrians, cyclists, and motorcyclists account for approximately 50 to 75 percent of all road traffic fatalities in Asia and the Pacific.

According to WHO (2018b), the Southeast Asia region accounts for the second highest road fatality rate globally, surpassed only by Africa. In 2016 there were approximately 20.7 road traffic fatalities per 100,000 people in the Southeast Asia region.

WHO also estimates the number of road traffic fatalities globally in 2016 at 18.2 per 100,000 people. The road traffic fatality rate in the Southeast Asia region was approximately 13 percent greater than the overall global road traffic fatality rate in 2016.

WHO road traffic fatality data show that several ASEAN nations have particularly high road traffic fatality rates. ASEAN nations such as Malaysia, Thailand, and Vietnam have road traffic fatality rates of 23.6, 32.7, and 26.4 deaths per 100,000 people respectively (figure 1.3). This is significantly greater than the global road traffic fatality rate.

Figure 1.3. Estimated Fatalities per 100,000 Population, ASEAN



Source: WHO 2018a.

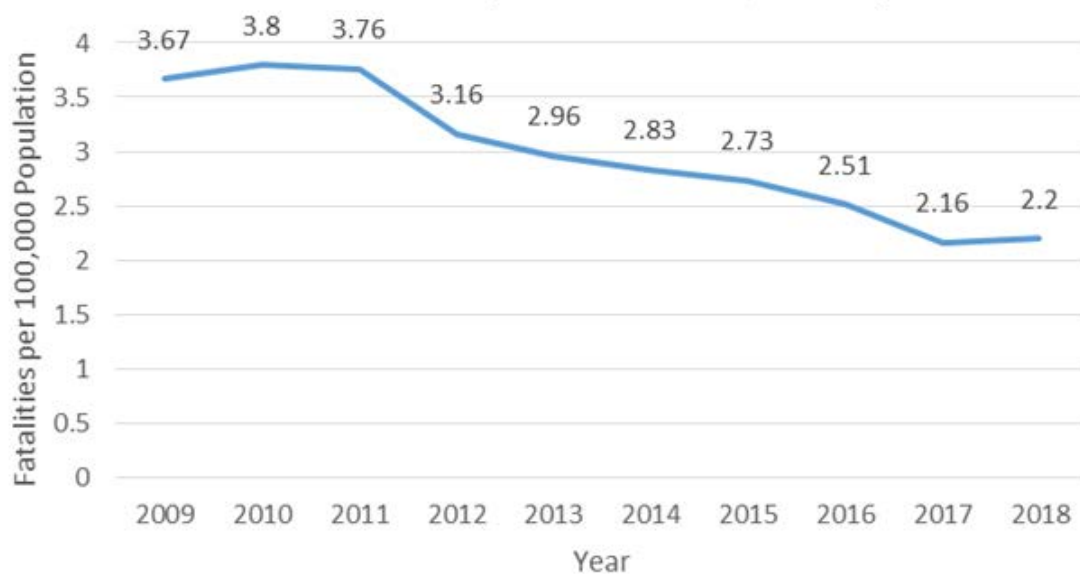
1.4. Overview of road safety status in Singapore

Singapore is located in Southeast Asia and consists of islands between Malaysia and Indonesia. It is the focal point for Southeast Asian sea routes. The land area is less than seven hundred square kilometers, with a coastline of 193 kilometers. The island is relatively flat in the lowlands and its highest point is 166 meters. The climate is tropical: hot, humid, and rainy with two distinct monsoon seasons.

Singapore is a highly developed and successful free market economy, enjoying a remarkably open and corruption-free environment, stable prices, and one of the highest per capita GDPs in the world. The population of Singapore is over 5 million people, with an average life expectancy of 83.2 years.

Singapore is considered one of the best performing countries globally and regionally in terms of road safety. Road safety statistics provided by the Singapore Traffic Police (2019) show that there is a downward trend in the number of road traffic fatalities, presented in figure 1.4.

Figure 1.4. Fatalities per 100,000 Population, Singapore

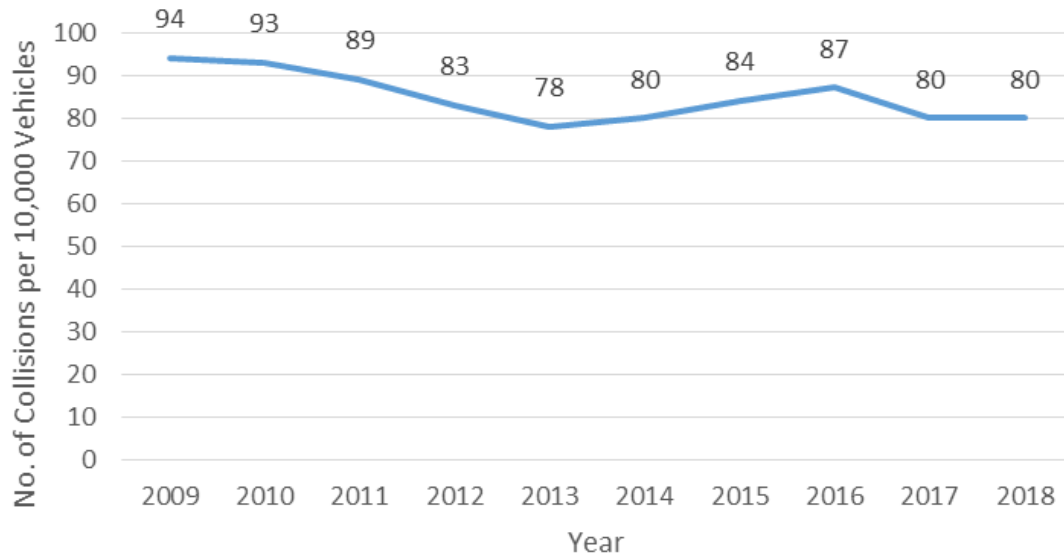


Source: Singapore Traffic Police 2019.

The total number of fatalities in 2009 was 183. Over a 10-year period (2009–18), Singapore was able to reduce the number of fatalities on its roads by approximately 32 percent, to 124 fatalities in 2018.

The overall number of collisions resulting in injury over a 10-year period has experienced decreases and increases (figure 1.5).

Figure 1.5. Collisions per 10,000 Vehicles, Singapore



Source: Singapore Traffic Police 2019.

It can be deduced from the data presented in both Figure 1.4 and Figure 1.5 that overall there is a decrease in the number of fatalities and the number of collisions resulting in injury. This can be attributed to several factors, such as lower speeds, increased driver awareness, safer vehicles, safer roads, and better post collision care.

2. Road Safety Management

The first and fundamental pillar of WHO's Global Plan for the Decade of Action for Road Safety is road safety management (WHO 2011). The *World Report on Road Traffic Injury Prevention* (Peden 2004) and the Global Plan highlight that a systematic and planned approach is required to improve road safety performance. The most effective way countries and organizations can improve road safety performance is by establishing an effective road safety management system.

In Singapore, the responsibility of road management is held by the Land Transport Authority (LTA) and the Singapore Traffic Police (TP). The LTA is responsible for the provision and maintenance of road facilities and vehicle safety, whereas the TP are entrusted with the responsibility of enforcing traffic regulations and providing publicity and education.

2.1. Road traffic collision classification in Singapore

A road traffic collision is an incident involving one or more vehicles, occurring on the public highway and resulting in personal injury that is recorded by the police. A road traffic collision is a rare, random, multifactor event always preceded by a situation in which one or more road users have failed to cope with the road environment.

In Singapore, road traffic collisions are classified into four categories of severity: (i) fatality, (ii) serious injury, (iii) slight injury, and (iv) property damage. A fatal casualty in a road traffic collision is one in which the victim dies within 30 days of the collision.

A seriously injured casualty is one who has suffered injuries such as a fracture, concussion, internal lesions, crushing, severe cuts and laceration, or severe general shock requiring medical treatment or hospitalization, such that the person is unable to perform his ordinary pursuits for at least seven days. A slightly injured casualty is one who is conveyed to the hospital from the scene in an ambulance or otherwise, one who requires subsequent medical treatment entailing hospitalization, and one who takes medical leave of up to three days.

Collisions are assigned the severity group according to the most seriously affected casualty in the collision. All reported collisions not involving injuries are classified as property-damage-only collisions.

A road traffic collision can be attributed to several factors. These include road factors, human factors, vehicle factors, and environmental factors.

2.2. Vehicle safety

As previously stated, vehicle factors can also contribute to a collision. The provision of safety features such as airbags and antilock braking systems can decrease the likelihood of a collision or the severity of a collision. Singapore allows the importation of new vehicles directly from the manufacturer or from countries with higher or equivalent safety and exhaust emission standards to Singapore's. The importation of used cars less than three years old and classic or vintage cars is allowed (LTA 2017a).

Imported vehicles are required to comply with the Road Traffic Act and its subsidiary legislations. Vehicles imported from EU countries, Japan, and the United States are deemed acceptable, as the LTA recognizes that these have adopted an internationally recognized high vehicle-safety standard.

Stringent regulation of the importation of vehicles prevents the use of unsafe vehicles on the roads of Singapore.

At the same time, in order to maintain a steady rate of vehicle growth with the development of transport infrastructure, vehicle quotas are enforced in Singapore. In order to own and operate a vehicle in Singapore, a Certificate of Entitlement (COE) is required. The COE allows the vehicle owner the right to own a vehicle for a period of 10 years.

The vehicle quota is determined by several conditions:

- The total number of deregistered vehicles
- The allowable growth in vehicle growth, that is, capacity for new vehicles
- Adjustments to account for changes in taxi population, replacements under the Early Turnover Scheme, past over projections, and expired or cancelled temporary COEs

The quota for the number of COE's available is updated every three months (LTA, 2019).

In addition, according to the Singapore Land Transport Master Plan 2040, 67 percent of all peak-period journeys are now undertaken on public transport, compared to 63 percent in 2012. This has a considerable impact on road safety, since public transport is considered the safest means of transportation on the road.

Table 2.1. outlines 52 items that are required for a vehicle to comply with in terms of vehicle safety standards.

Table 2.1. Vehicle Safety Items (LTA 2017a)

Item	Item
1 Anti-theft and immobilizer	27 Lateral protection
2 Audible warning	28 Masses and dimensions
3 Braking	29 Parking lamps
4 Couplings	30 Prevention of fire risks
5 Defrost/demist	31 Protective steering
6 Diesel Smoke	32 Rear registration plate lamps
7 Direction indicators	33 Rear registration plate space
8 Door latches and hinges	34 Rear visibility
9 Electromagnetic compatibility (EMC)	35 Registration plates
10 Emissions	36 Retro reflectors
11 End-outline, front position (side), rear-position (side), stop, side marker, daylight running lamps	37 Reversing lamps
12 Engine power	38 Safety glass
13 Exterior projections	39 Seat belt anchorages
14 Fog lamps (front)	40 Seat belts
15 Fog lamps (rear)	41 Seat strength
16 Forward vision	42 Side impact (side beams)
17 Front underrun protection	43 Sound level 18 Frontal impact
18 Frontal Impact	44 Speed limiters
19 Fuel consumption	45 Speedometer and reverse gear
20 Fuel tanks/rear protection device	46 Steering effort
21 Head restraints	47 Towing hooks
22 Headlamps (including bulbs)	48 Tires
23 Heating systems	49 Vehicle and component marking (including vehicle identification number, or VIN)
24 Identification of control	50 Vehicle using CNG/electric/hybrid etc.
25 Installation of lightings and light signaling devices	51 Wash/wipe
26 Interior fitting	52 Wheel guards

2.3. Awareness and education

A key aspect of road safety is the education of all road users, including drivers and pedestrians. Driver education and road safety awareness predominantly falls under the TP's responsibility.

The TP frequently organize road safety campaigns extended to all road users, including pedestrians and cyclists. There are three driver training centers in Singapore:

- Bukit Batok Driving Centre Ltd
- ComfortDelGro Driving Centre Pte Ltd
- Singapore Safety Driving Centre Ltd

The driving centers are responsible for the training of new drivers as well as conducting retraining courses for the suspended drivers. The driving centers are also responsible for testing drivers in collaboration with the TP.

The driving instructors at the driving centers are of a high standard and are closely monitored by the TP. The centers make use of structured theory and practical course as well as driving and riding simulators in their teaching program.

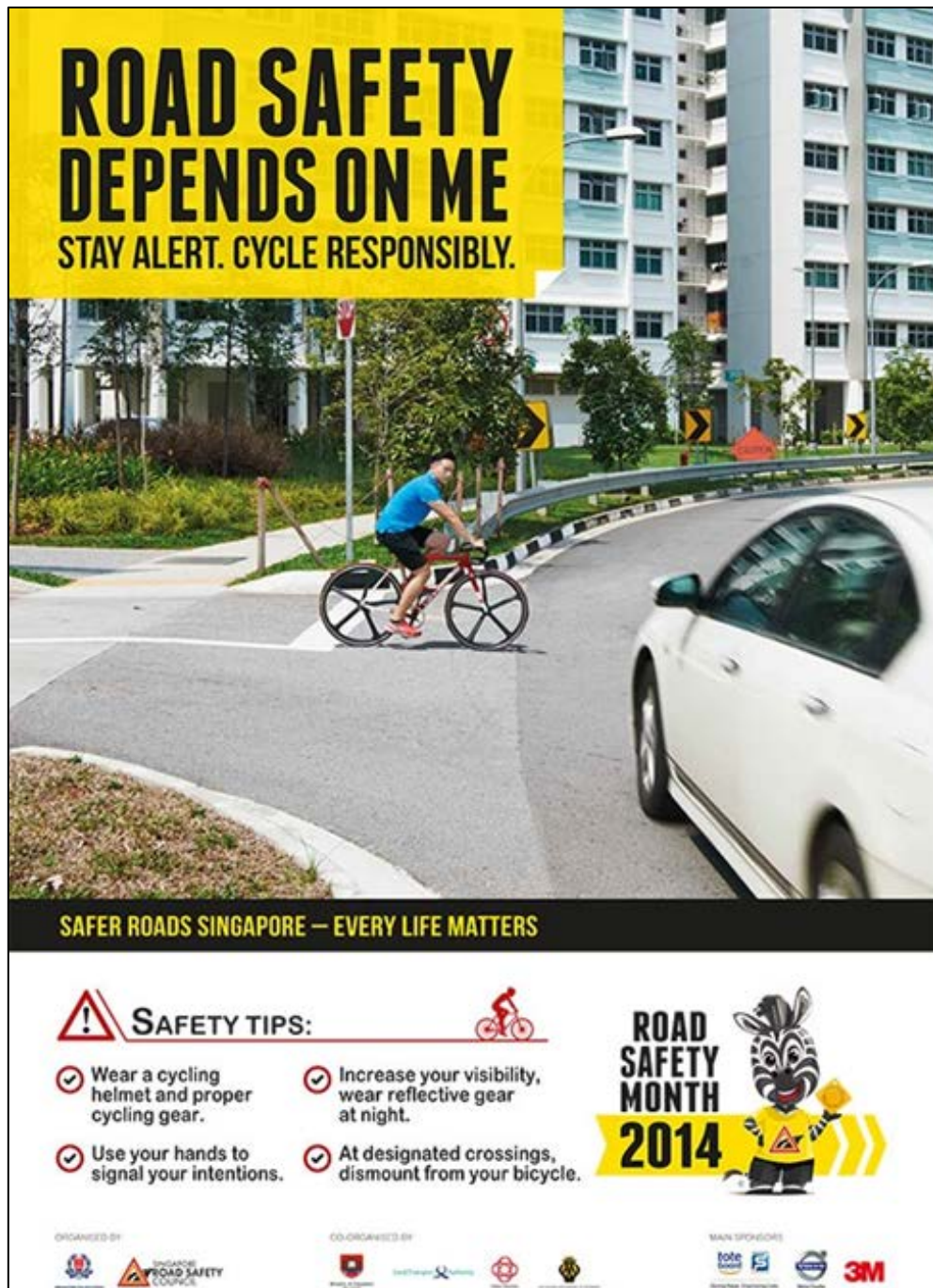
The Road Safety Division of the TP holds the responsibility of delivering road safety education to the public. They work hand in hand with various community groups to promote road safety for all road users. The TP reach the population using the following communication avenues:

- Television commercials
- Radio commercials
- Newspaper advertisements
- Cinema advertisements
- Bus and taxi advertisements
- Publicity materials such as leaflets, banners, posters, and stickers (figure 2.1)
- Internet and information communication technology

Figure 2.1. Singapore Road Safety Campaign Poster in Public Transport Vehicles

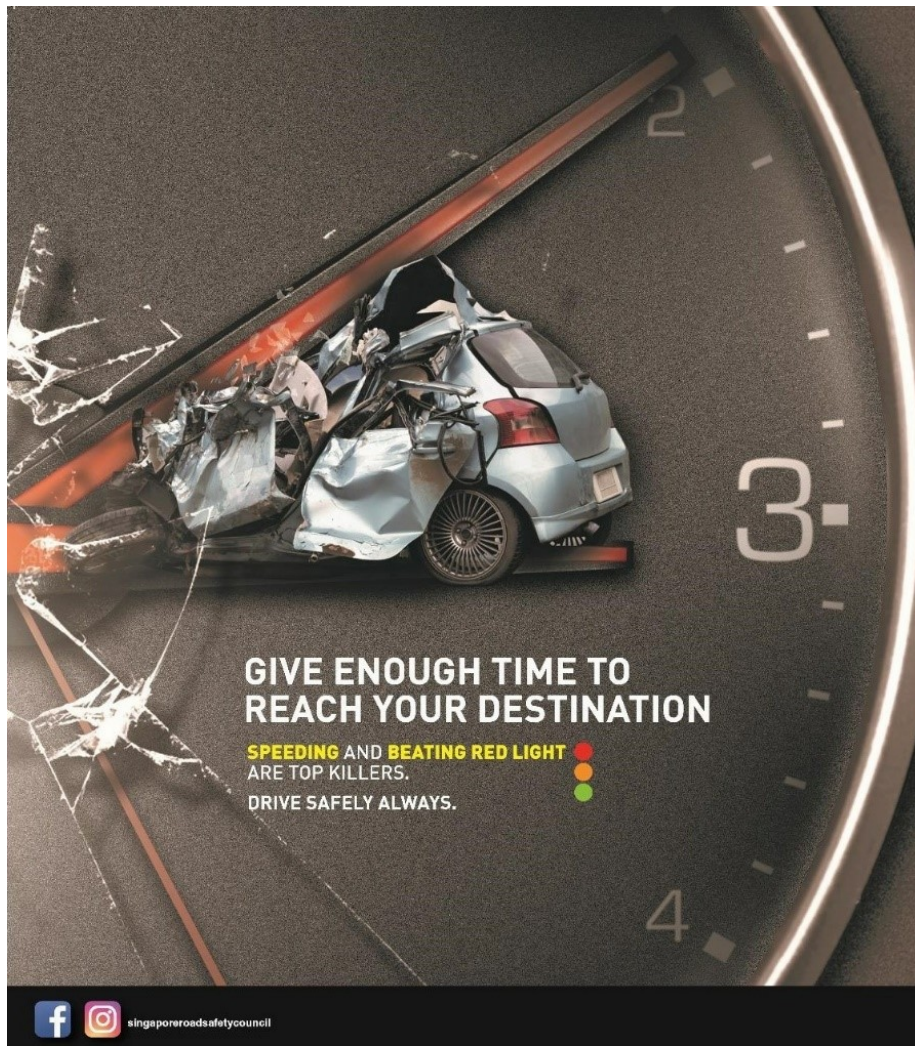


Figure 2.2. Singapore Road Safety Poster for Cyclists' Safety



A typical road safety awareness poster provided by the TP is presented in Figure 2.2. The poster targets cyclists to inform them on how to correctly and safely use the road infrastructure available.

Figure 2.3 Road Safety Poster for speeding



Road safety campaigns also seek to highlight to drivers of the dangers of speeding. The poster presented in Figure 2.3 informs drivers that speeding and “beating the red light” are among the top killers.

Several other nongovernmental organizations play a role in delivering road safety education to the public. These include the Singapore Road Safety Council (SRSC) and the Automobile Association of Singapore. The SRSC was established in 2009 to focus on road safety issues. It is funded mainly through private donations and small government grants.

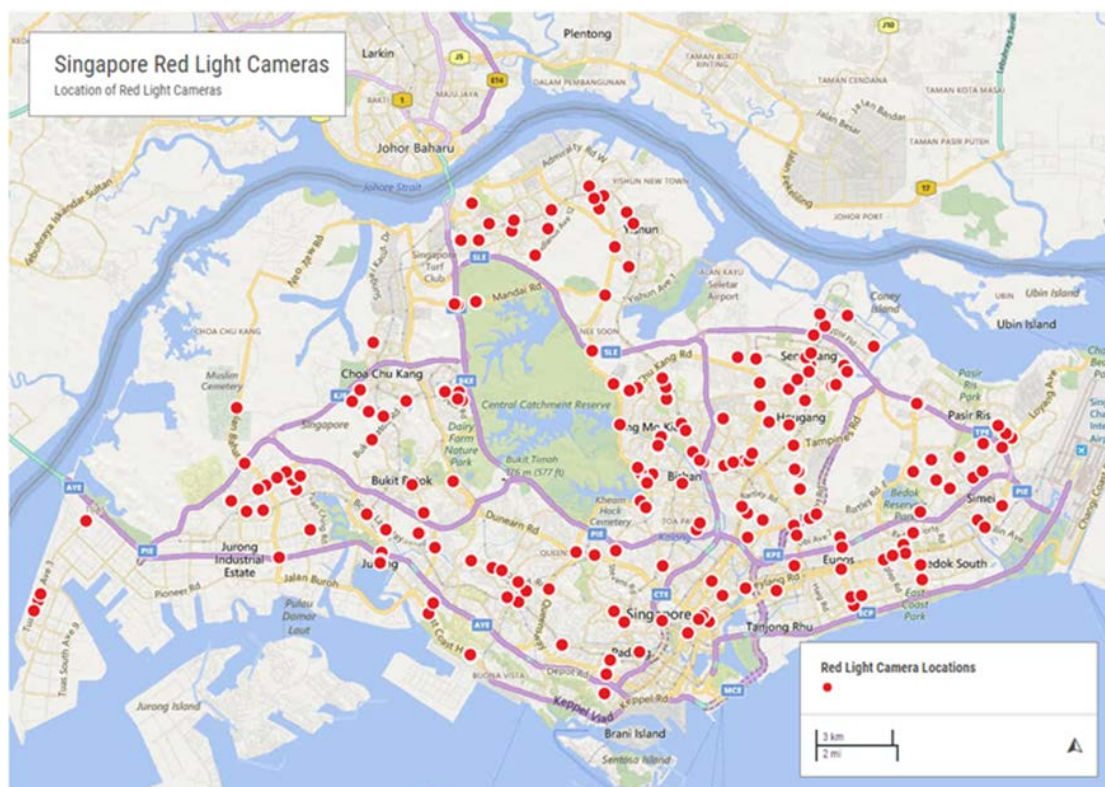
2.4. Red-light camera system

Several studies have been undertaken at signalized junctions with a red-light camera (RLC) system. The studies show that there was a reduction in the number of violations in the order of 30 percent to 50 percent.

RLC studies (Retting, Ferguson, and Hakkert 2010) have observed changes in red-light violations at noncamera sites, that is, at similar signalized intersections in the same communities that were not equipped with RLC. Large reductions in violation rates, of an order resembling those at camera sites, were observed at these sites, indicating a spill over or “halo” effect. This shows that in some cases the implementation of RLC can have a positive effect on nearby areas.

As of 2019, there are a total of 240 RLCs located across Singapore. Figure 2.4 provides a visual representation.

Figure 2.4. Red-Light Camera Locations, Singapore



Source: Traffic Police

The existing network of RLCs was introduced to the Singapore road network in 1986. Since their installation, the number of vehicles on the road has increased significantly, from under half a million vehicles in 1987 to over 900,000 vehicles in 2018. Furthermore, the number of

driving license holders has increased considerably, from 735,480 holders in 1987 to over two million in 2018.

The number of red-light violation cases recorded in 2018 was 53,910, representing a 15.7 percent increase from 46,599 cases in 2017. The number of collisions from running a red light increased slightly, by 2.6 percent, to 120 collisions in 2018 from 117 collisions in 2017. Although an increase in the number of violations has been recorded between 2018 and 2019, over a long-term period there is a decline.

Photo 2.1 shows the standard type of RLC used in Singapore.

Photo 2.1. Red-Light Camera, Singapore



2.5. Road infrastructure

2.5.1. Road safety audits

Safer roads are one of the core components of the Safe System Approach, as well-designed road infrastructure can reduce the likelihood and the severity of a collision. The LTA in Singapore is responsible for the planning, design, construction, operation, maintenance, and regulation of roads in Singapore. Roads are designed in accordance with design standards set out by LTA. This entails several design specifications documents including the “Code of Practice—Street Work Proposals Relating to Development Works.” The Code of Practice outlines the essential submission procedures and technical requirements pertaining to the design and construction of street work (LTA 2019b).

The Austroads guidelines define a road safety audit as a “formal examination of a future road or traffic project, an existing road, or any project which interacts with road users, in which an independent, qualified team assesses the crash potential and safety performance.” (Austroads 2019).

The aims of a road safety audit are (i) to ensure roads operate as safely as practical, (ii) to minimize the number of collisions and severity, (iii) to consider the safety of all road users, and (iv) to improve the awareness of safety design practices by design, construction, and maintenance staff. Road safety audits can lead to safe roads by removing or treating safety hazards and promoting the incorporation of safety or collision-reduction features; they can reduce the risk, severity, and likelihood of a crash to occur. In addition, road safety audits can reduce costly remedial works.

Road safety audits comprise two complementary approaches: collision reduction and collision prevention. A road safety audit is required for developing remedial measures for sites where collisions are frequent and also for modifying existing roads or designing safer ones to prevent crashes (Austroads 2019).

Road safety audits were introduced to Singapore in 1998 by the LTA as a requirement for new road projects as well as for temporary traffic schemes. The LTA offers road and transport professionals the opportunity to become a certified road safety reviewer by attending a four-day training course. Road safety audits are also known as a Project Safety Reviews (PSRs) in Singapore. The PSR is not a design check, it is a review of the safety and adequacy of the design. The PSR is an independent review and assessment of the project team’s assertion that the proposed road system is safe to use (LTA 2019c).

The PSR process in Singapore consists of four stages through which an audit of a road scheme must pass:

1. *Planning*: preliminary design safety submission
2. *Design*: detailed design safety submission
3. *Construction*: temporary traffic control safety submission
4. *Completion*: postconstruction safety submission

An independent safety review report is required for each of the stages, highlighting safety deficiencies and proposing remedial countermeasures. Table 2.2 provides a summary of the PSR process and responsibilities held by various stakeholders.

Table 2.2. PSR Stages

Stage	Role	Responsibility
<i>Preparation of design details</i>	Contractor/traffic consultant	Prepare design details and project Brief
	LTA project team	In-principle approval of design details
<i>Conduct of safety review</i>	Independent safety review team	Prepare draft safety review report
	LTA project team contractor/traffic consultant	Review and accept draft safety review report
	Independent safety review team	Prepare final safety review report
<i>Preparation of response</i>	Contractor/traffic consultant	Prepare response to recommendations in safety review report
	LTA project team	Approve safety submission
<i>Audit Endorsement</i>	LTA Safety Division	Audit safety submission
	PSR Committee (roads)	Endorse safety submission
<i>Implementation</i>	Contractor/traffic consultant	Implement design details on site

Safety hazards are identified and categorized using the risk assessment matrix provided within the *Project Safety Review Procedure Manual for Road Projects*.

The frequency and severity of collisions are classified from Incredible to Frequent and Negligible to High (presented in Table 2.3). The frequency and severity of collisions are assigned to four categories which define the level of acceptability of the risk. Table 2.4 shows the different risk categories defined by LTA.

Table 2.3. Collision Frequency and Severity

Risk category		Accident severity index			
		Negligible (NEG)	Low (LOW)	Medium (MED)	High (HIG)
Accident frequency index	Frequent (FRE)	B	A	A	A
	Occasional (OCC)	C	B	A	A
	Remote (REM)	D	C	B	A
	Improbable (IMP)	D	D	C	B
	Incredible (INC)	D	D	D	C

Table 2.4. Definition of Risk Category

Risk category		Definition
A	Intolerable	Risk shall be reduced by whatever means possible.
B	Undesirable	Risk shall be accepted by the LTA if further risk reduction is not practical.
C	Tolerable	Risk shall be accepted by LTA subject to endorsement by the PSR (Roads) Committee.
D	Acceptable	Risk shall be accepted by LTA.

The frequency and likelihood of a collision to occur is classified into five categories. These are presented in Table 2.5.

Table 2.5. Guide on Accident Frequency Index

Frequency index	Definition	Frequency guide
Frequent (FRE)	Likely to occur often	10 times per year or more
Occasional (OCC)	Likely to occur several times	Less than 10 times per year but more than once per year
Remote (REM)	Likely to occur sometime during the system's operational life	Less than once per year but more than once every 10 years
Improbable (IMP)	Unlikely to occur but possible	Less than once every 10 years but more than once every 100 year
Incredible (INC)	Unlikely to occur	Once every 100 years or less

The severity of injuries resulting from a collision can be classified into four categories, these are presented in Table 2.6.

Table 2.6. Guide on Accident Severity Index

Severity index	Definition	Guide
High (HIG)	Multiple fatalities and/or severe injuries	High-on collision Right-angle collision High speed collision
Medium (MED)	Single fatality or severe injury, with possible other minor injuries	Pedestrian or cyclists struck by car Side swipe collision Medium speed collision
Low (LOW)	Minor injuries or property damage only	Low speed collision Pedestrian or cyclist fall
Negligible (NEG)	Property damage only	Car reverse into post

Recommendations provided to remove or reduce a hazard are defined as either “practical” or “not practical.” Table 2.7 provides a definition for each category.

Table 2.7. Definition of Practicability Category

Practicability category	Definition
P	Likely typical cost of implementing the recommendation is commensurate with the level of risk reduction which it achieves.
NP	Likely typical cost of implementing the recommendation is <i>not</i> commensurate with the level of risk reduction which it achieves.

The safety review report is required to identify and present hazards in the following format as specified by the LTA:

- Hazard location: Specify the design reference and exact location of the Hazards.
- Hazard description: Describe the nature of the safety concern.
- Collision description/potential risk: Describe the type of collision or conflict.
- Initial risk category: Indicate the risk assessment of the potential risk.
- Recommendation:
 - Describe the measures to be undertaken to mitigate the risk associated with the hazard.
 - The risk is to be reduced to an acceptable level.
- Practicability category:
 - Indication that the recommendation is practical
 - Site constraints taken into consideration

As presented in Table 2.3, hazards vary in the level of severity. Photo 2.2 presents an example of a hazard identified during a Postconstruction Safety Review (PCSR).

Photo 2.2. PCSR Hazard, Singapore



Photo 2.2 shows an exposed vehicle impact guardrail (VIG), which poses a high threat to vehicles. VIGs are designed to prevent vehicles from running off the roadway, but they can pose as a hazard when the termination is not properly anchored or ramped down into the ground.

2.5.2. LTA road maintenance program

Road maintenance is vital for the preservation of a road's safety and quality. The frequent maintenance of a road can lead to a reduction in the probability a collision will occur due to hazards located on the road. Furthermore, regular maintenance ensures that the level of safety is adequate for all road users.

In Singapore, the LTA operates a comprehensive road maintenance program, which encompasses the maintenance of roads, roadside features and pedestrian facilities. The maintenance program covers several facilities, including carriageways, footpaths, streetlights, signage, pedestrian overhead bridges, and other structures. Identified defects are treated promptly and potholes are fixed within an average of 24 hours of being reported (LTA 2019d). Additionally, the LTA implemented the Black Stop Program to identify, monitor, and treat locations with a high number of collisions.

Public roads and road facilities are checked and maintained regularly. The frequency of checks and maintenance of a road is as follows:

- *Expressways*: daily
- *Major roads*: every two weeks
- *Minor roads*: once every two months

3. Speed Management

Speed is considered a key risk factor in collision severity and causation of collisions. Speed accounts for approximately 30 percent of road deaths in high-income countries, and it is estimated that speed is the main contributing factor for half of all road collisions occurring in low- and middle-income countries (WHO 2018).

The number of speeding violations detected in Singapore was 156,157 in 2018. This represents a 5 percent decrease from 164,319 violations in 2017. Speed-related collisions amounted to 719 cases in 2018, a 5.6 percent decrease from 762 cases in 2017 (Singapore Traffic Police 2019).

Roads in Singapore are classified in five categories based on their function:

1. *Expressways* form the primary network where all long-distance traffic movements should be directed. They are planned to optimize long-distance mobility from one part of the island to another.
2. *Major arterial roads* predominantly carry through traffic from one region to another, forming principle avenues of communication for urban traffic movements. They connect expressways with minor arterial and other major arterial roads.
3. *Minor arterial roads* distribute traffic within the major residential and industrial areas. They are planned to optimize circulation within the area and facilitate through traffic between adjacent towns.
4. *Primary access roads* form the link between local accesses and arterial roads. They provide access to developments, and through-traffic is discouraged. However, where a development is also accessible by a local access road, the access shall be located at the local access road.
5. *Local access roads* give direct access to buildings and other developments and should connect only with primary access (LTA 2019b).

3.1. Setting speed limits

Speed limits should be set by evidence and should be self-explaining, seeking to reinforce the driver's assessment of what is a safe speed to travel. Speed limits should encourage drivers to be self-compliant. Drivers should view the speed limit as the maximum speed and not a target speed.

There is a strong correlation between the probability of a collision—as well as the severity of injuries sustained due to a collision—and speed. Research has shown that the probability of a collision can be reduced by 5 percent with every 1 mile-per-hour (1.6 kilometers per hour) reduction in average speeds (Taylor, Lynam, and Baruya 2000).

When setting an appropriate speed limit for a road, several essential factors are taken into consideration:

- *History of collisions:* including the frequency, severity, types and causes
- *Road geometry and engineering:* including width, sightlines, bends, junctions, accesses and safety barriers
- *Road function:* strategic, including through-traffic and local access
- *Composition of road users:* including existing and potential levels of vulnerable road users
- *Existing traffic speeds*
- *Road environment:* including level of road-side development

There are several approaches used when setting appropriate speed limits:

- *Engineering approach:* the base speed limit of a road is set according to several factors, including the 85th percentile speed, the design speed of the road, and other conditions.
- *Expert system approach:* speed limits are determined by the use of computer programs that take into consideration several factors relating to road conditions.
- *Safety systems approach:* speed limits are based on the type of collision that can occur, the likely severity of the collisions, and the human body's tolerances to the forces of the collision.

3.2. Enforcement of speed limits

The enforcement of traffic regulations falls under the responsibility of the Singapore Traffic Police. The Road Traffic Act states that the speed limit for vehicles travelling along roads in Singapore is limited to 50 kilometers per hour unless stated otherwise (Statutes of The Republic of Singapore 2004). The LTA bears the responsibility of determining the speed limit for roads in Singapore. Table 3.1 presents the speed limit for different vehicles travelling on roads and expressways and in tunnels in Singapore.

Table 3.1. Singapore Speed Limits (kilometers per hour)

Type of vehicle	Roads	Expressways	Tunnels
Cars and motorcycles	50	70–90	50–80
Buses and coaches	50	60	50–60
Light commercial vehicles (includes light goods vehicles and small buses not exceeding 3.5 tones and seating capacity of up to 15 passengers)	50	60–70	50–70

Exceptions to speed limits stated in Table 3.1 do apply to fire emergency vehicles, ambulances, and government vehicles used by the Singapore Police Force or the Singapore Civil Defence Force.

Lower speed limits are enforced in designated zones. These include School Zones and Silver Zones where speed limits are set at 40 kilometers per hour. School Zones are roads in close proximity to a school or roads located between School Zone signs. Silver Zones are located in residential neighborhoods. In addition to lower speed limits (when possible), several safety features are implemented in order to enhance road safety for elderly pedestrians. Silver Zone features are the following:

- Rest points are created on the road divider, to assist elder pedestrians crossing in two stages (Photo 3.1).

Photo 3.1. Two-Stage Crossing



Source: LTA 2017b.

- Upon entering the Silver Zone, road signs are displayed in addition to three rumble strips on the road to slow drivers (Photo 3.2).

Photo 3.2. Silver Zone Sign and Rumble Strips, Bukit Merah View



Source: LTA 2017b.

- Other traffic features, including chicanes, reduced lane widths and gentle curves along sections of the road (Photo 3.3).

Photo 3.3. Chicanes, Bukit Merah View



Source: LTA 2017b.

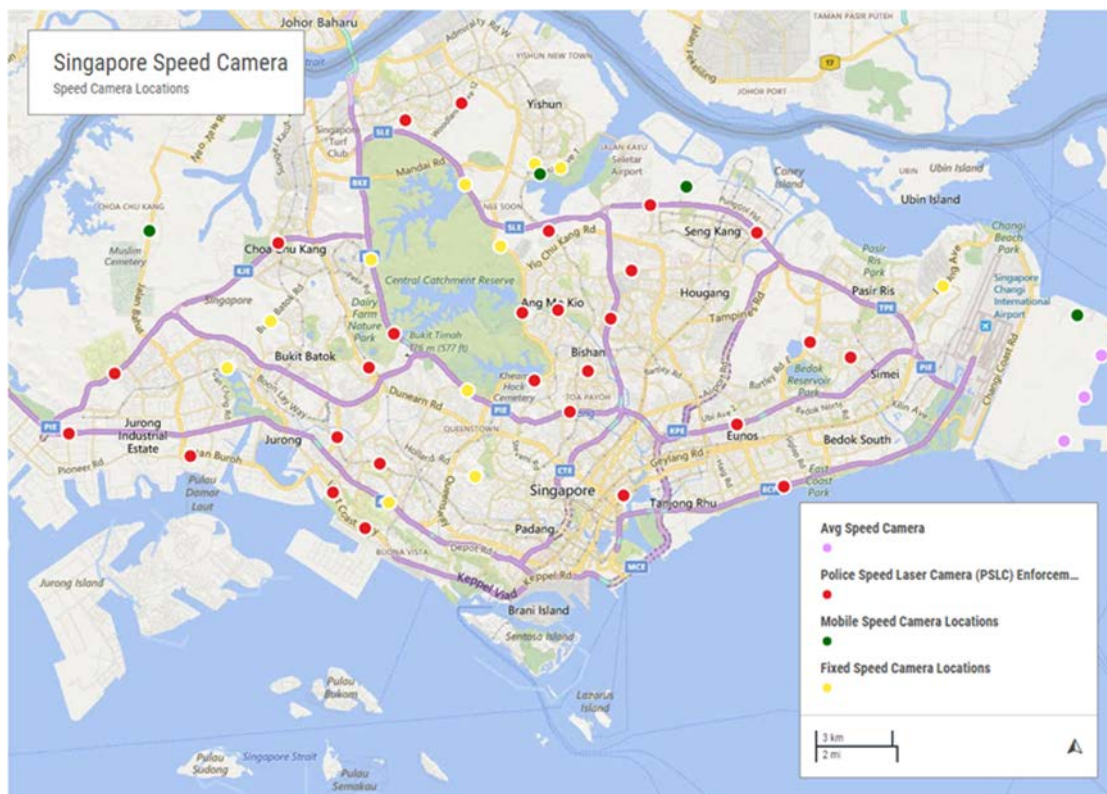
3.3. Speed cameras

Speed cameras have long been used as an effective method of reducing traffic speeds and thus reducing casualties and collisions. Several speed camera studies have shown that speed cameras can lead to a reduction in the number of collisions. In some cases, collisions can be reduced by as much as 27 percent (Pérez et al. 2007).

Speed cameras are one of the speed enforcement measures utilized in Singapore. Four different types are used: fixed speed camera, mobile speed camera, police speed laser camera, and average-speed camera.

There are a total of 87 speed camera locations across Singapore. The location of the speed cameras is presented in Figure 3.1.

Figure 3.1. Speed Camera Locations, Singapore



Source: Traffic Police

The different types of speed cameras used in Singapore are presented in Photo 3.4, Photo 3.5, Photo 3.6, and Photo 3.7.

Photo 3.4. Fixed Speed Camera, Singapore



Photo 3.5. Mobile Speed Camera, Singapore

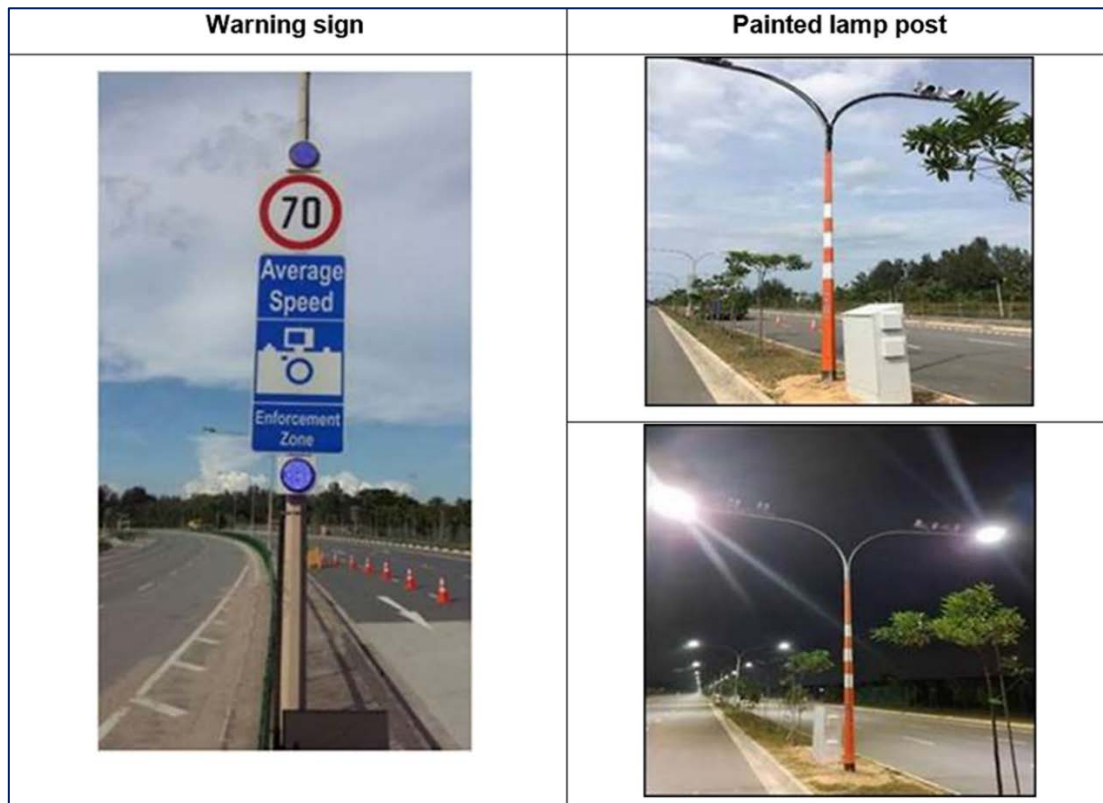


Photo 3.6. Police Speed Laser Camera



Source: Straits Times 2016

Photo 3.7. Average-Speed Camera, Singapore



There is a perception among certain members of the public that speed cameras are only a revenue-generating apparatus used by authorities. Although the use of speed cameras can generate significant income for authorities, their effectiveness in reducing collisions is undeniable.

Figure 3.2. Speeding Violations 2010–18, Singapore

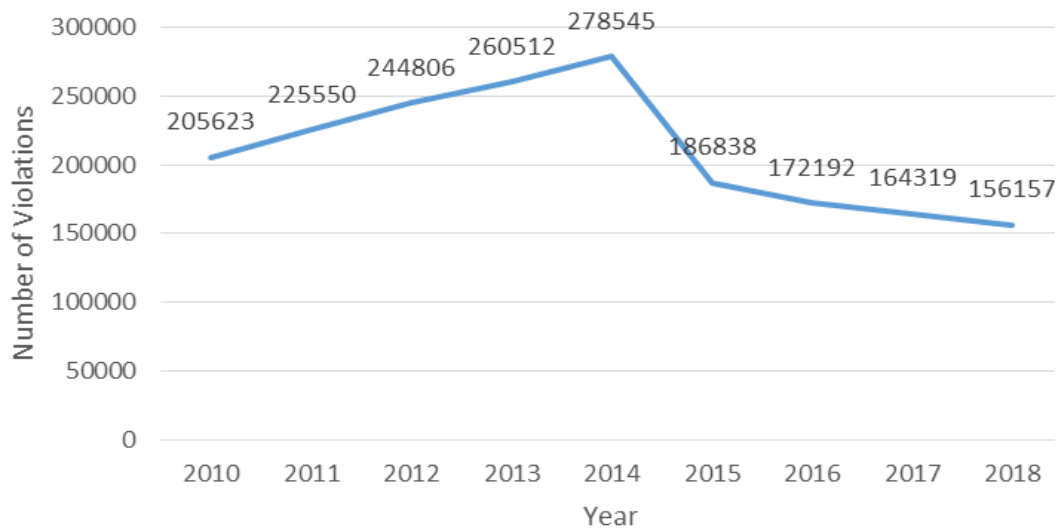


Figure 3.2 shows the number of speeding violations recorded by the Singapore Traffic Police, who are operating the speed cameras, between 2010 and 2018. A noticeable decline in the number of violations is observed between 2014 and 2015. Speeding violations declined from 278,545 in 2014 to 186,838, in 2015 representing a 33 percent decrease.¹ This decline can be directly attributed to measures implemented by the Singapore Traffic Police, such as the installation 20 speed cameras at 11 locations on March 1, 2015. However, it is difficult to know whether this decline is due entirely to the introduction of new speed cameras and/or other contributing factors.

3.4. Traffic-calming measures

Traffic calming is a system that uses various design and management strategies to achieve a balance of traffic on roads and streets, particularly those with vulnerable road users. Traffic-calming measures not only act to slow down vehicles but also improve safety and convenience for pedestrians, cyclists, and motorcyclists. This can be achieved, for example, by implementing measures to shorten crossing distances for pedestrians.

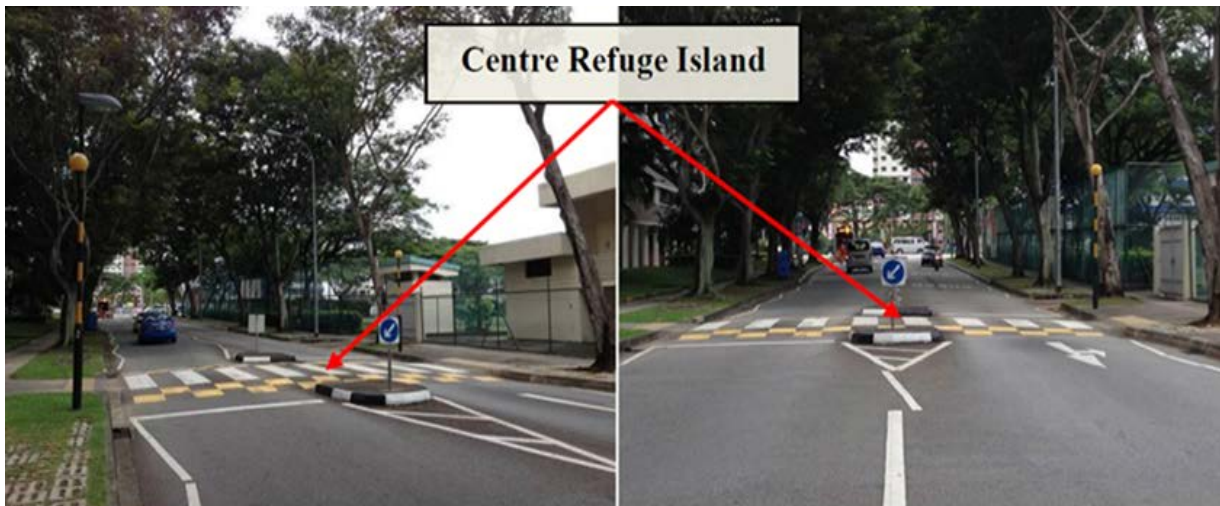
Traffic-calming measures can include the following:

- Vertical and horizontal measures such as road humps, chicanes, and road narrowing

¹ Fines collected by government agencies go into the Ministry of Finance’s Consolidated Fund, as defined by the Constitution of Singapore.

- Optical measures, which include the use of rumble strips, shortened sightlines, and road surface changes, including color and texture
- Changes to road environments, including the abundant use of vegetation and placement of street furniture
- Lower speed limit zones, which include School Zones or Silver Zones.

Photo 3.8. Centre Refuge Island, Singapore



Source: LTA 2016.

Traffic-calming measures can be found on several Singapore streets, including central refuge islands. These are usually positioned at zebra crossings along undivided two-lane roads. The positioning of the center refuge island along the carriageway assists pedestrians in crossing the road in two stages. Additionally, the pedestrian island structure narrows the width of the carriageway, alerting vehicles to slow down. The pedestrian crossing is slightly raised, acting as a speed hump. This also makes the crossing more visible to oncoming vehicles. The design specification for a raised pedestrian crossing is provided in appendix A. An example of a center refuge island is presented in Photo 3.8.

Center dividers provide a physical segregation of oncoming traffic, in addition to narrowing the width of the carriageway so oncoming vehicles approach at a slower speed. An example of a center divider located on Singapore road is presented in Photo 3.9. The photo on the right-hand side includes a treatment calcined bauxite (skid resistance treatment). That is good practice at pedestrian crossings, bends, and locations where the likelihood of running off the road is high.

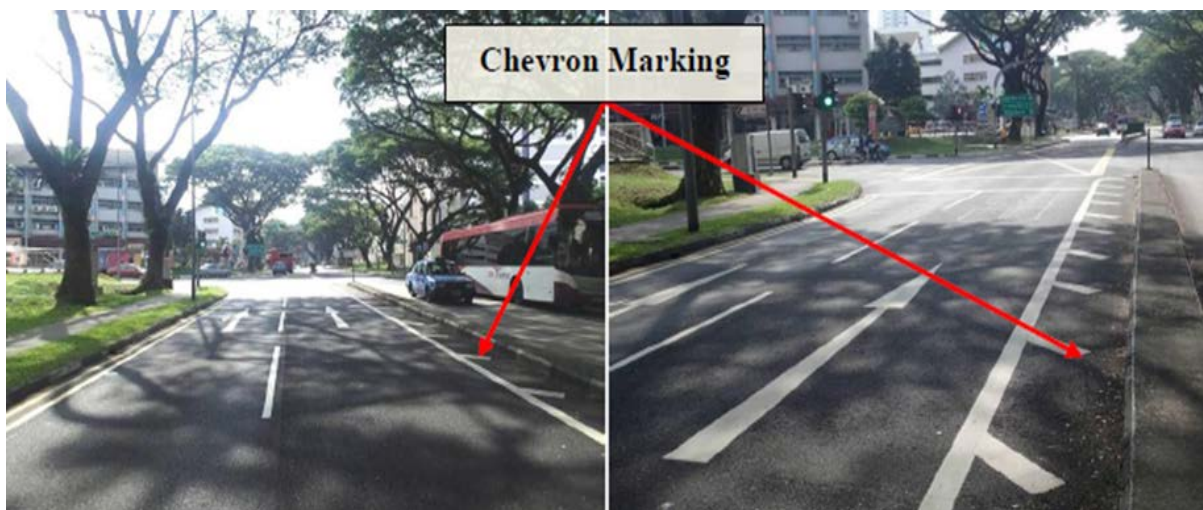
Photo 3.9. Centre Divider, Singapore



Source: LTA 2016.

Chevron markings are used as an alternative to physical structures. The markings lead the driver to perceive the road narrower than it is, thus slowing vehicles. An example is presented in Photo 3.10.

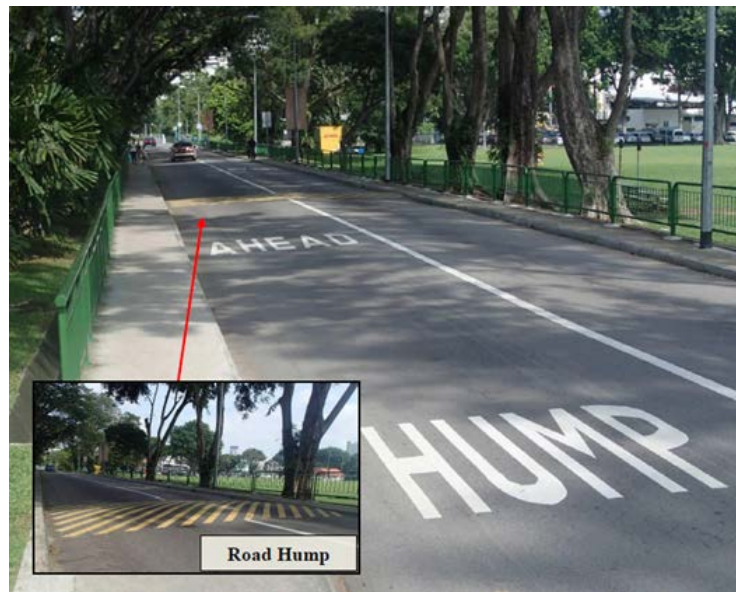
Photo 3.10. Chevron Markings, Singapore



Source: LTA 2016.

Physical measures used to calm traffic include road humps. Road humps can be effective in reducing vehicle speeds along minor arterial roads. Vehicles drivers are alerted to the presence of the speed hump prior to approaching it, giving them time to reduce their speed. Bus-friendly road humps are implemented on bus routes. They are designed to allow buses to pass safely. An example of a road hump in Singapore is presented in Photo 3.11.

Photo 3.11. Road Hump, Singapore



Source: LTA 2016.

Hatching can be provided along the edge of a carriageway at the turn of a road. This is seen in Photo 3.12, where there is a high number of jaywalkers and driver visibility is reduced due to the presence of vegetation and street furniture. The hatching along the carriageway gives the perception of a narrower carriageway, guiding drivers away from the edge of the carriageway where a pedestrian could be present.

Photo 3.12. Hatching Marking, Oldham Lane, Singapore



In summary, traffic-calming measures can be used as a cost-effective measure to improve the safety of a road.

4. Road Infrastructure

“Safer roads and safer mobility” is the second pillar of the UN Global Plan for the Decade of Action for Road Safety 2011–2020. The necessity to increase the safety and quality of road networks for all road users, especially the most vulnerable, is highly emphasized in this pillar. In order to achieve this, measures such as improved safety-conscious planning, design, construction, and operation of roads need to be adopted.

Road infrastructure, which includes roadway and roadside design elements, can have a significant role in determining the risk of a traffic collision. A collision can be caused directly due to a defect on the road, or in some cases misleading elements of the road environment can lead to human error. Road safety design concepts such as “forgiving” and “self-explaining” roads are significant and should be adopted in the design of roads in order to reduce and minimize the risk of traffic collisions.

There is a strong correlation between poor road design and a higher risk of a collision. Roads should be self-explaining, providing guidance to roads users on what they should be doing. Collisions can be triggered by negative road engineering factors or misleading road environments which lead to collisions through human error.

4.1. Road parameters

The inadequate design of a road can be a leading causation factor for a collision. Several road design parameters are considered to have a significant impact on the safety of a road.

The cross-section of a road can have a significant impact on the frequency of collisions. Research has shown that there is a correlation between carriageway width and the collision rate of a road. There is a direct tendency for the collision rate to increase with increased lane widths (Othman, Thomson, and Lannér 2009). This can be attributed to lane change maneuvers and higher speeds experienced on wider carriageways.

Road surface conditions contribute significantly to the usability and safety of a road. Several studies have looked at the relationship between collisions and road surface parameters such as pavement roughness and friction. The studies have shown that pavement conditions expressed in terms of the International Roughness Index have significant impact on the collision rate of a road (Tighe et al. 2000).

Road marking and road signs are significant road features that guide and inform drivers about their surroundings. Inadequate signage or inconsistent signage can misinform or confuse drivers this can likely lead to a collision. Therefore, it is essential that road signs be consistent,

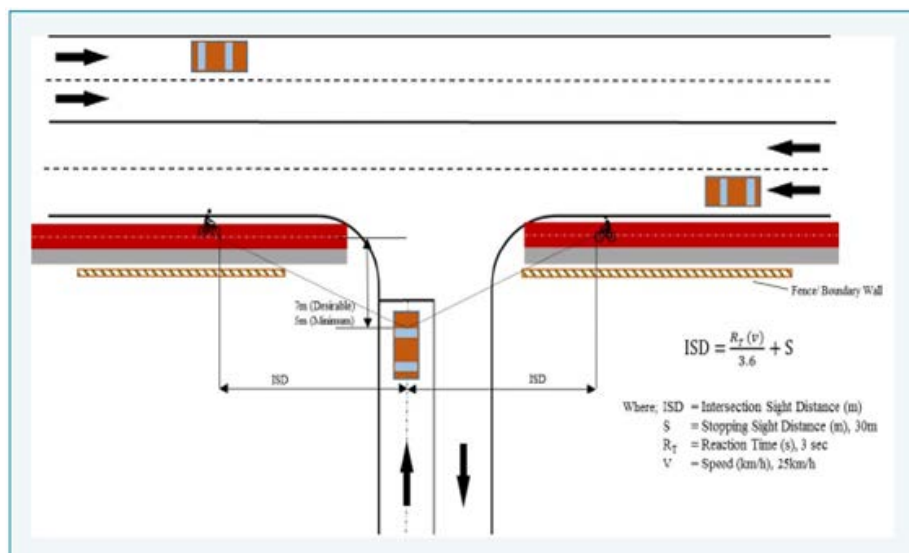
conspicuous, and comprehensible. Road markings and road signs usually complement one another by providing guidance to the road user.

Roadside conditions can have a great impact on the safety of a road. Obstructions and inadequate roadside safety measures such as crash barriers can contribute to collisions. Obstructions located on roadsides include sign posts, traffic signal boxes, and other street furniture. When designing safe roads, adequate lateral offset to vertical obstructions such as sign posts is required in order to reduce likelihood of crashes.

Road curvature and speed are connected parameters in road design that reduce the probability of a collision. A vehicle navigating around the curved section of road experiences centrifugal forces. These forces try to deviate the vehicle from the desired line of movement. Super elevation is provided at the curved sections of roads in order to prevent vehicles from deviating from the desired line. The curvature of a road is designed to accommodate vehicles travelling at a certain speed. Therefore, vehicles travelling at speeds above the design speed of the curve will lose control.

The inability of a driver to see ahead is considered as a collision causation factor. A *sight distance* of sufficient length is required in order for a driver to safely control a vehicle in order to avoid hitting an unanticipated object on the road (Ahmed 2013). Guidance on safe stopping sight distances can be found within the LTA Code of Practice (LTA 2019b).

Figure 4.1. Sight Stopping Distance



Source: LTA 2019b.

Figure 4.1 shows the parameters required in order to calculate a safe sight distance at junctions where pedestrians and cyclists are present.

4.2. Safer roadsides for forgiving roads

A large number of research studies have been conducted in the past years, studies which contributed to the development of the road design standards for improving roadside design. They suggest that the stages in any strategy for improving the siting and design of street equipment can be further developed and extended (ETSC 1998), as shown in table 4.1.

Table 4.1. Main Principles for Forgiving Roads

Existing roads	Designed roads
Eliminating unnecessary obstacles	Designing roads free of obstacles
Moving obstacles further away from the roadside	Designing a clear zone at the side of the road
Modifying the structure of the obstacles	Designing street equipment to be more forgiving
Isolating certain obstacles with new and improved types of safety devices	Protecting street equipment with a barrier to absorb some of the energy of the impact

To develop a forgiving road environment, certain characteristics must be included, and standard road safety measures should be taken, such as the assessment of the effectiveness of a roadside treatment. The aim of the forgiving roads approach to road design is not only to prevent collisions from occurring but also to reduce the damage inflicted on the driver if a collision does happen due to human error. A forgiving road is largely based on how the roadside is designed and equipped, taking into consideration how several inadequately designed roadside elements pose a risk to drivers. A series of measures can be implemented to create forgiving roads. They are presented in the following subsections.

4.2.1. Vehicle impact guardrail

Vehicle impact guardrails (VIGs) or safety barriers are a form of forgiving roadside treatment, designed to prevent vehicles from running off the carriageway. However, VIGs can also act as a hazard in circumstances where installation is incorrect or the wrong type of VIG is used. The VIG ends are considered hazardous when the end is not properly anchored to the ground, or when it does not flare away from the carriageway (La Torre 2012). Collisions with an “unforgiving” VIG end can result in fatal consequences.

VIGs can be classified as energy-absorbing and non-energy-absorbing, dependent on whether it is a tangent terminal or a flared terminal. Tangent terminals are aligned parallel to the carriageway edge and are energy absorbent; they are designed to stop a vehicle. Flared terminals deviate from the alignment of the carriageway edge; typically they are not designed to dissipate significant amounts of energy when a head on collision occurs.

Design specifications for guardrails can be found within the LTA Standard Details of Road Elements document. A copy of a good practice guardrail design specification is provided within appendix B.

4.2.2. Rumble strips

Rumble strips are a road safety feature designed to alert drivers to potential hazards. When a vehicle comes into contact with the rumble strips a rumbling sound is transmitted in addition to a vibrating effect.

In Singapore, rumble strips are typically used in pedestrian priority areas such as Silver Zones. Three yellow rumble strips are installed in order to alert vehicle drivers of pedestrians.

4.2.3. Raised profile marking

Raised profile markings function similarly to rumble strips. They can be installed along a carriageway in order to prevent vehicles from deviating. This road safety feature is particularly useful in preventing drowsy or distracted drivers from causing a potential collision; drivers are alerted by the vibration and sound emitted from the strips.

The LTA provides guidance on where raised profile markings should be provided. Raised profile markings are to be provided for the following (LTA 2017b):

- From the start of the shoulder marking at the exit road to 10 meters behind the gore area
- From the start of chevron to 10 meters after the gore area
- From the start of the deceleration lane along the expressway next to paved shoulder
- Continuously along the expressway shoulder lane next to slow lane

Design specification for raised profile markings provided by within the LTA SDRA are presented in Figure 4.2 and Figure 4.3.

Figure 4.2. Raised Profile Marking

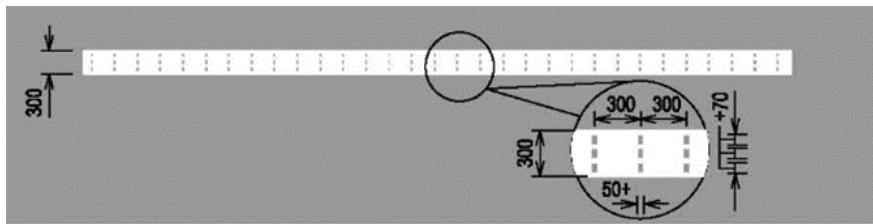
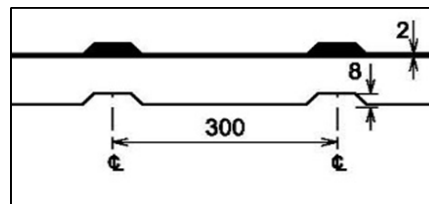


Figure 4.3. Raised Profile Marking, Side Profile View



4.2.4. Crash cushions

Crash cushions are considered highly effective in reducing the consequences of a crash. The crash cushion is designed to absorb the impact of the collision. Crash cushions are usually positioned in front of diverging roads and along expressways and major arterial roads.

The use of crash cushions has been very effective in some cases. A 40 percent reduction in injury crashes was observed at study sites in Birmingham, United Kingdom. The treated site also experienced a reduction in the number of fatal and serious crashes from 67 percent to 14 percent (TMS Consultancy 1994).

Photo 4.1 provides an example of a typical crash cushion found along an expressway in Singapore.

Photo 4.1. Crash Cushion, Singapore



Source: LTA 2019.

4.3. Self-explaining roads

Self-explaining roads are designed so that the appropriate speed and driving behavior required on the road is self-evident to drivers. Self-explaining roads can be implemented through the implementation of several measures such as appropriate road markings and roadside features (photo 4.2).

Photo 4.2. Examples of Self-Explaining Roads in Singapore



Self-explaining roads have been successfully implemented in several urban areas around the world. According to a study undertaken by Charlton et al. (2010), the implementation of self-explaining roads resulted in a significant reduction in vehicle speeds. The study area was segregated into two sections, one receiving treatment measures such as increased landscaping and limiting forward visibility and the other receiving no treatment. The results of the study showed a significant reduction in vehicles speeds for the section that had received the treatments.

4.4. Pedestrian footbridges

Separation of different traffic flows depending on types of road users is very important to ensure increased safety, especially for the most vulnerable users. Based on this principle, Singapore is hosting a high number of user-friendly and attractive footbridges. These are positioned near bus stations and mass-rapid transit stations, are accessorized with elevators for the elderly and the disabled, and linked to sheltered footpaths going to and from

residential areas. Basically, these footbridges become points of attractions or standing gardens across the city, as in photo 4.3.

Photo 4.3. Examples of Frequently Used Footbridges in Singapore



5. Dangerous Infrastructure

5.1. Identifying dangerous existing streets

Several methods can be utilized to assess the safety of a street or road. This includes road safety audits and collision hotspot schemes. A road safety audit can be undertaken for an existing road or route on the road network. The aim of a road safety audit of an existing road is to identify hazards that may cause a collision in the future. Remedial measures can be applied to hazards identified during the safety audit.

Collision data are an important factor in identifying and treating collision hotspots. However, collision data are prone to confounding factors of regression toward the mean and general collision trends. A confounding factor is any factor other than the measure whose effects the study is designed to evaluate (Elvik 2002).

Regression to the mean is the tendency for unusually high or low counts to be followed by values closer to the underlying mean. General trends in collisions can be observed due to several factors such as changes in vehicle safety and driver education. (Thorpe 2018).

Collision data should be comprehensive and inclusive of the following information:

- *General collision information:* date, location, road features, speed limit, junction features, weather and lighting conditions, and road surfaces
- *Vehicles involved:* type, maneuvers, location, skidding and overturning, striking objects, points of impact, age, gender and address of driver, alcohol test, vehicle registration, and journey purpose
- *Casualties involved:* type of casualty (for example, driver, pedestrian), gender, age and severity of causality, location and movement direction, front versus rear passenger, and address
- *Contributory factors:* road environments, vehicle defects, injudicious actions, driver and/or rider error or reaction, impairment or distraction, behavior or inexperience (Thorpe 2018)

Collision hotspots can be identified by looking at a baseline period, which is usually three to five years. Clusters are identified by defining a minimum threshold in a defined radius. A collision hotspot can then be defined as an area in which the number of collisions exceeds the predetermined threshold during the baseline period.

As previously stated, collision data is prone to confounding factors, which can be misleading. Confounding factors can lead to false positives, which in turn can result in a non-hotspot area

being treated. Additionally, there is a risk of false negatives, which can result in a genuinely unsafe site being left untreated.

Since 2005, the LTA has implemented a road safety initiative known as the Black Spot Programme. The key objective of the Black Spot Programme is to identify, monitor, and treat locations with a high number of traffic collisions. The Black Spot Programme has proven to be a success with an average of 5 to 10 locations being removed per year due to the collision rate falling below the defined threshold level. The program has resulted in a 75 percent drop in collisions over a three-year period in some cases (LTA 2014). A range of interventions have been used, included the provision of signalized pedestrian crossings. One success case of the Black Spot Programme is the Moulmein Road–Newton Road—Thomson Road junction. The junction was monitored for 36 months; prior to treatment a total of 19 collisions were recorded compared to 7 after treatment. The treatment at the junction comprised of the provision of a fully controlled right turn (red-amber-green arrows). This is presented in Photo 5.1.

Photo 5.1. Fully Controlled Right Turn (red-amber-green arrows)



Additional methods utilized in Singapore for identification of dangerous roads or streets include the LTA road maintenance program discussed in previous sections.

The LTA frequently checks and maintains roads and road facilities on the road network. Expressways are checked and maintained on a daily basis, major roads are checked and maintained every two weeks, and minor roads are checked and maintained every two months.

Identified defects are treated promptly, and potholes are fixed within an average of 24 hours of being reported (LTA 2014).

5.2. Dangerous road designs

Badly designed roads can be a major contributing factor leading to a collision. Faults can include road defects and misleading road infrastructure.

Several different road elements such as markings, signs, road geometry, lighting, road surface, and traffic and speed management are essential to maintain the safety of a road. Roads are considered one of the key causation factors of collisions, together with human and vehicle factors.

Road alignment has a significant influence on the safety of a road, which includes the dimension of radii, ratio of consecutive curves, dimensions of vertical curves, and sight distance conditions. (Mohammed 2013)

Road design standards in Singapore are set and regulated by the LTA. Road designers follow guidelines and standards included within several LTA publications, such as the LTA Code of Practice and the LTA Standard Details of Road Element. Examples of standard design elements can be found in the appendixes of this report.

The guidance and standards provided do promote safe design, but without comprehensive audits, significant safety hazards can be neglected.

Photo 5.2. Signal box located unsafely on the edge of the carriageway, Singapore

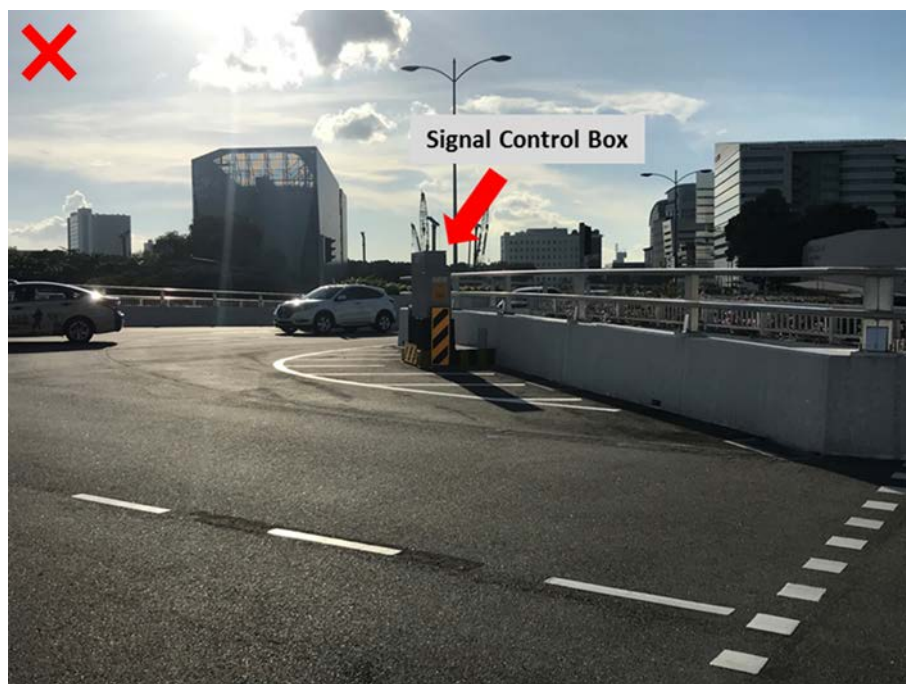


Photo 5.2 shows a signal control box positioned on the carriageway at a bend in the road. This hazard was identified during a Post Construction Safety Review. Hazards such as the one present in photo above pose a risk to drivers. Without road safety audits, hazard like this can go unnoticed until it's too late (LTA 2019).

Photo 5.3. Inadequate Visibility Along Vertical Curve, Singapore



There is inadequate visibility along the vertical curve of the road displayed in Photo 5.3. Driver's visibility and sight stopping distance are greatly affected, as drivers are unable to see and react to potential hazards which lay ahead.

5.3. Dangerous Pedestrian and Cyclist Infrastructure

Pedestrians and cyclists are considered the most vulnerable road users. Surprisingly, it is very common in many countries to focus on road design to accommodate vehicles and neglect the need for safe pedestrian and cyclist infrastructure. This can be due to shortcomings in road design standards or a lack thereof.

Vulnerable road users, which include pedestrians, cyclists and motorized two- and three-wheelers, account for over half of all road deaths globally. In Southeast Asia, motorized two- and three-wheelers account for the highest proportion of road deaths, meaning approximately 43 percent of the total numbers of road fatalities (WHO 2018a).

Although Singapore has been making strides in promoting walking and cycling, pedestrians and cyclists are still very vulnerable on roads. The number of collisions on Singapore roads involving pedestrians was 1,036 in 2018, with elderly pedestrians accounting for 25 percent

of pedestrian collisions. Pedestrian fatalities in 2018 were 40; 62.5 percent were elderly pedestrians. Jaywalking is attributed to 40 percent of collisions involving elderly pedestrians (Singapore Traffic Police 2019).

Although the quality and provision of pedestrian and cyclist infrastructure is considered better than that of neighboring countries, inferior pedestrian and cycling facilities can still be found around the country.

Photo 5.4. Unremoved Crossing, Singapore



Photo 5.4 shows two pedestrian crossings with tactile paving. The crossing directed toward the main carriageway on the left formed part of a crossing across the main carriageway, which is now removed, but the dropped curb and tactile paving remain in place. The unremoved dropped curb and tactile paving can be confusing and pose a risk to pedestrians, especially visibility impaired pedestrians.

Inadequate design of pedestrian infrastructure is an unfortunate but recurring theme in some streets in Singapore. The common design errors observed include no dropped curbs and tactile paving at pedestrian crossing areas, incorrect positioning of tactile paving, inadequate widths of pedestrian footpaths, and dangerous level changes along edge of pedestrian footpaths.

Photo 5.5. Inadequate Crossing, Singapore



Photo 5.5 shows a crossing area where adequate dropped curbs and tactile paving is provided on one side but not the other. Inadequate pedestrian infrastructure such as that presented in Photo 5.6 impacts the most vulnerable of pedestrians. A significant level of difference can be seen along the pedestrian footpath, which poses a high risk to pedestrians, especially vulnerable pedestrians.

Photo 5.6. Hazardous Footpath, Singapore



Dangerous designs can also be found in temporary road works, where inadequate or unsafe pedestrian infrastructure is sometimes provided (LTA 2019).

Photo 5.7. Inadequate Crossing



The location and positioning of the plastic barricades in Photo 5.7 forced pedestrians onto a live carriageway, putting them in potential danger.

6. Safer Design Principles: Before-and-After Study on Sustainable Cycling and Pedestrian Infrastructure

Singapore has implemented a range of measures such as Certificates of Entitlement and road pricing to maintain adequate capacity on roads. In recent times, initiatives such as Car-Lite have been introduced in order to promote sustainable modes of transport and reduce dependency of cars.

Several roads have been redeveloped and equipped with infrastructure to support sustainable modes of transport, such as walking and cycling. Bencoolen Street in Singapore is an example of this, having recently undergone a transformation to become more pedestrian and cycle friendly.

Bencoolen Street was formerly a four-lane street with no cycle infrastructure and narrow pedestrian footpaths. The past street configuration is presented in Photo 6.1.

Photo 6.1. Previous Street Configuration, Bencoolen Street, Singapore



The new revitalized Bencoolen Street provides pedestrians with wider footpaths and cyclists have segregated cycle paths. The carriageway width has been reduced to two lanes in order to accommodate the provision of a cycling path and wider pedestrian footpaths. Photo 6.2 and Photo 6.3 and show Bencoolen Street after improvements have been implemented.

Photo 6.2. New Street Configuration, Bencoolen Street, Singapore



Photo 6.2 shows the reduced carriageway width of Bencoolen Street. A cycle lane can be seen in red adjacent to the pedestrian footpath.

Photo 6.3. Improved Pedestrian Facilities, Bencoolen Street, Singapore



The revitalized Bencoolen Street can be seen in Photo 6.3. The provision of segregated cycle lanes, cycle parking, and wide pedestrian footpaths have made the area more sustainable and inclusive to pedestrians and cyclists.

7. Conclusions

We are still in an era where road engineers are focused only on design standards and creating roads for cars. Even if a street goes next to a school, if there's too much traffic, what is the first recommendation? "Let's add another lane!" This couldn't be more wrong.

It is necessary to change this mentality in order to have safer streets, and Singapore is a good example of success story for building a safer road infrastructure for safer communities, especially through the coordination of different institutions.

Let's make road engineers think "Safety First!"

Singapore enjoys a high level of safety on its road network due several complementary factors. Local authorities have made significant progress in addressing the road safety issue faced by the nation.

Government agencies such as the Land Transport Authority (LTA) and Singapore Traffic Police (TP) have contributed significantly to road safety on Singapore's roads. Road safety management under the LTA and the implementation of numerous road safety measures and tools such as the Black Spot Programme and road safety audits and collision data collection by the TP have made a positive contribution to the success of road safety in Singapore. A crucial aspect for the success of a road safety program is to have a dedicated budget and good data to analyze the most vulnerable locations that need immediate treatments.

There is no single solution to tackle road safety, but there are collective solutions. These include improved education and awareness linked to high vehicle standards, improved design and maintenance of road and roadsides, and better road management systems.

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

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Appendix A – Pedestrian Infrastructure Design Guidance

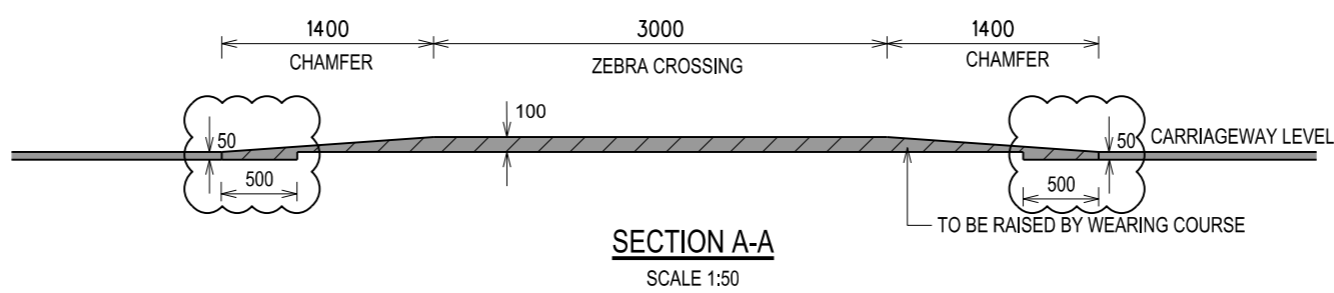
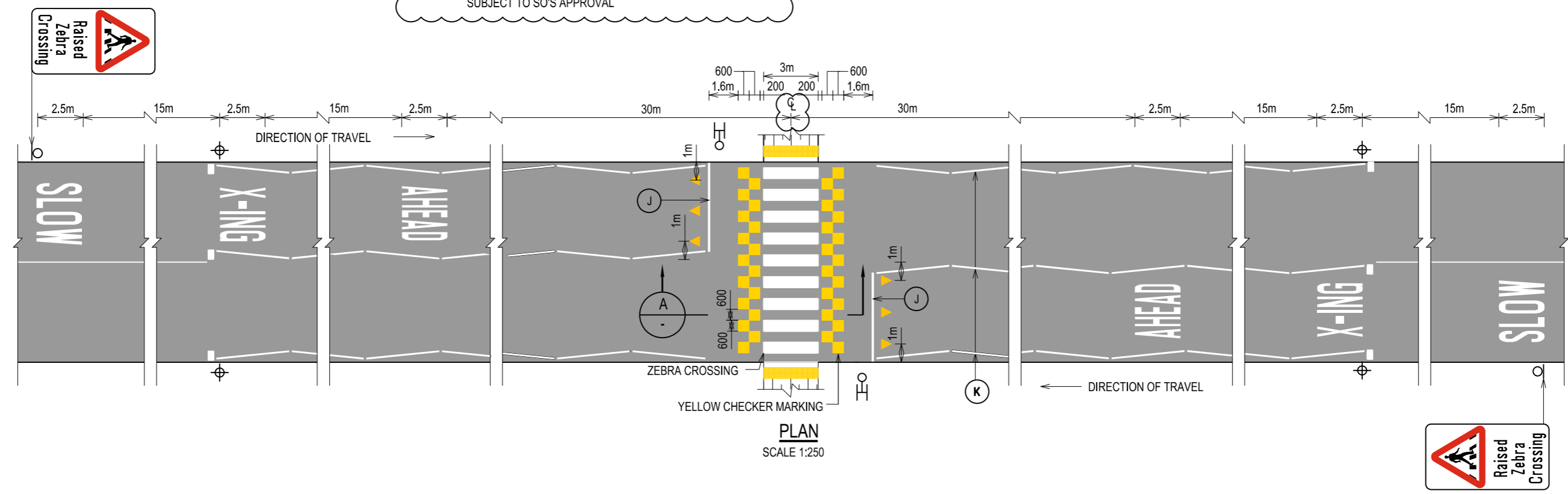
LEGEND

-  RAISED REFLECTIVE PAVEMENT MARKERS (AMBER)
-  REFER TO LANE MARKINGS
-  FLASHING BEACON WITH 'PEDESTRIAN CROSSING' SIGNS
-  HOMOGENEOUS TACTILE TILES

 'PEDESTRIAN CROSSING PROHIBITION' SIGN TO BE PLACED PERPENDICULAR TO THE 'ARROW' SIGN


 'ARROW' SIGN TO BE PLACED PARALLEL TO SIDE OF ROAD

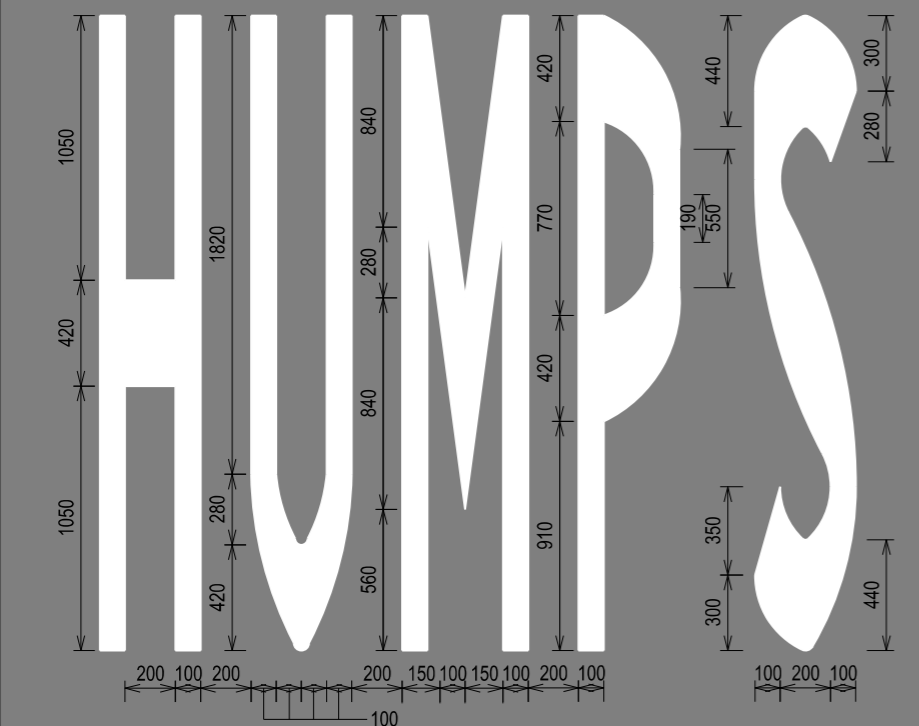
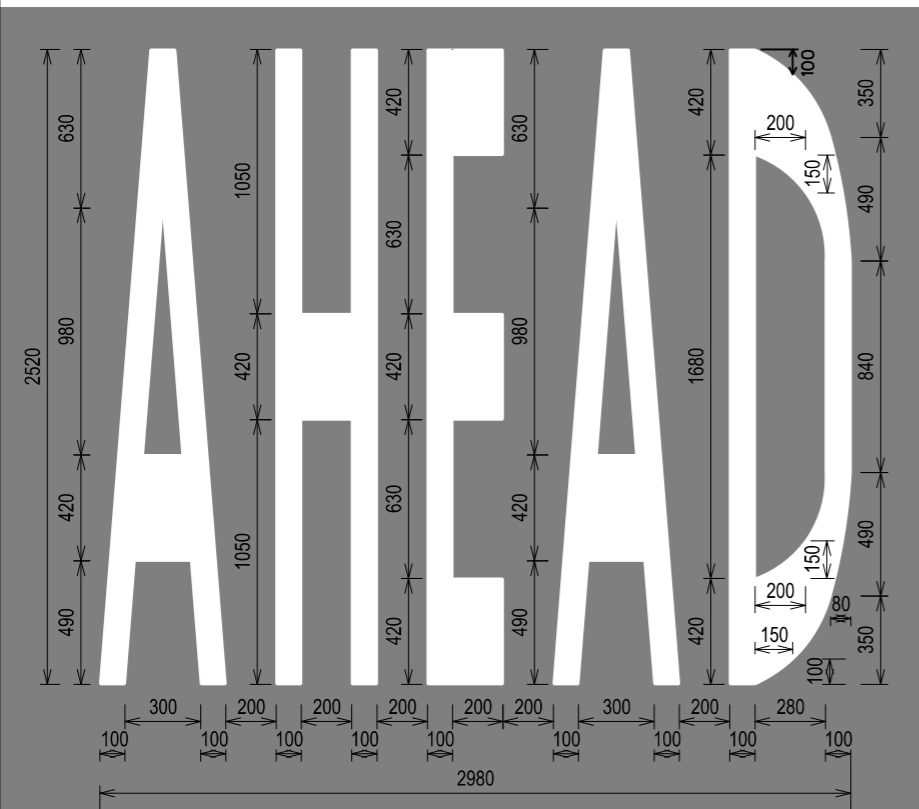
ALL SIGNS TO BE CLAMPED ONTO THE NEAREST EXISTING LAMPPOSTS WHEREVER POSSIBLE AND SUBJECT TO SO'S APPROVAL



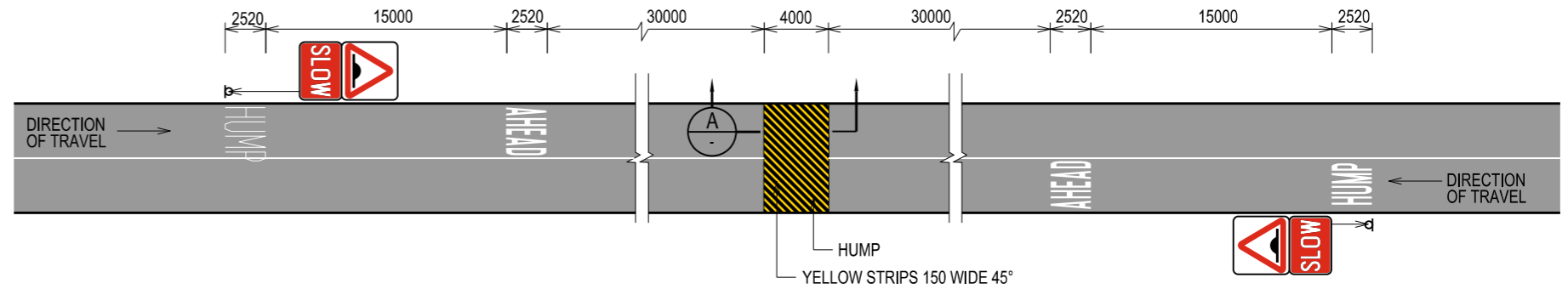
SECTION A-A
SCALE 1:50
RAISED ZEBRA CROSSING

NOTES:
 1. Footpath joining pedestrian crossings shall be flushed with zebra crossing.
 2. Checker markings to be painted in yellow.

STANDARD DETAIL			
RAISED ZEBRA CROSSING		REV. B	REV. B
		DATE OF ISSUE 1st APR 2014	SHEET NO. 1 OF 1
		SCALE AS SHOWN	

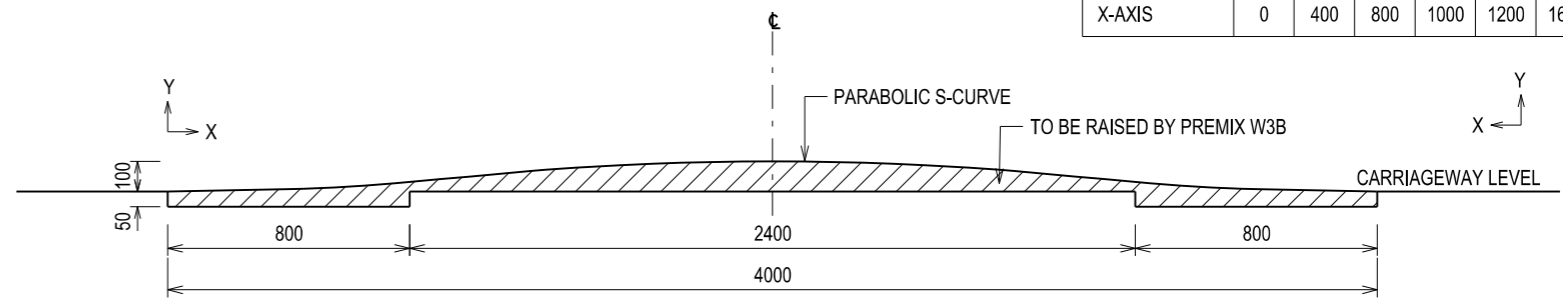


MARKINGS FOR HUMP AHEAD
SCALE 1:30

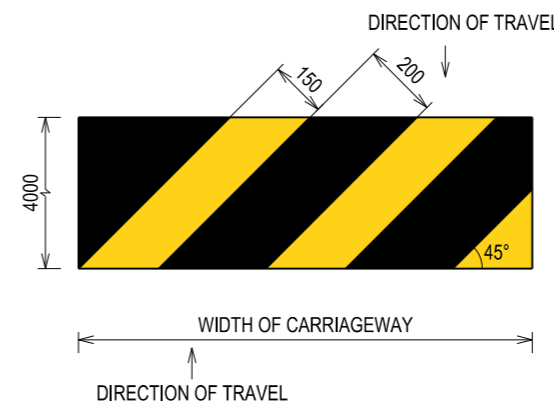


TYPICAL PAVEMENT WARNING MESSAGE FOR ROAD HUMP
SCALE 1:400

Y-AXIS	0	8	32	50	68	92	100
X-AXIS	0	400	800	1000	1200	1600	2000



SECTION A-A
SCALE 1:25



COLOUR SCHEME FOR HUMP
SCALE 1:20

NOTES:
1. Thickness of thermoplastic paint for hump ahead marking is 3mm.

STANDARD DETAIL		Land Transport Authority	
REV.	DATE	DRAWING NO.	REV.
A	SEP 2017	LTA/SDRE14/9/TMM6	A
		DATE OF ISSUE	SHEET NO.
		1st APR 2014	1 OF 1
		SCALE	AS SHOWN

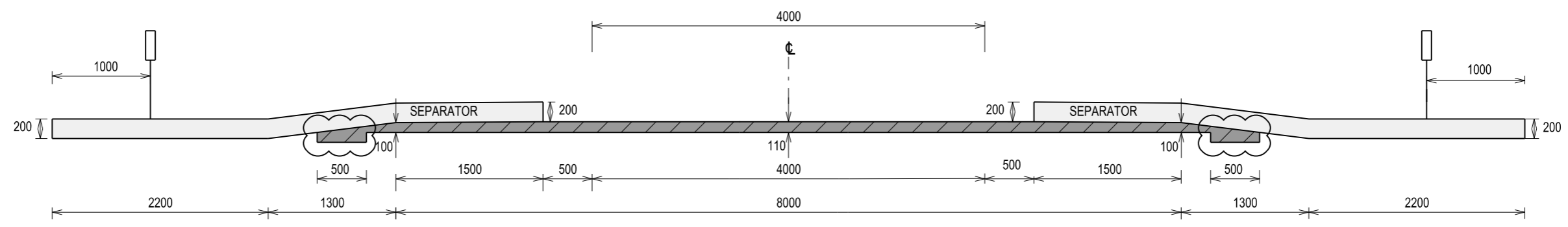
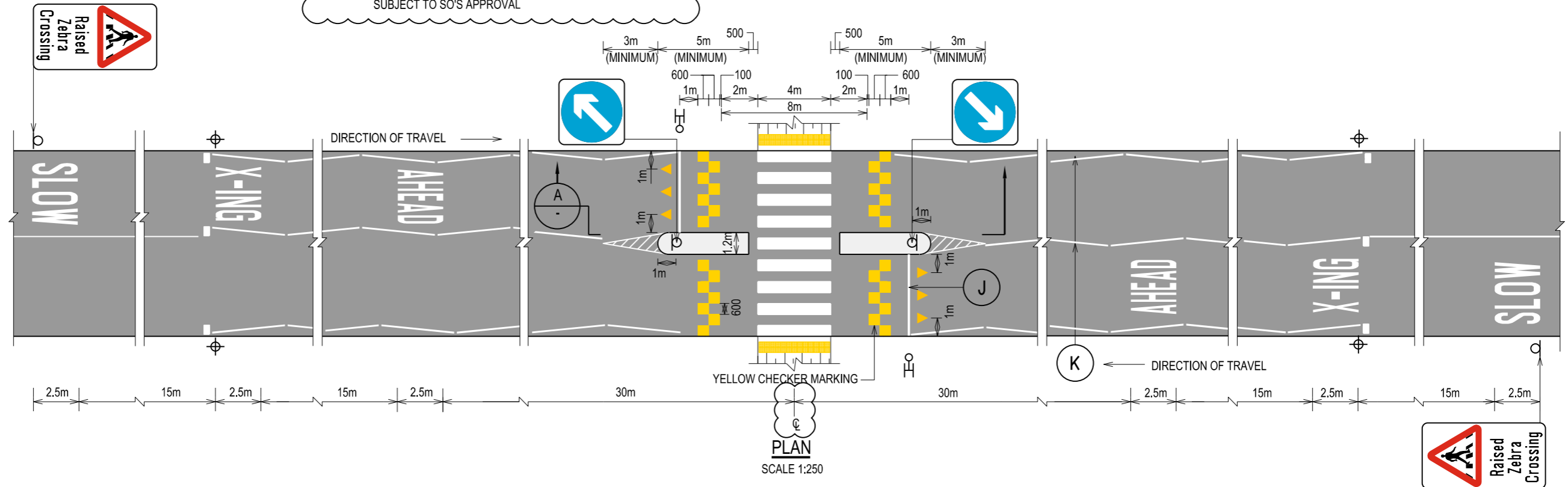
LEGEND

- ▲ RAISED REFLECTIVE PAVEMENT MARKERS (AMBER)
- Ⓧ REFER TO LANE MARKINGS
- Ⓛ FLASHING BEACON WITH 'PEDESTRIAN CROSSING' SIGNS
- HOMOGENEOUS TACTILE TILES

Ⓧ 'PEDESTRIAN CROSSING PROHIBITION' SIGN TO BE PLACED PERPENDICULAR TO THE 'ARROW' SIGN

➔ 'ARROW' SIGN TO BE PLACED PARALLEL TO SIDE OF ROAD

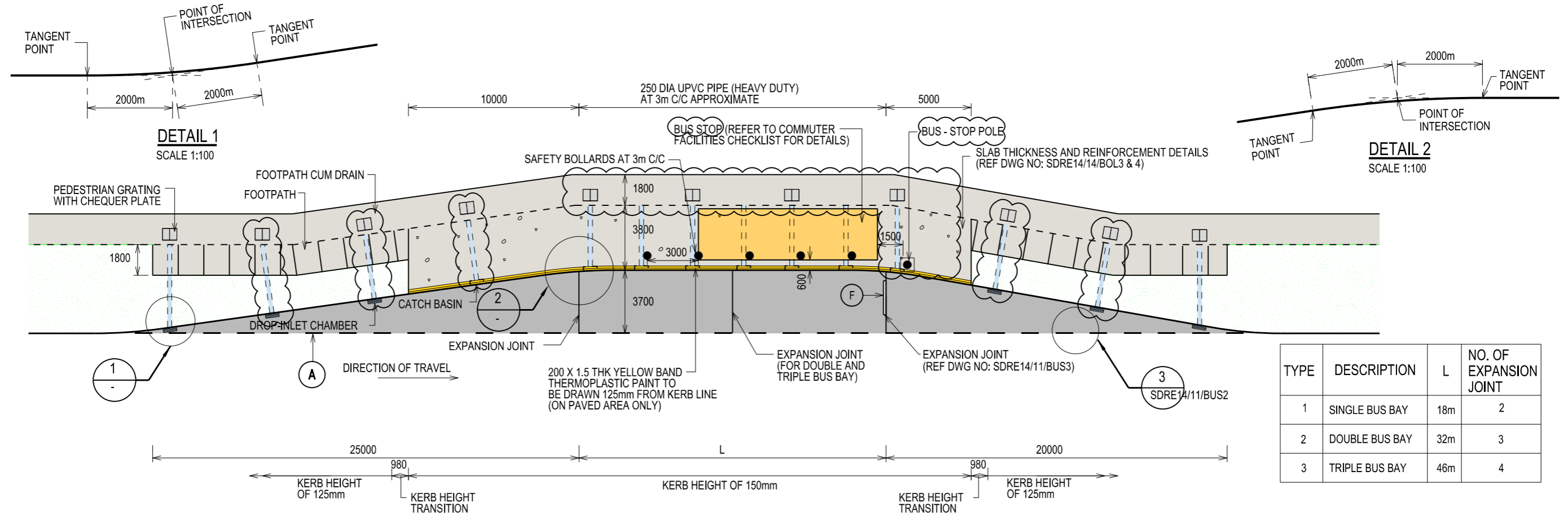
ALL SIGNS TO BE CLAMPED ONTO THE NEAREST EXISTING LAMPOSTS WHEREVER POSSIBLE AND SUBJECT TO SO'S APPROVAL



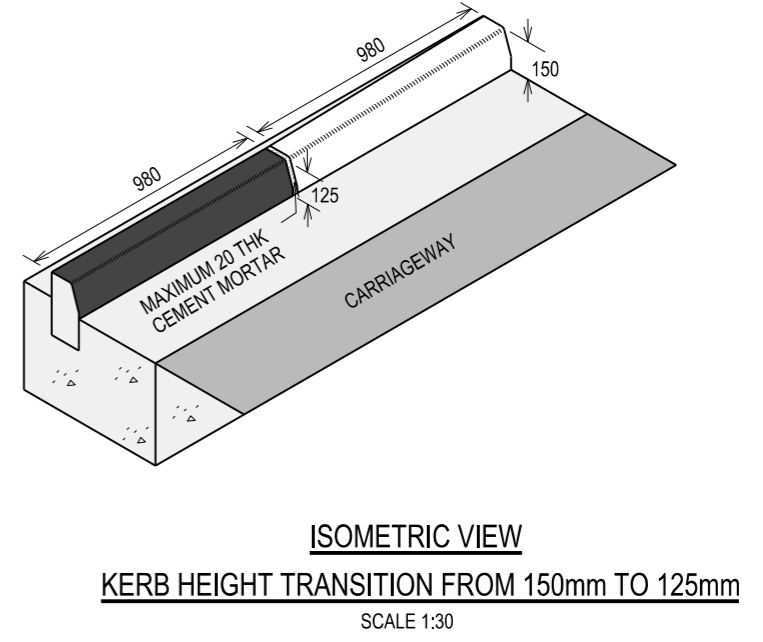
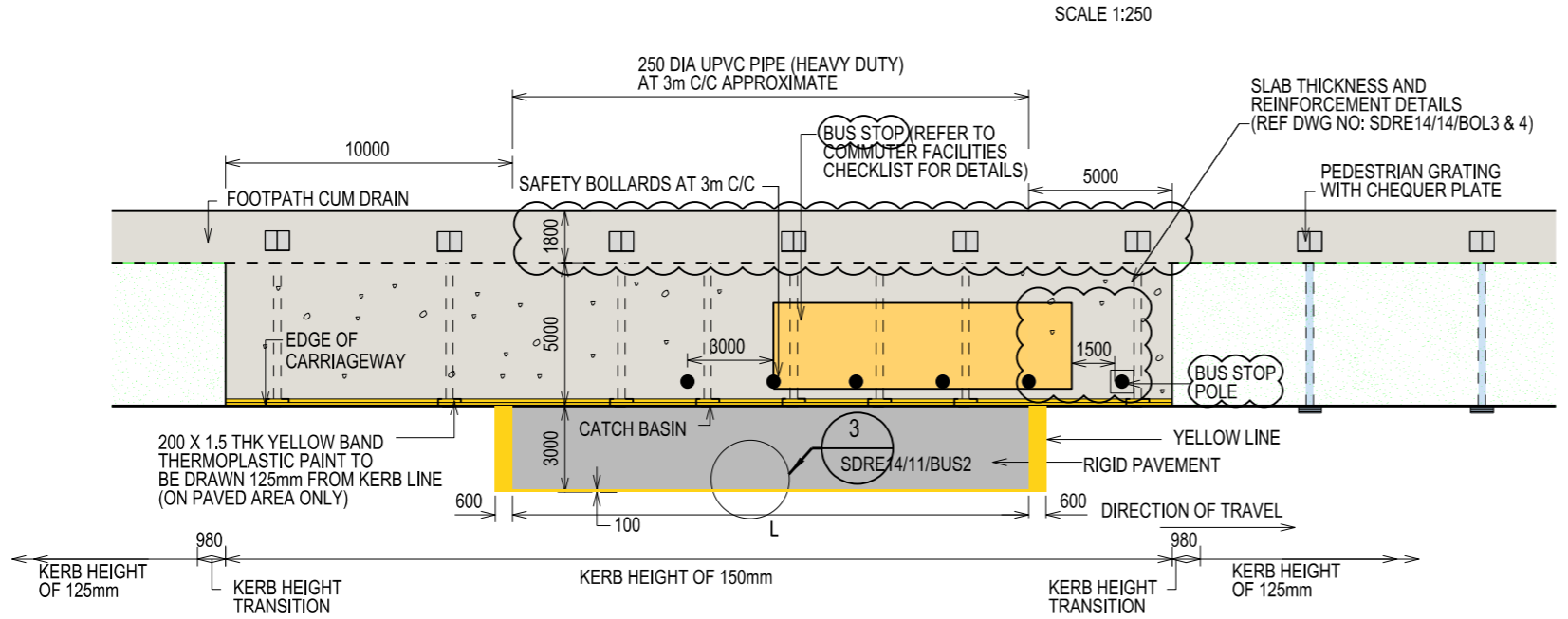
BUS FRIENDLY HUMPS CUM RAISED ZEBRA CROSSING

- NOTES:**
- Footpath joining pedestrian crossings shall be flushed with zebra crossing.
 - Center refuge island shall terminate near a lamp pole.
 - Floodlight to be provided if necessary.
 - The use of skid resistant pavement before the zebra crossing is recommended, particularly in wet environments.

<p>STANDARD DETAIL</p> <p>BUS FRIENDLY HUMPS CUM RAISED ZEBRA CROSSING</p>		<p>Land Transport Authority</p>		
		<p>DRAWING NO.</p> <p>LTA/SDRE14/9/TMM8</p>	<p>REV.</p> <p>B</p>	
<p>REV. B</p> <p>SEP 2017</p>	<p>REV. A</p> <p>OCT 2015</p>	<p>DATE OF ISSUE</p> <p>1st APR 2014</p>	<p>SCALE</p> <p>AS SHOWN</p>	<p>SHEET NO.</p> <p>1 OF 1</p>



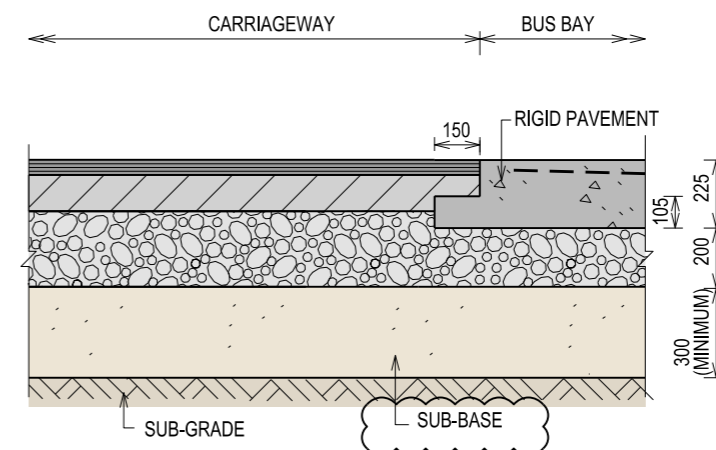
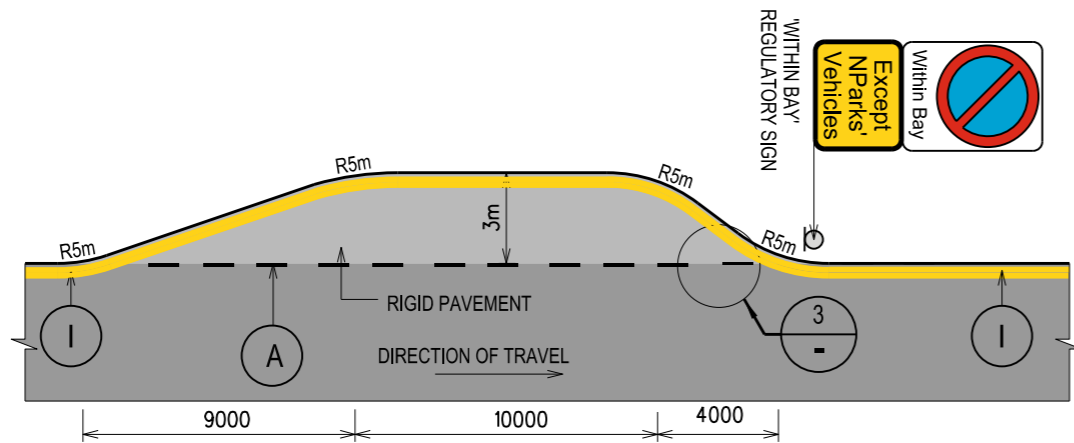
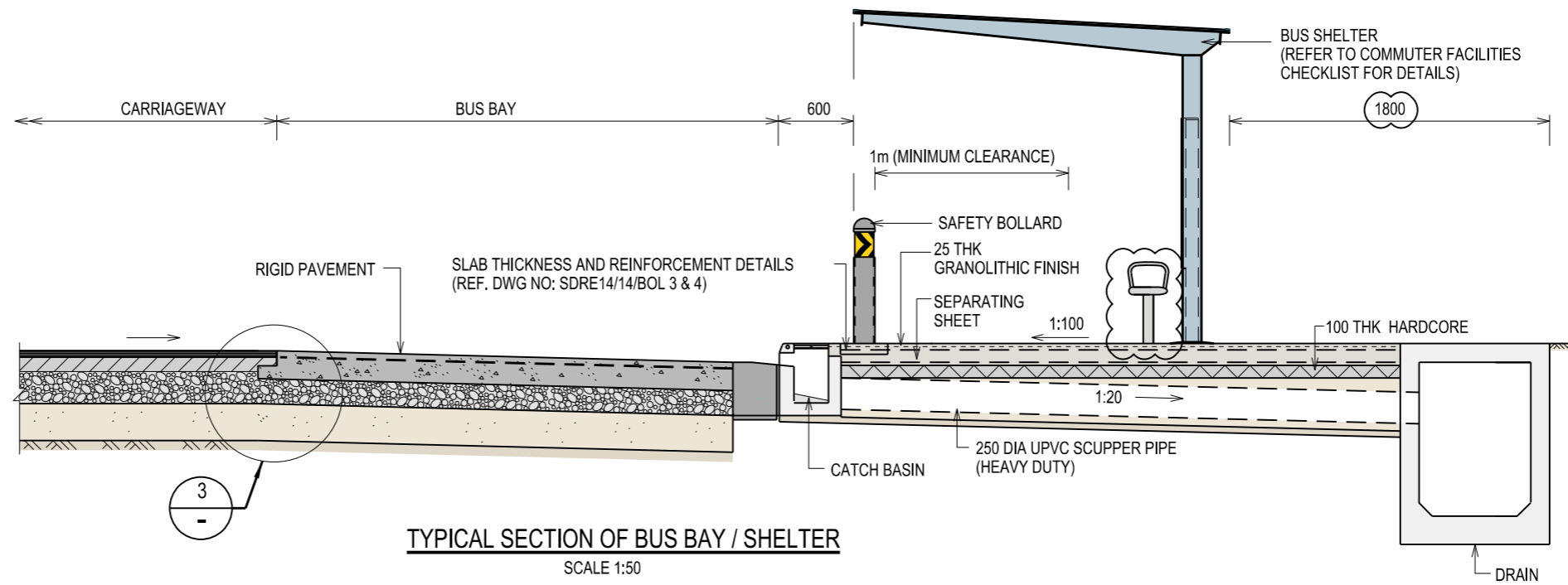
TYPE	DESCRIPTION	L	NO. OF EXPANSION JOINT
1	SINGLE BUS BAY	18m	2
2	DOUBLE BUS BAY	32m	3
3	TRIPLE BUS BAY	46m	4



- NOTES:**
1. Size and type of bus shelter shall be subject to approval from LTA.
 2. Safety bollards shall be provided at all bus stops, according to the posted speed limit.
 3. Location of advertising panel and bus stop sign shall not obstruct pedestrian movements and the view of the approaching buses.
 4. Where there is site constraints, width of bus bay can be reduced to an absolute minimum of 3m subject to approval from LTA.

5. The kerb line (L) shall always be a straight line even when the bus stop is located in a curve / bend.
6. Where there is site constraints, width of bus bay can be reduced to an absolute minimum of 3m subject to approval from LTA.
7. Safety bollards shall not be erected on scupper pipes.
8. Refer to the table in DWG No: LTA/SDRE14/4/GRA1 for the type and spacing of pedestrian grating.

<p>STANDARD DETAIL</p> <p>BUS BAY (SHEET 1 OF 2)</p>		<p>Land Transport Authority</p>			
		<p>DRAWING NO. LTA/SDRE14/11/BUS1</p>	<p>REV. B</p>		
<p>B SEPT 2017</p>	<p>A OCT 2015</p>	<p>DATE</p>	<p>DATE OF ISSUE 1st APR 2014</p>	<p>SCALE AS SHOWN</p>	<p>SHEET NO. 1 OF 2</p>



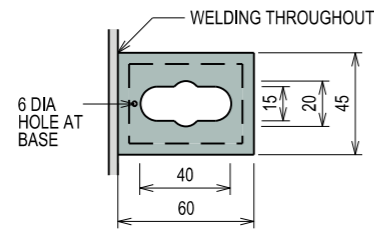
STANDARD DETAIL

BUS BAY / LAYBY FOR NPARKS' WATER TANKER (SHEET 2 OF 2)

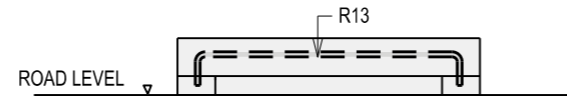
B	SEPT 2017
A	OCT 2015
REV.	DATE



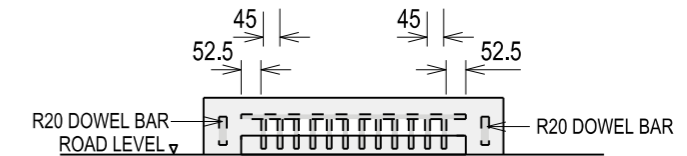
DRAWING NO. LTA/SDRE14/11/BUS2		REV. B
DATE OF ISSUE 1st APR 2014	SCALE AS SHOWN	SHEET NO. 2 OF 2



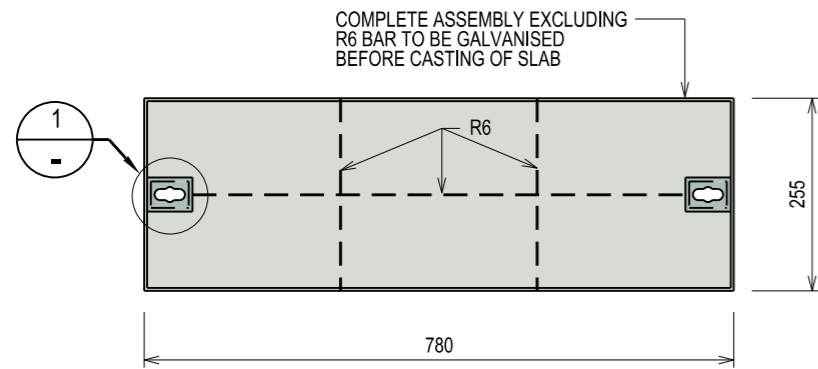
DETAIL 1
SCALE 1:3



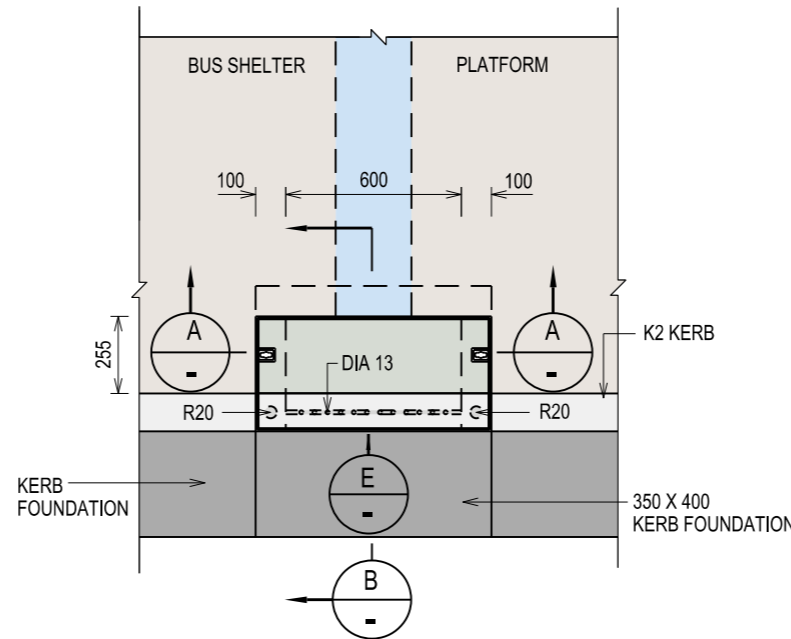
VIEW E
SCALE 1:20



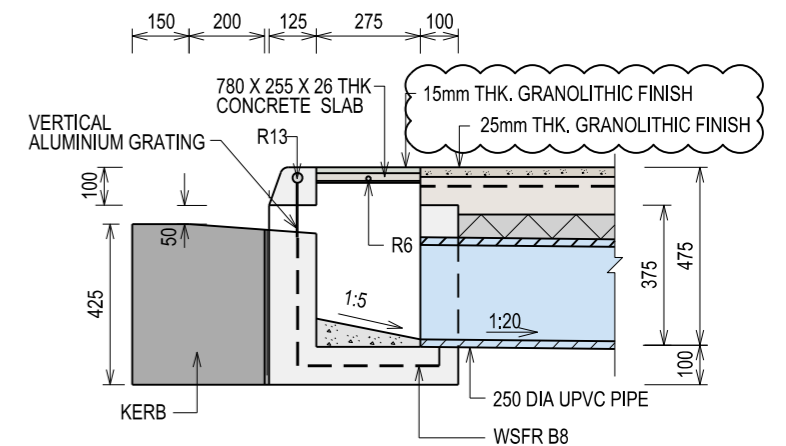
VERTICAL ALUMINIUM GRATING
SCALE 1:20



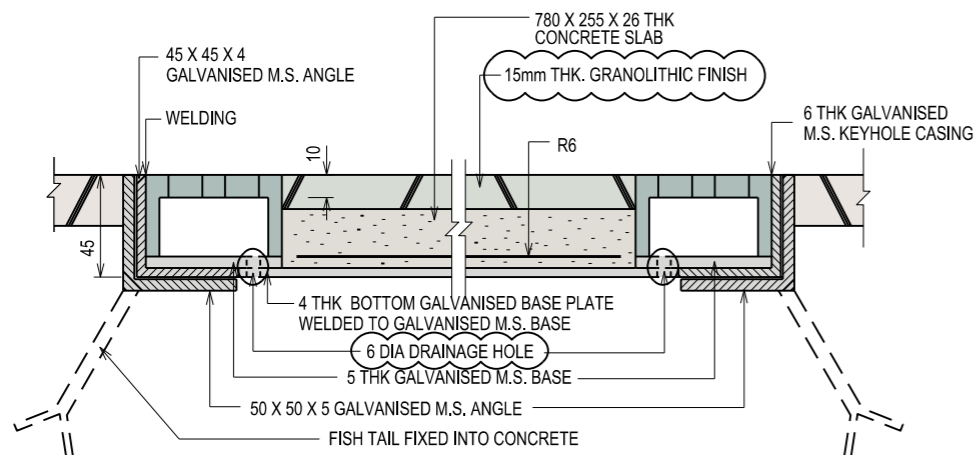
PLAN VIEW OF SLAB FOR CATCH BASIN
SCALE 1:10



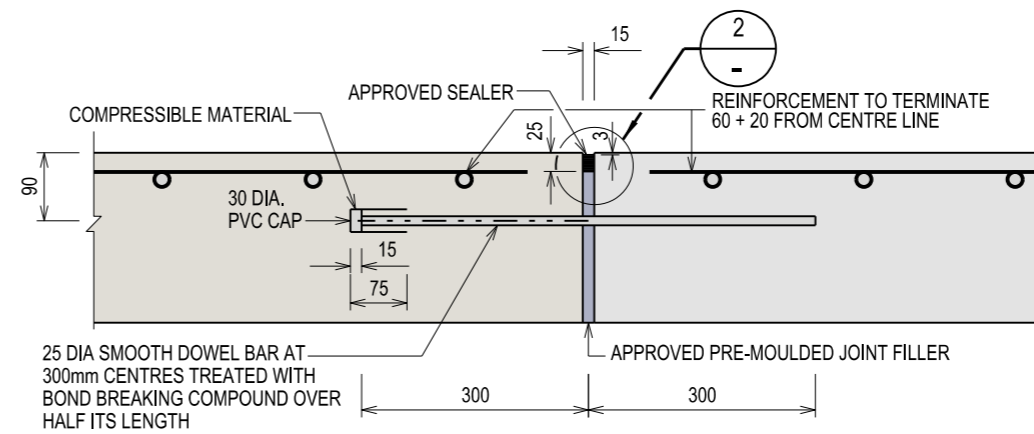
PLAN VIEW OF CATCH BASIN
SCALE 1:25



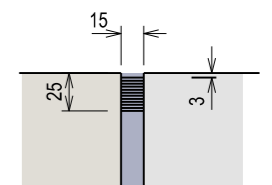
SECTION B-B
SCALE 1:20



SECTION A-A
SCALE 1:3



EXPANSION JOINT
SCALE 1:10



DETAIL 2
SCALE 1:5

NOTES:

1. All m.s., angle, base plate to be hot galvanised in accordance to ISO 1460, ISO 1461.
2. All flats and angles are to be fillet welded throughout.

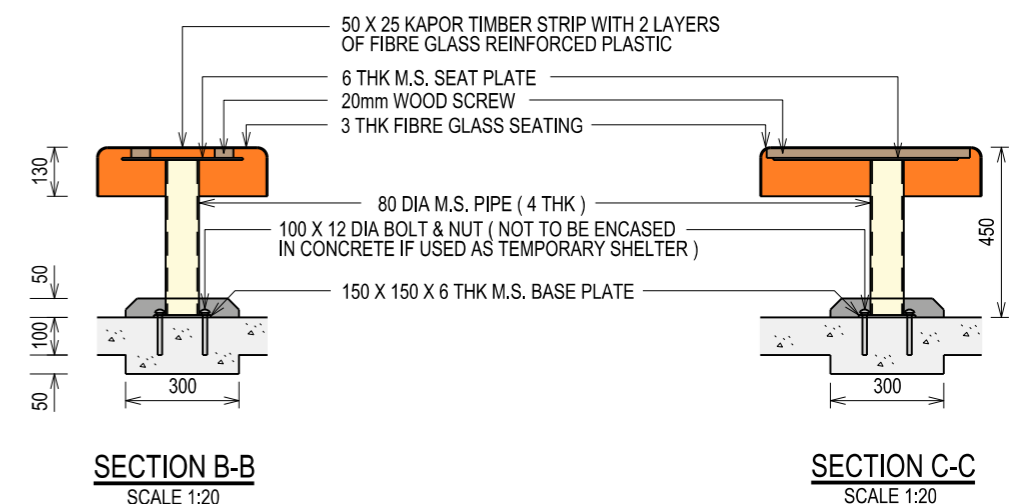
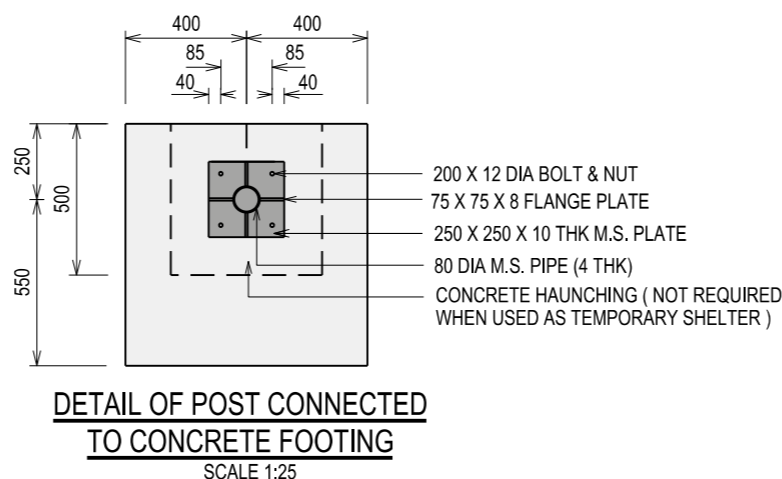
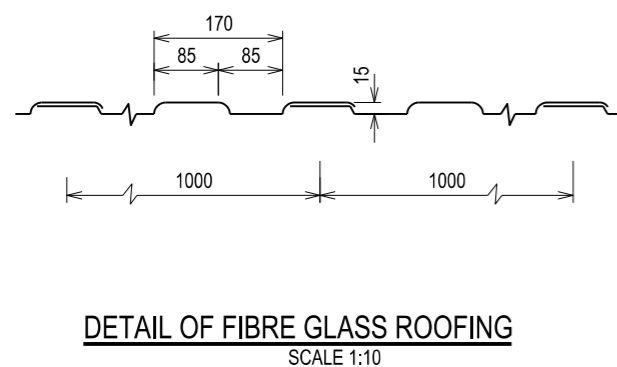
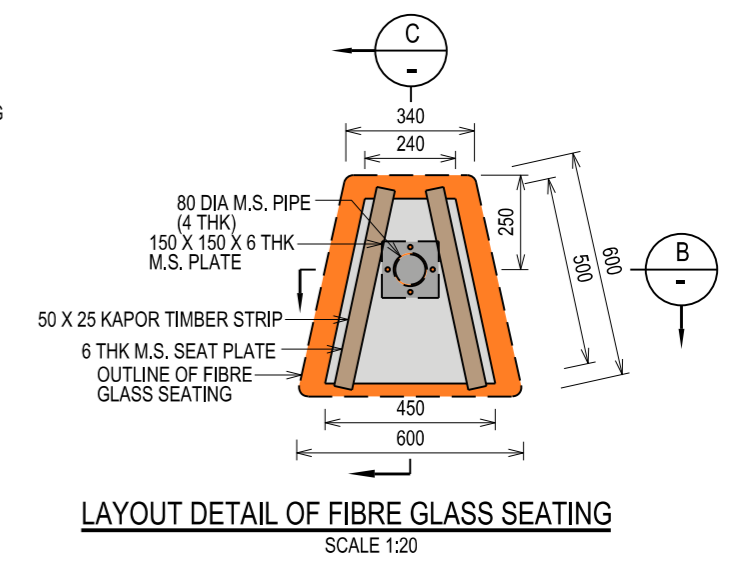
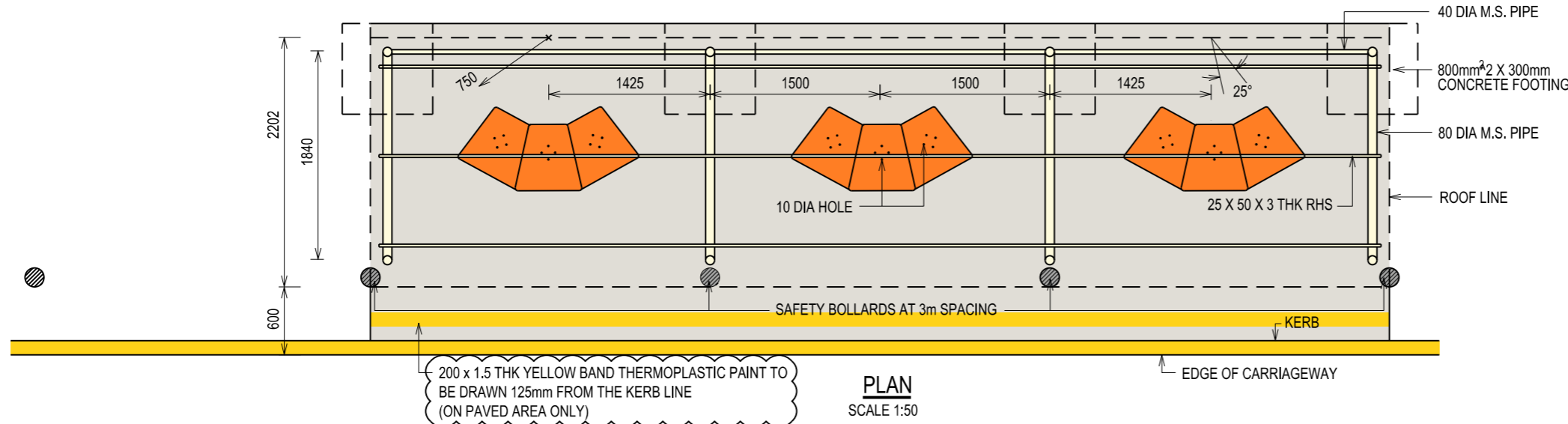
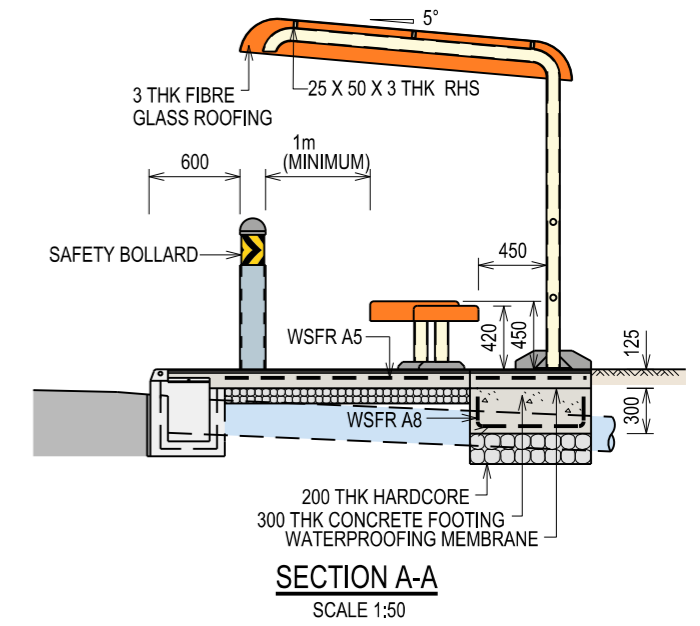
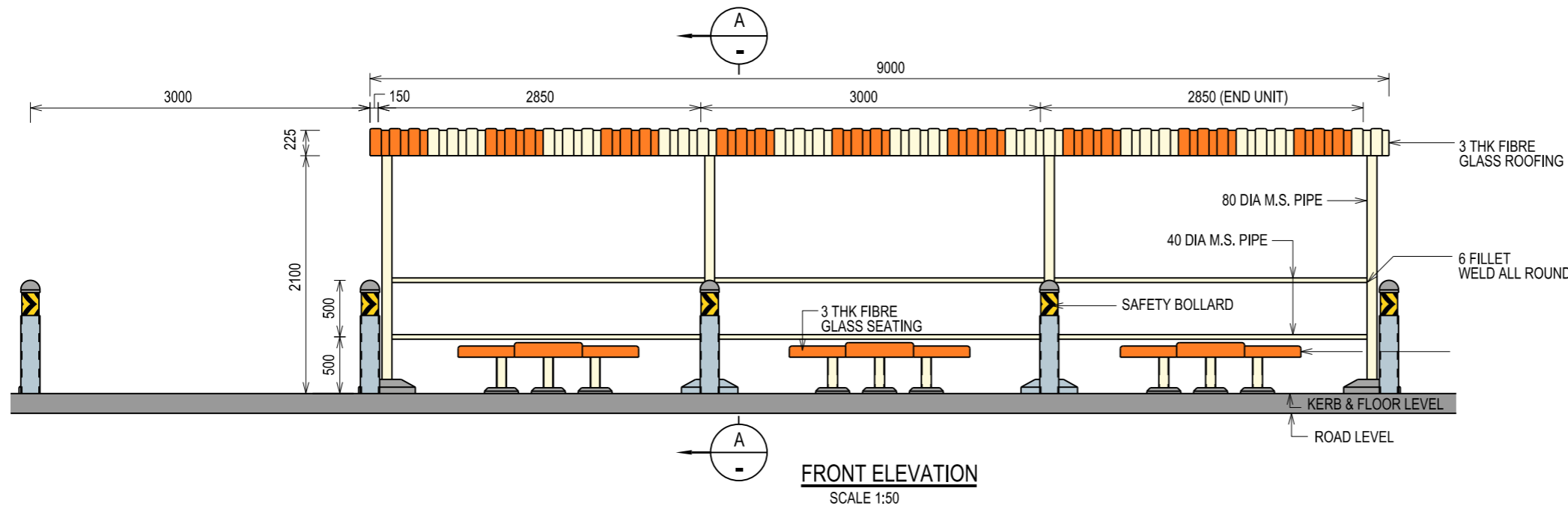
STANDARD DETAIL

BUS BAY DETAILS



DRAWING NO.		REV.
LTA/SDRE14/11/BUS3		B
DATE OF ISSUE	SCALE	SHEET NO.
1st APR 2014	AS SHOWN	1 OF 1

B	SEPT 2017
A	OCT 2015
REV.	DATE



NOTES:

1. Type A bus shelter shall be used for temporary shelter use. (with 2 units unless otherwise specified).
2. All pipes to be class medium (B) in accordance with SS EN 10255:2013
3. All exposed metal surface to be coated with a layer of red lead undercoat and 2 layers of finishing paint of approved quality and colour specified by the S.O.

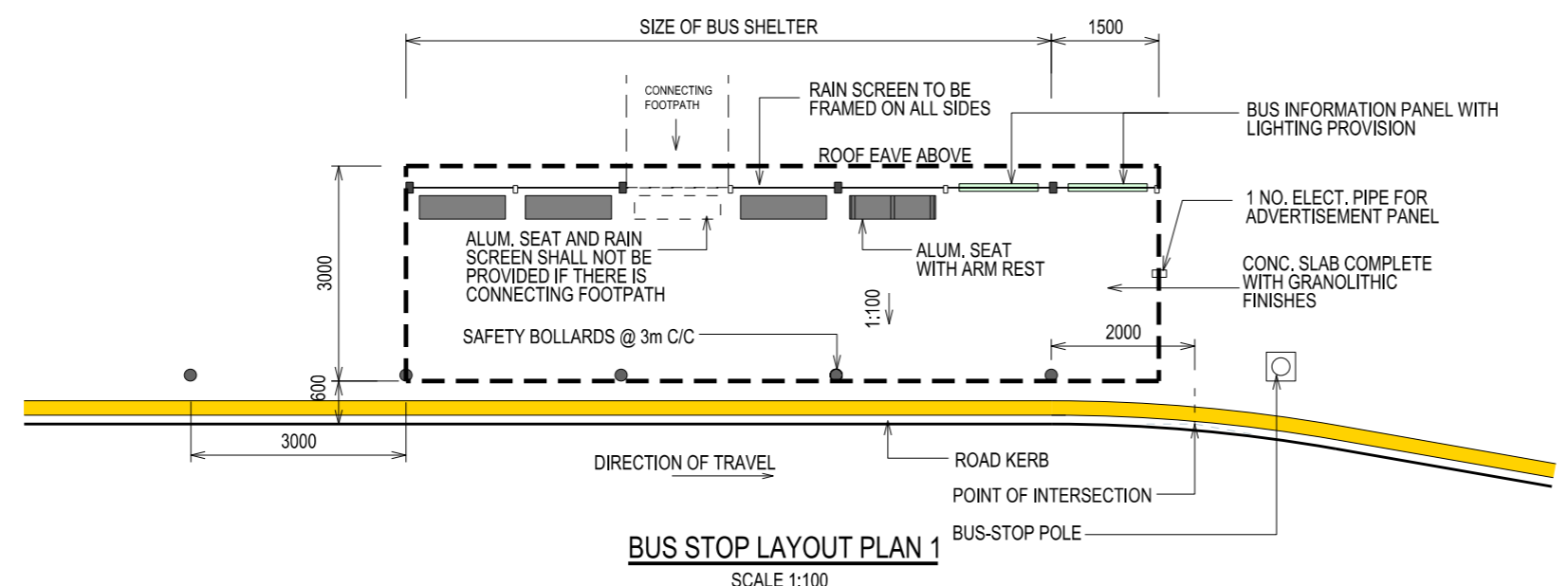
STANDARD DETAIL

BUS SHELTER - TYPE A
TEMPORARY USE ONLY

REV.	DATE
A	OCT 2015
B	SEPT 2017



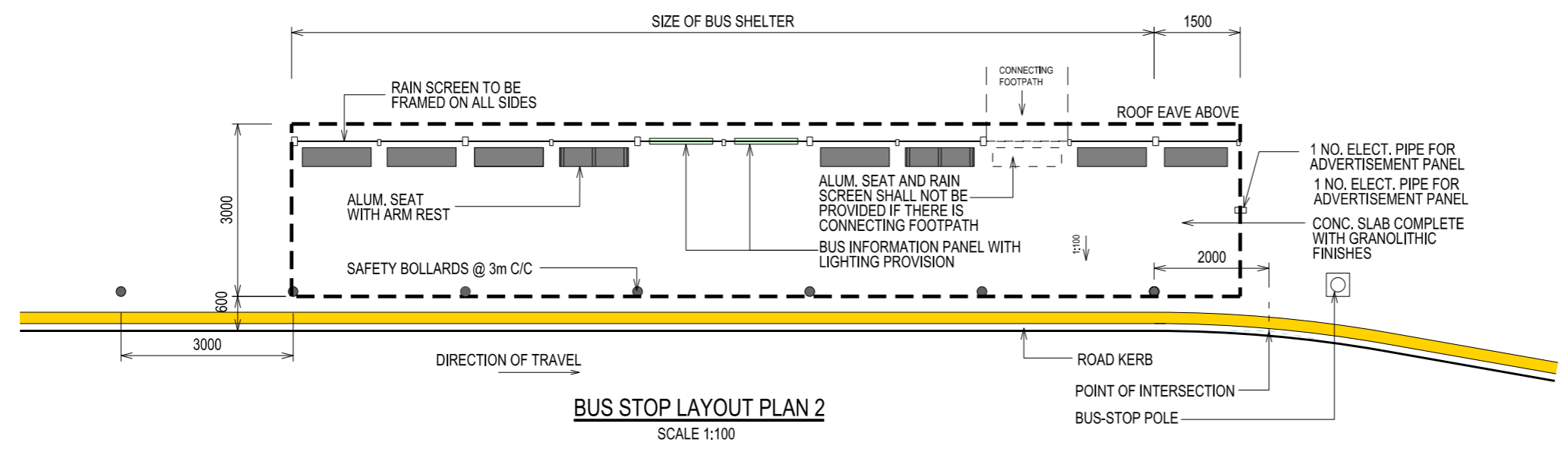
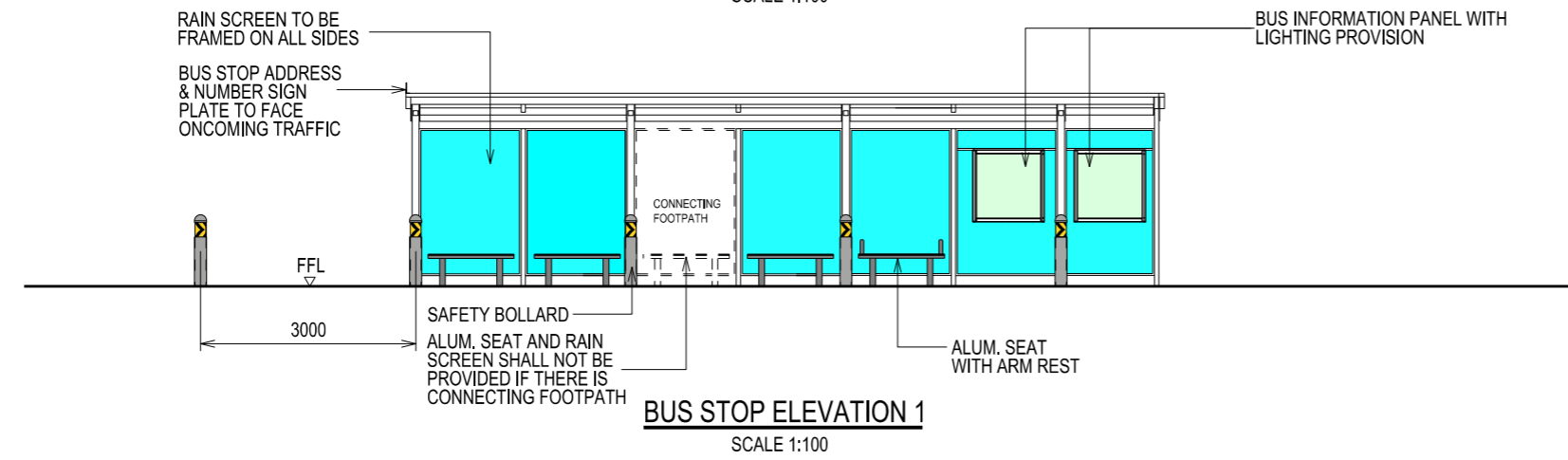
DRAWING NO.		REV.
LTA/SDRE14/11/BUS4		B
DATE OF ISSUE	SCALE	SHEET NO.
1st APR 2014	AS SHOWN	1 OF 1



LOCATION AND NUMBER OF BUS INFORMATION PANEL TO BE PROVIDED

S/N	SIZE OF BUS SHELTER(m)	LOCATION	MINIMUM NUMBER
1	9	FRONT	1 SET
2	12	FRONT	1 SET
3	15	CENTER	1 SET
4	18	CENTER	1 SET
5	21	CENTER	1 SET
6	24 AND ABOVE	FRONT AND CENTER	2 SETS

NOTE: 1 SET= MINIMUM 2 NUMBERS

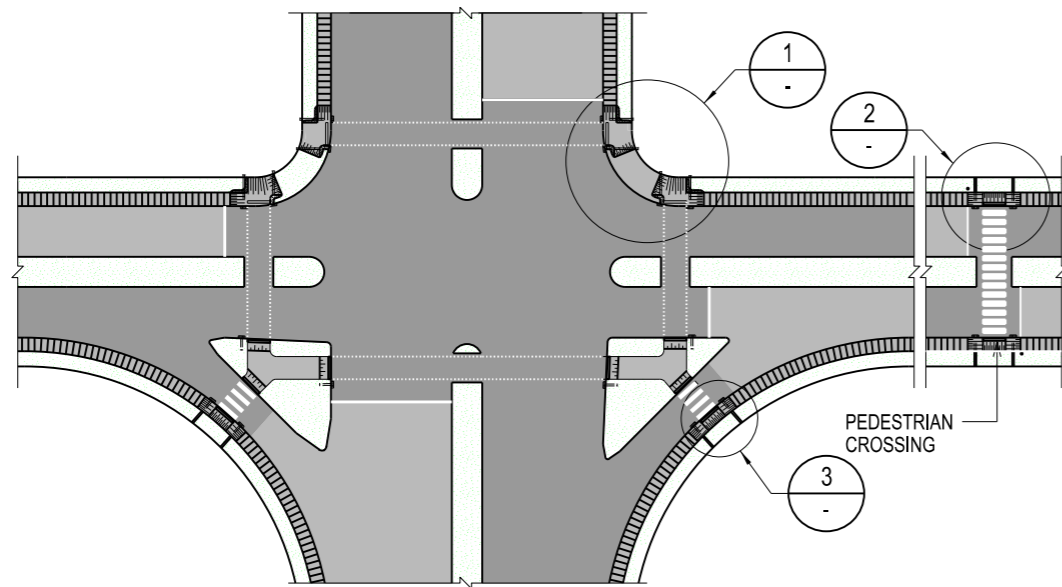


NOTES:

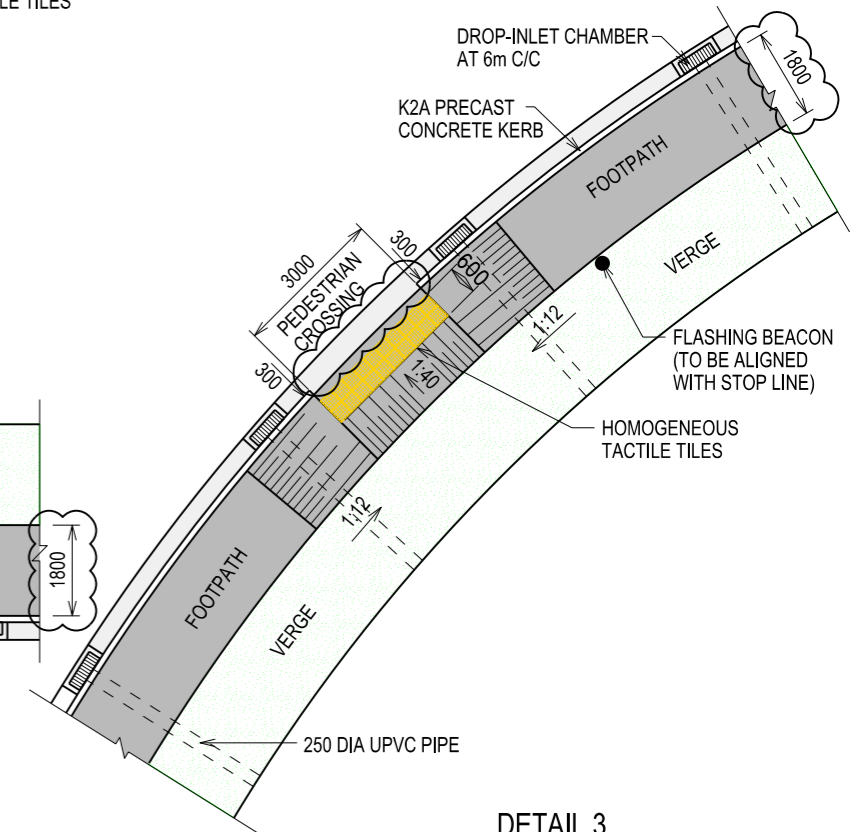
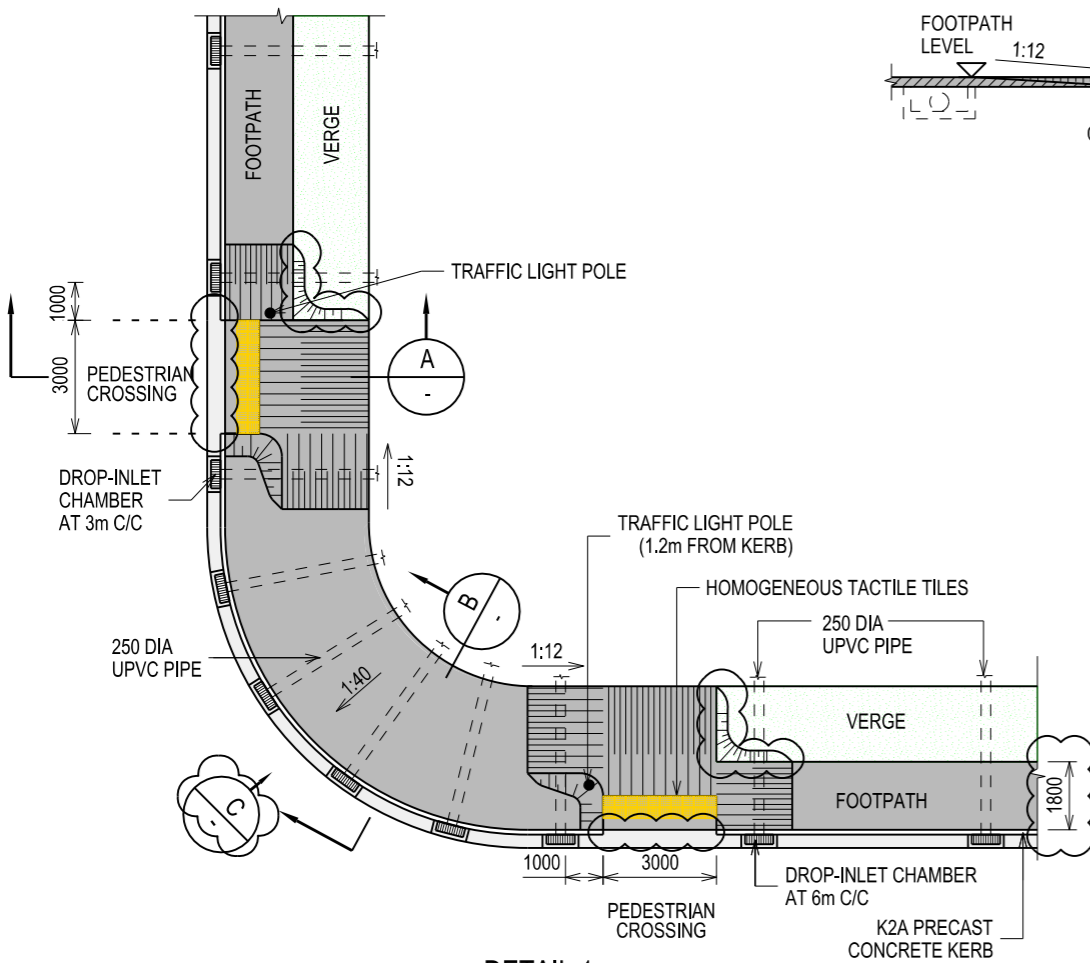
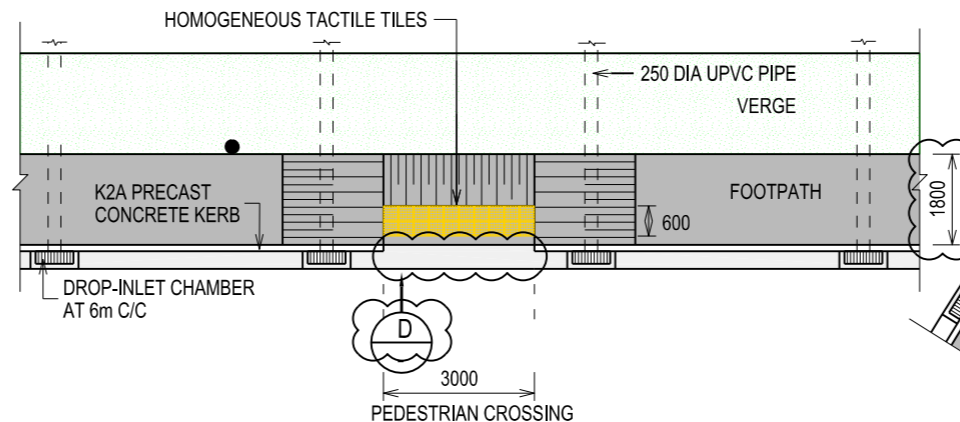
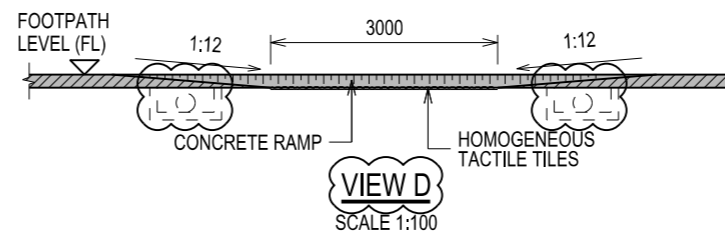
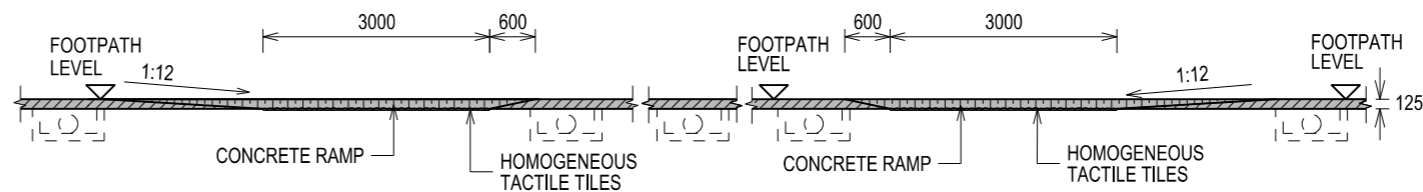
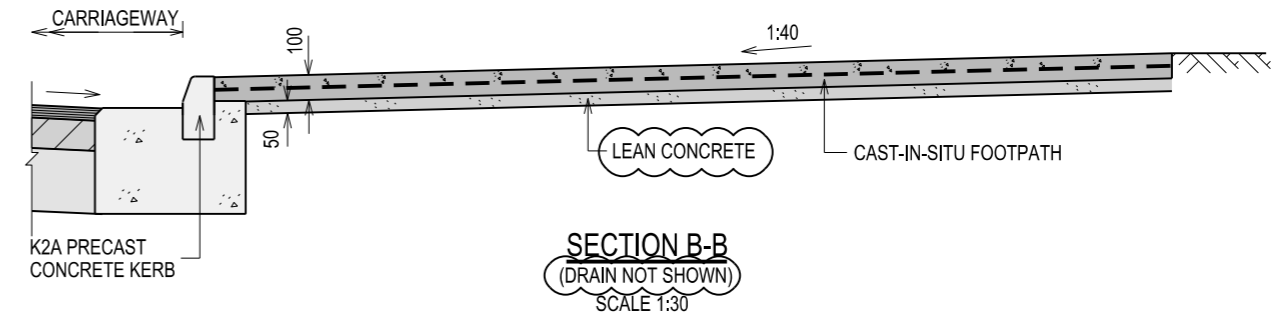
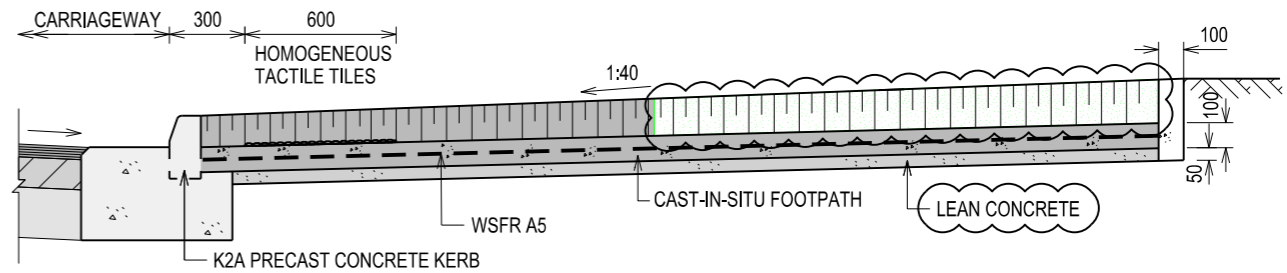
1. This drawing shall be read in conjunction with LTA Architectural Design Criteria (ADC) checklist and Material and Workmanship Specifications.
2. The size of the bus shelter shall be in accordance to ADC checklist.
3. All aluminium elements (bench, flashing piece, roof capping etc) shall be in powder coated finish.
4. 25% of all the seats shall be provided with arm rests.

5. The design of the bus stop shall comply with BCA Code on Accessibility in the Built Environment.
6. "No smoking" sign shall be provided at every 9m spacing of bus shelter.
7. The location of bus-stop pole shall be subjected to approval from LTA.
8. All aluminium seats shall be of a darker shade than the floor finish.

STANDARD DETAIL			
BUS STOP LAYOUT AND ELEVATION		DRAWING NO. LTA/SDRE14/11/BUS5	
		DATE OF ISSUE SEP 2017	SCALE AS SHOWN
		SHEET NO. 1 OF 1	
REV.	DATE		



GENERAL LAYOUT WITH TYPE 1 PEDESTRIAN CROSSING POINTS
(NTS)



NOTES:

1. Gradient of ramps shown in the details shall not be exceeded.
2. All concrete shall be C25/30, unless otherwise stated.
3. Details to be used when footpath is next to the kerbs.
4. Homogeneous tactile tiles for tactile warning indicator requirements to refer to LTA/SDRE14/3/KER12.
5. Yellow coloured tactile tiles shall be provided on the concrete footpath ramp.
6. No obstruction shall be placed within the pedestrian crossing zone.
7. No drop-inlet chamber shall be placed within the pedestrian crossing zone.

8. The ramps shall be broom brushed.
9. Zebra crossings to be 'raised crossings' when necessary, particularly in areas with high pedestrian volumes.
10. Pedestrian refuge island dimensions can be adapted as necessary.

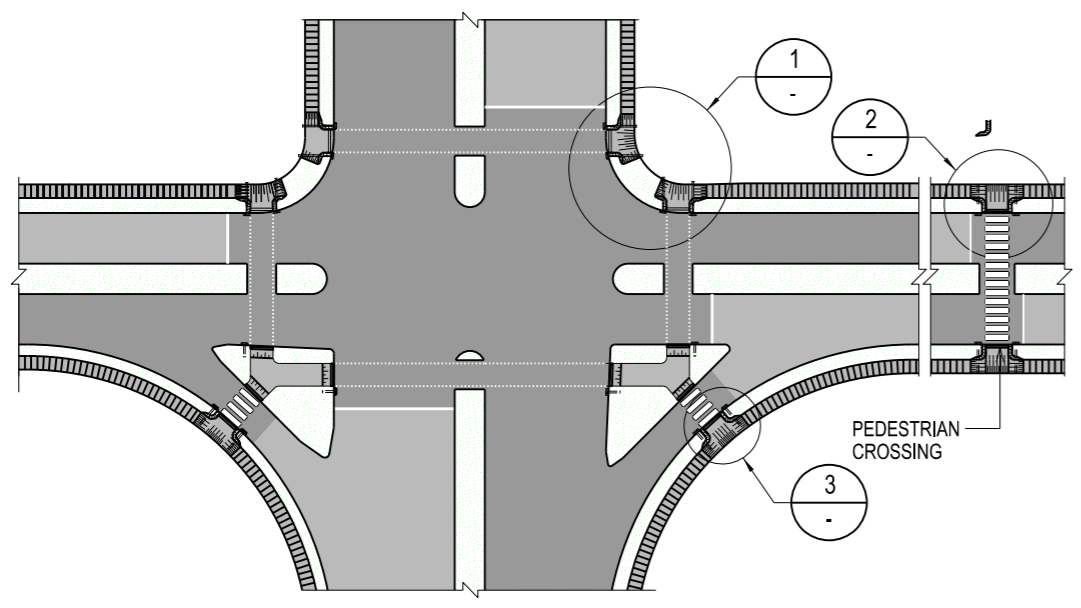
STANDARD DETAIL

FOOTPATH RAMP - TYPE 1 PEDESTRIAN CROSSING POINTS

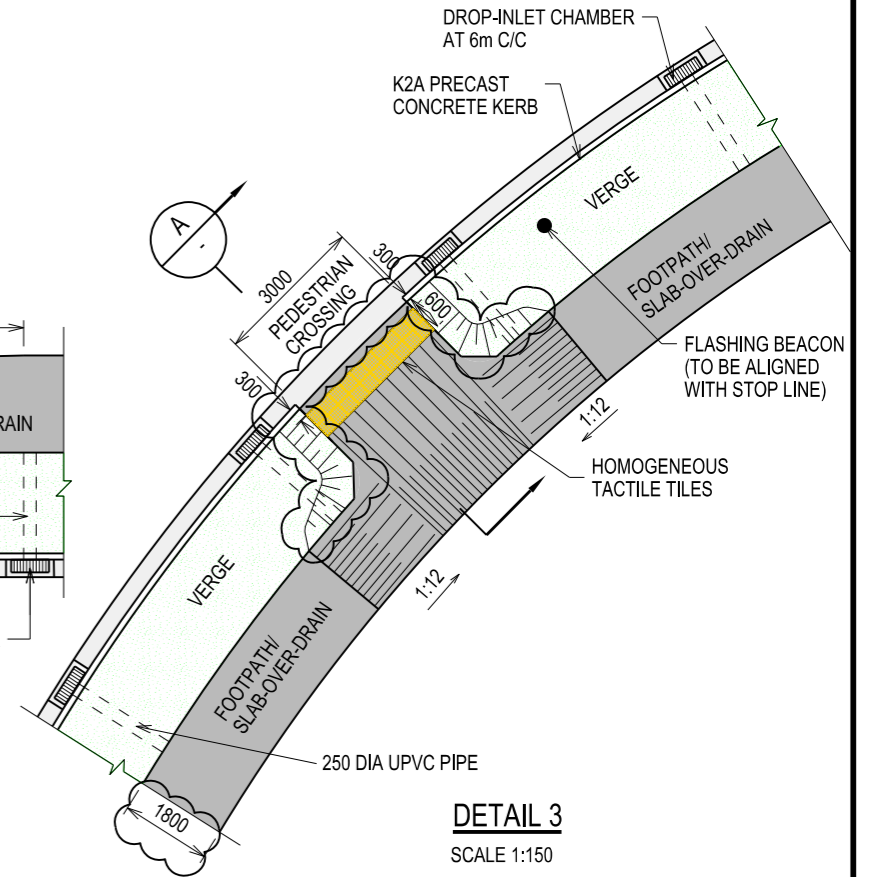
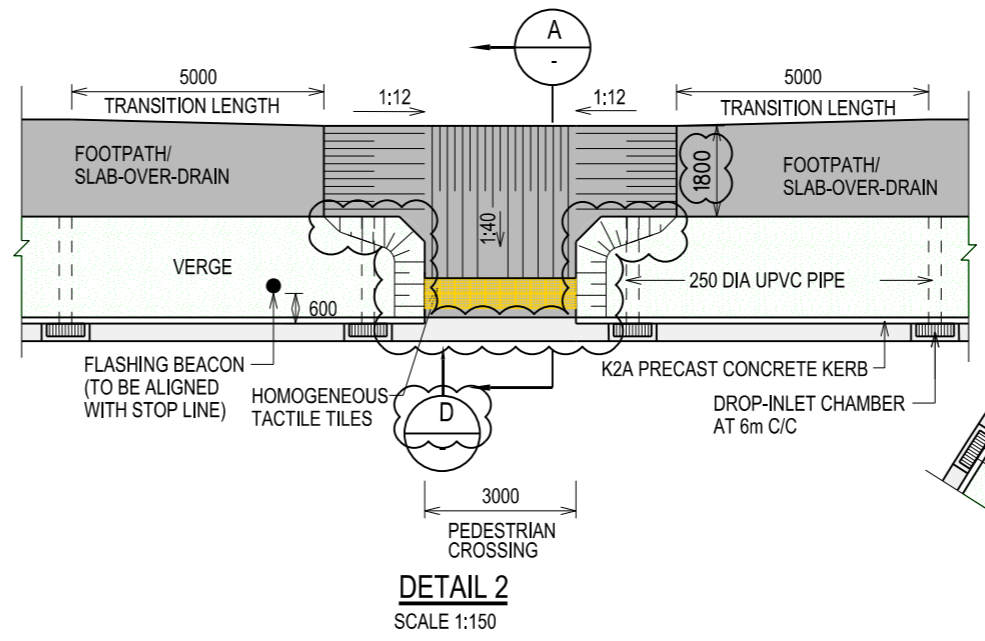
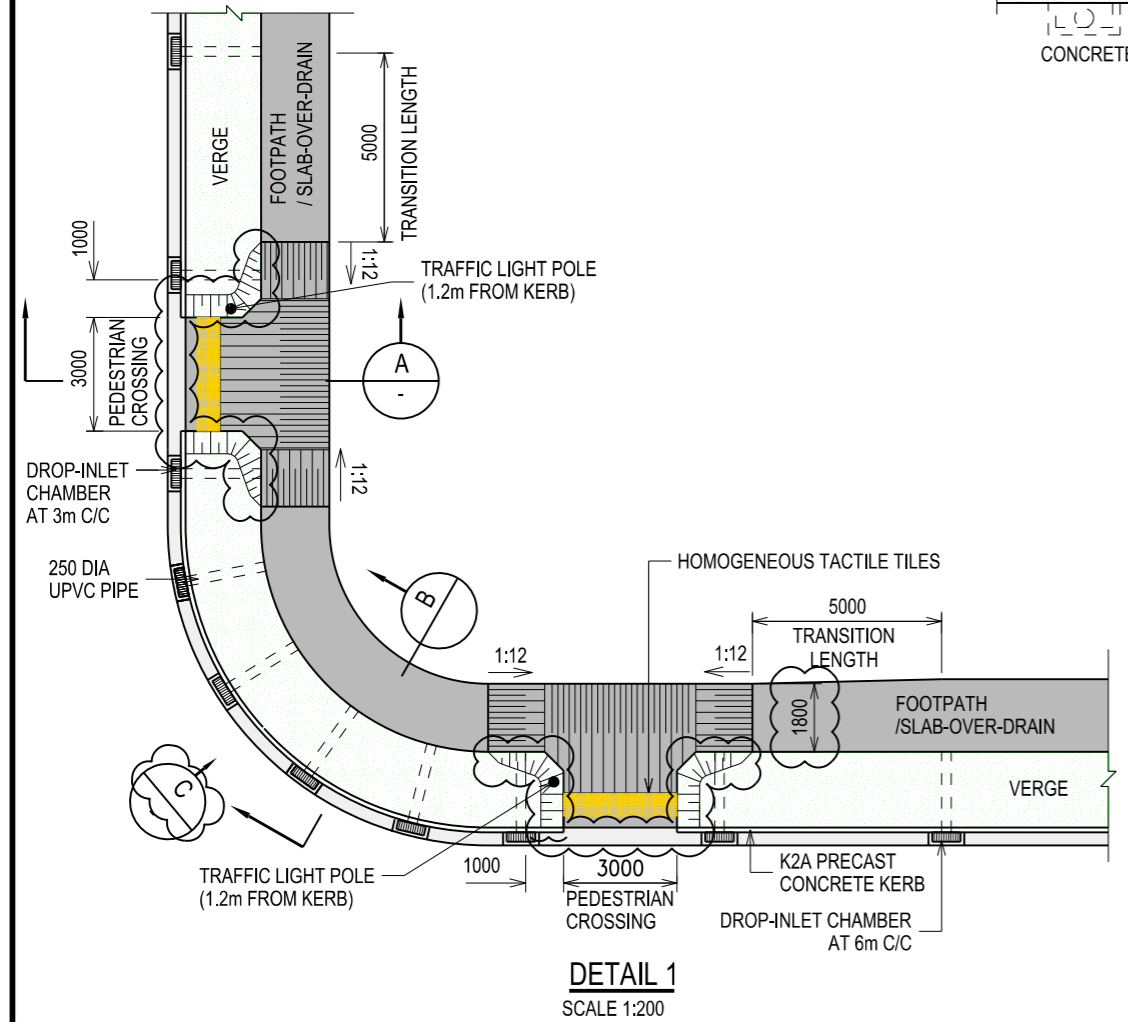
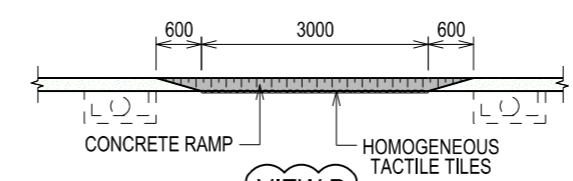
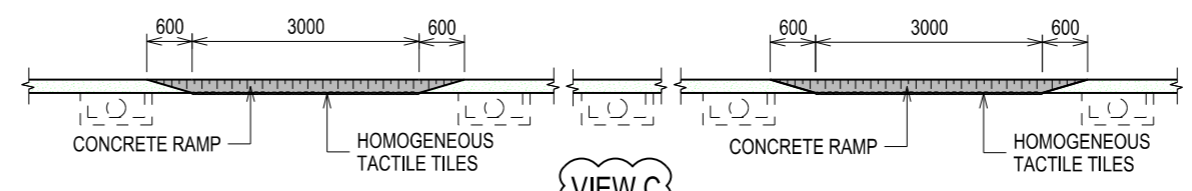
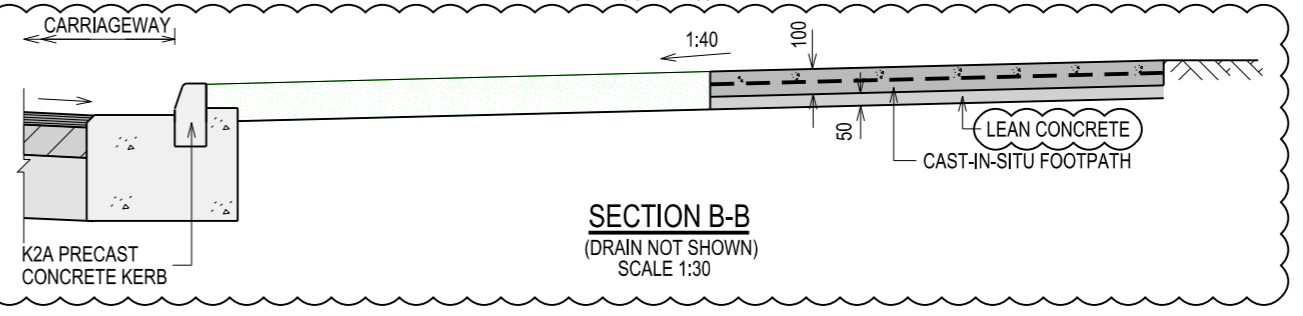
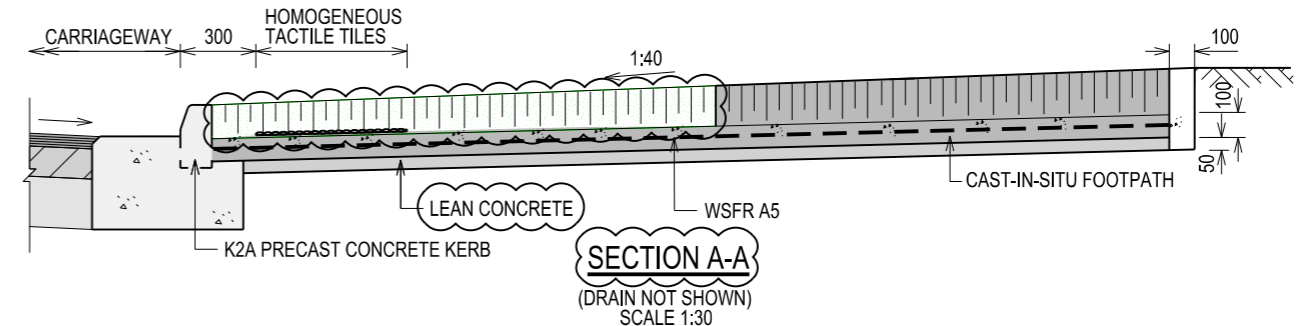
REV.	DATE
A	OCT 2015
B	SEP 2017



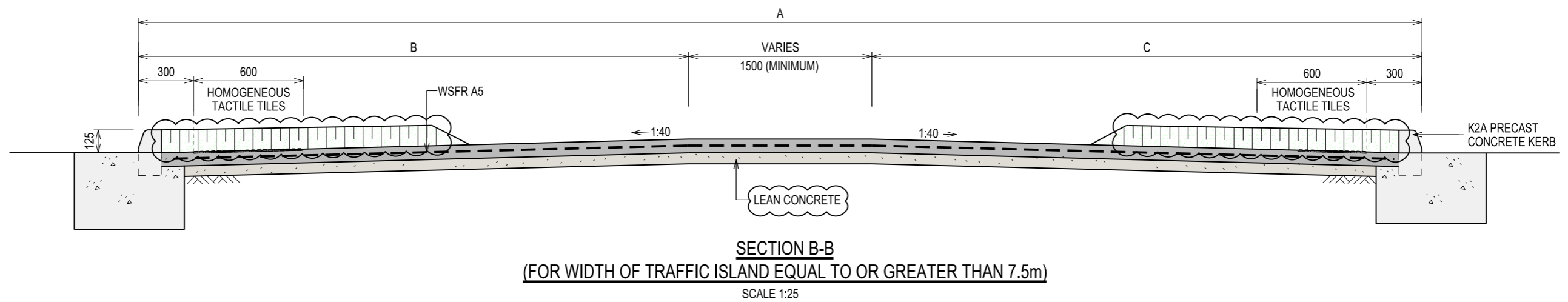
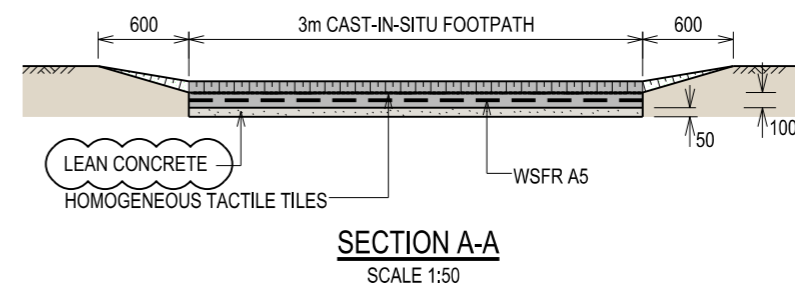
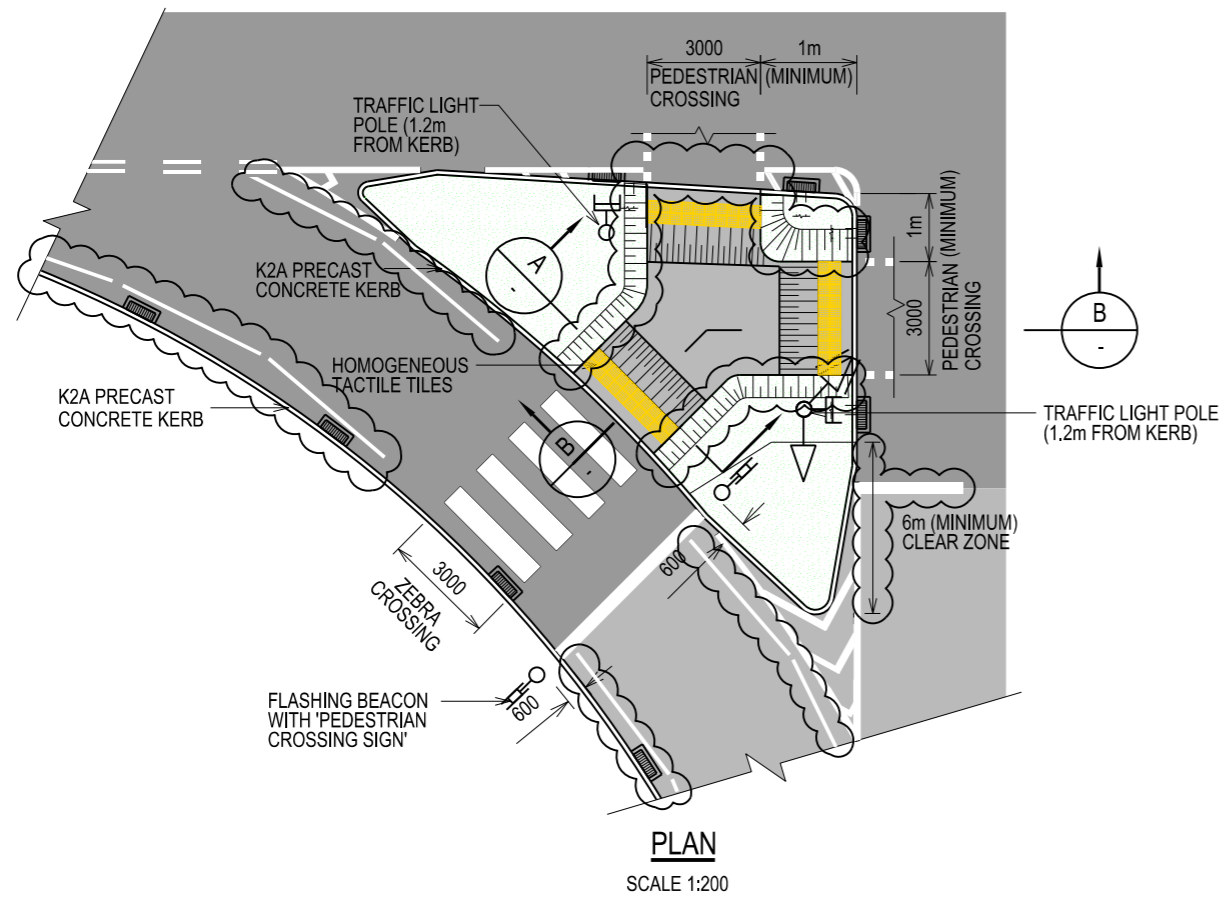
DRAWING NO.	LTA/SDRE14/3/KER5	REV.	B
DATE OF ISSUE	1st APR 2014	SCALE	AS SHOWN
		SHEET NO.	1 OF 7



GENERAL LAYOUT WITH TYPE 2 PEDESTRIAN CROSSING POINTS



<p>STANDARD DETAIL</p> <p>FOOTPATH RAMP - TYPE 2 PEDESTRIAN CROSSING POINTS</p>		<p>Land Transport Authority</p>	
		<p>DRAWING NO. LTA/SDRE14/3/KER6</p>	<p>REV. B</p>
<p>B SEP 2017</p>	<p>A OCT 2015</p>	<p>DATE OF ISSUE 1st APR 2014</p>	<p>SCALE AS SHOWN</p>
<p>REV. DATE</p>	<p>REV. DATE</p>	<p>SHEET NO. 2 OF 7</p>	<p>SHEET NO. 2 OF 7</p>



WHEN A ≥ 7.5m	WHEN A < 7.5m
B = 3m	B = VARIES (MIN 1.5m)
C = 3m	C = VARIES (MIN 1.5m)

NOTES:

- Drop-inlet chamber and scupper pipe is to be provided only where there is a provision of a drain at the traffic island.
- Clear zone shall be free of obstruction.

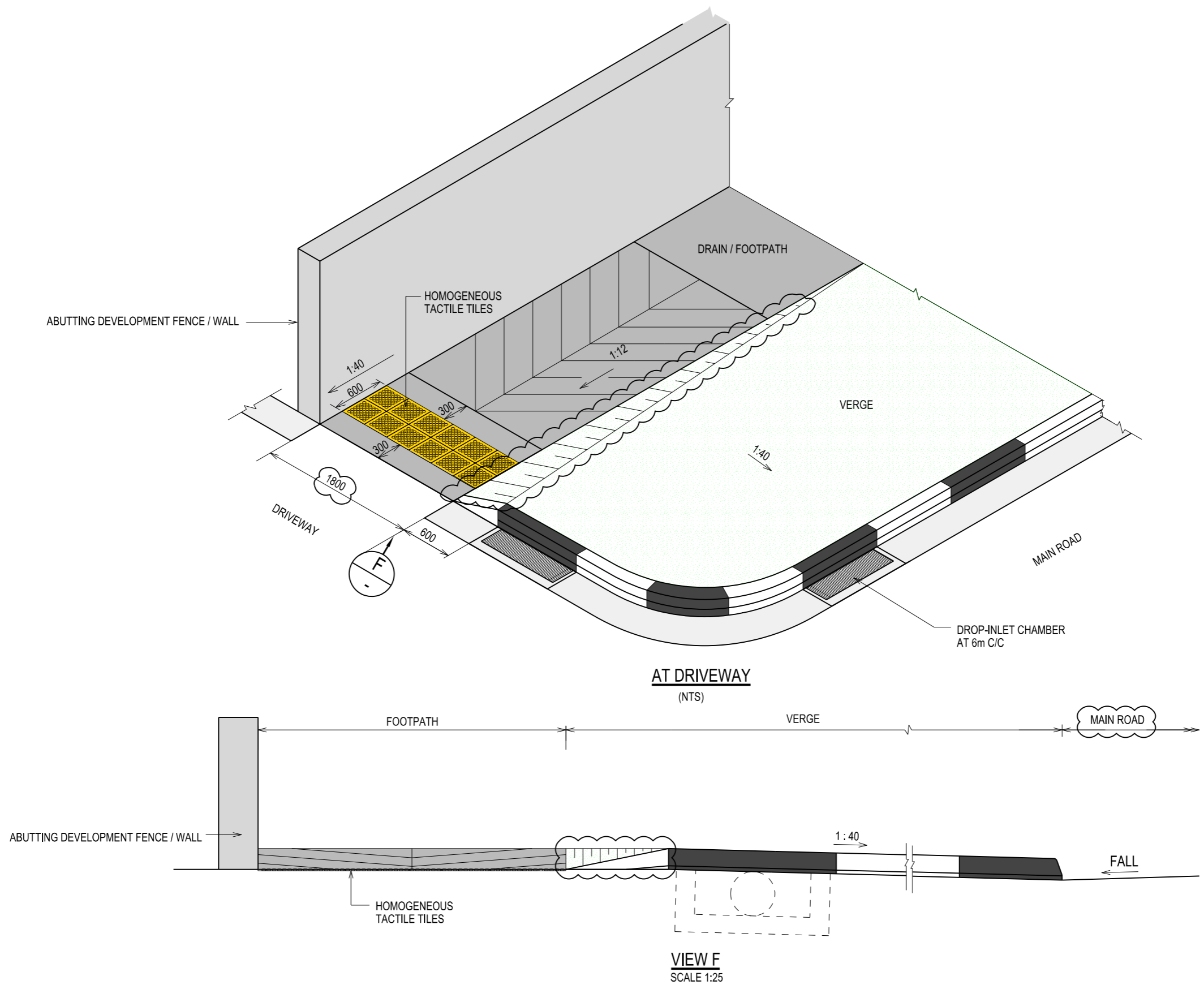
STANDARD DETAIL

FOOTPATH RAMP - TRAFFIC ISLAND

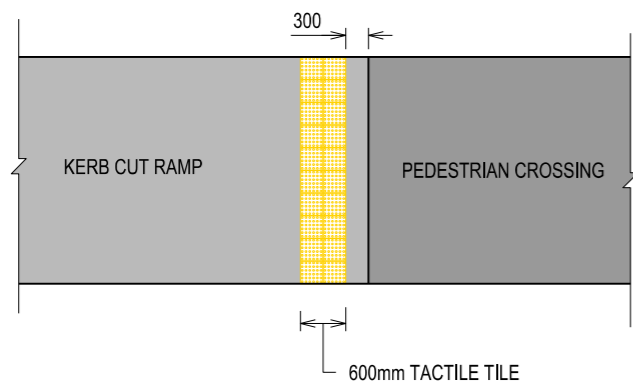


DRAWING NO.	LTA/SDRE14/3/KER7	REV.	B
DATE OF ISSUE	1st APR 2014	SCALE	AS SHOWN
SHEET NO.	4 OF 7		

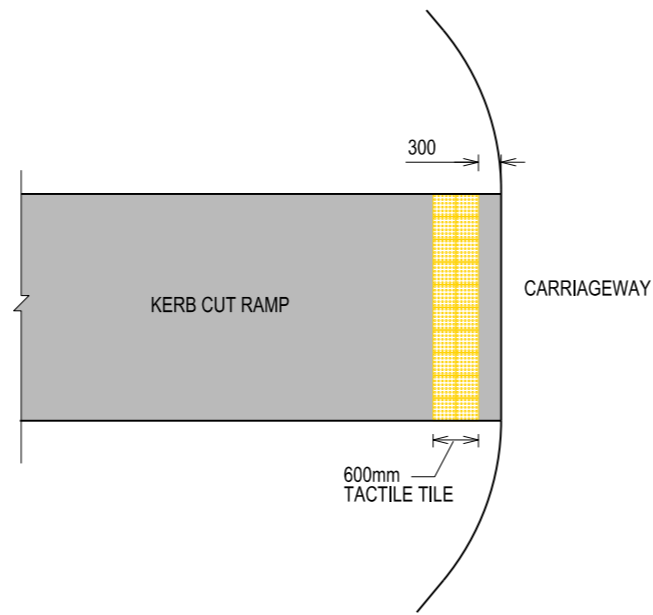
B	SEP 2017
A	OCT 2015
REV.	DATE



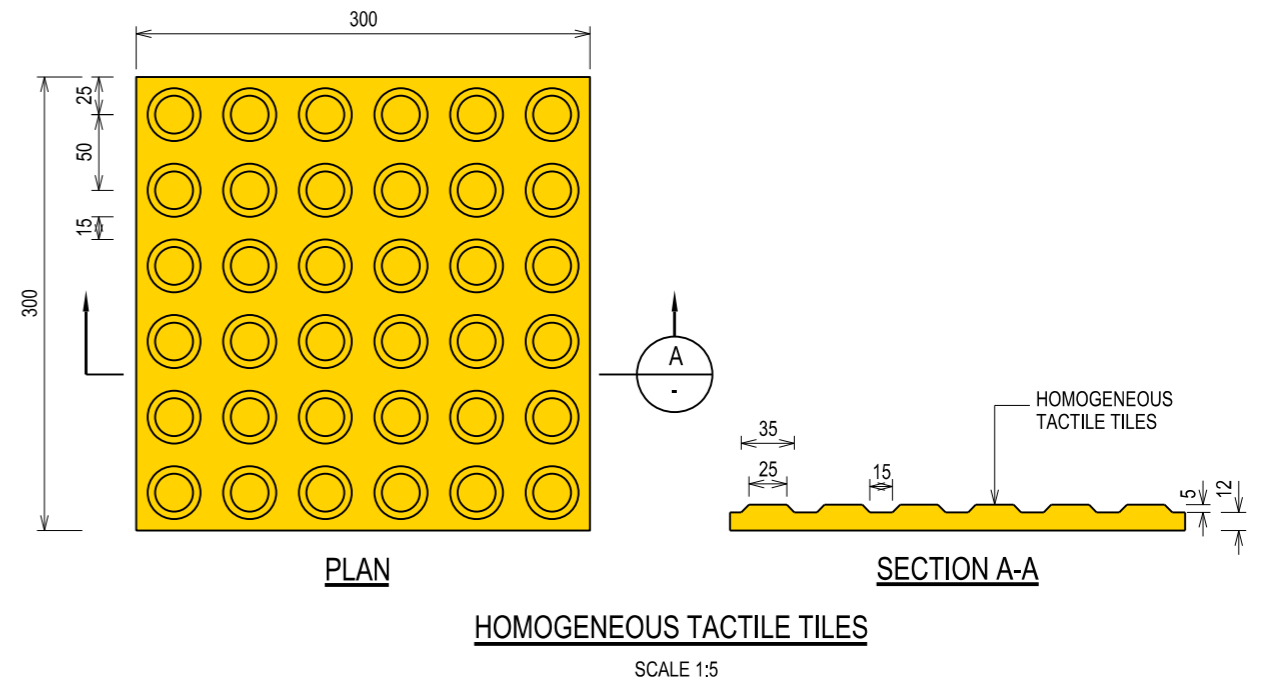
		STANDARD DETAIL			
		FOOTPATH RAMP - DRIVEWAY		DATE OF ISSUE	SHEET NO.
				1st APR 2014	6 OF 7
REV.	DATE			SCALE	AS SHOWN
B	SEP 2017				
A	OCT 2015				



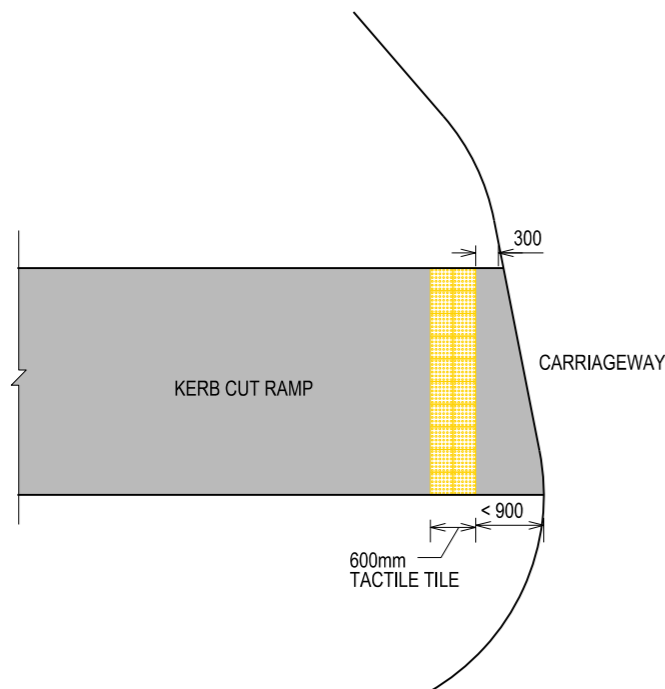
**TYPE A - ARRANGEMENT OF TACTILE TILES
(STRAIGHT KERB CUT RAMP)**
SCALE 1:100



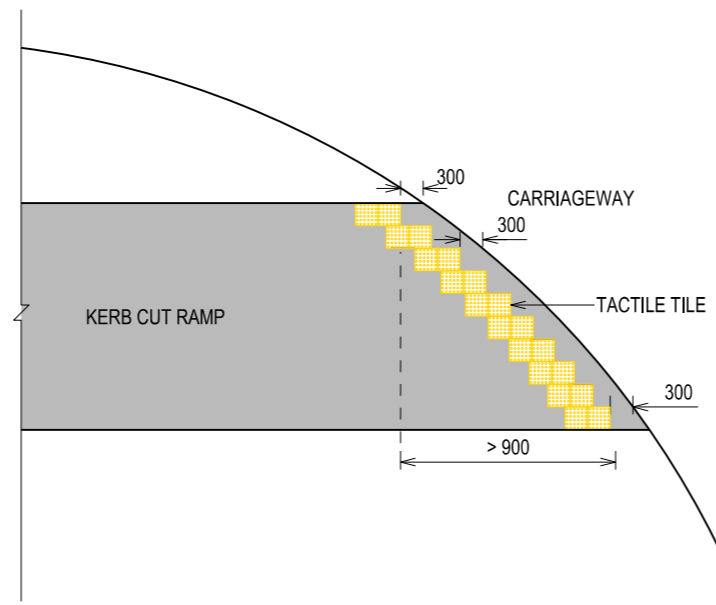
**TYPE B - ARRANGEMENT OF TACTILE TILES
(CURVE KERB CUT RAMP)**
SCALE 1:100



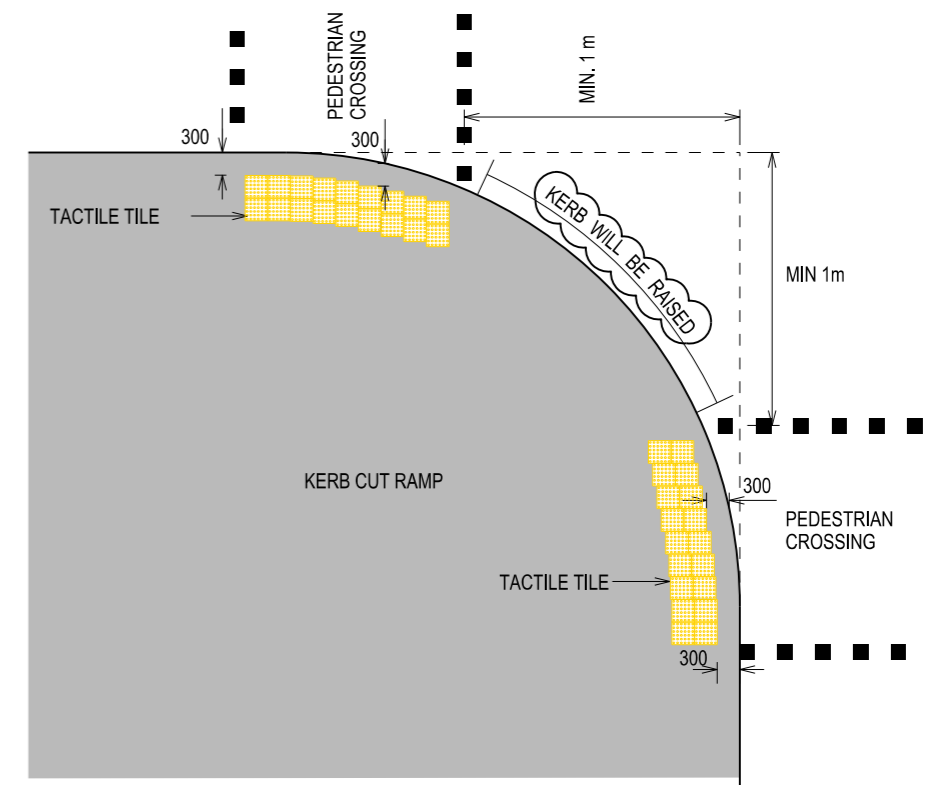
HOMOGENEOUS TACTILE TILES
SCALE 1:5



**TYPE C - ARRANGEMENT OF TACTILE TILES
(CURVE KERB CUT RAMP)**
SCALE 1:100



**TYPE D - ARRANGEMENT OF TACTILE TILES
(CURVE KERB CUT RAMP)**
SCALE 1:100



**TYPE E - ARRANGEMENT OF TACTILE TILES
(CURVE KERB CUT RAMP)**
SCALE 1:100

NOTE:
Minimum 2 set of tactile tiles to be laid for both side of type e ramp

NOTES:

- The tactile tiles shall have a minimum of 30% luminance contrast with the footpath ramp.
- All homogeneous tiles shall comply with the following:
 - Water absorption : 0.4% maximum per ASTM C72
 - Modules of rupture : 10.34 MN/m² per ASTM C99
 - Compressive strength : 131 MN/m² per ASTM 0170
- All homogeneous unglazed ceramic tiles shall comply to ISO 13006:2012.

- Tactile tiles shall comply to SS485:2011 for skid resistance based on wet pendulum test (Classification V).
- For driveways leading to two or less individual house units, a flushed kerb is to be provided without any tactile tiles.
- For closely-spaced driveways with footpath separated from the carriageway by a green verge or kerb, and with footpath length less than 10m, the whole footpath is to be flushed.

STANDARD DETAIL





HOMOGENEOUS TACTILE TILES AND ARRANGEMENT OF TACTILE TILES

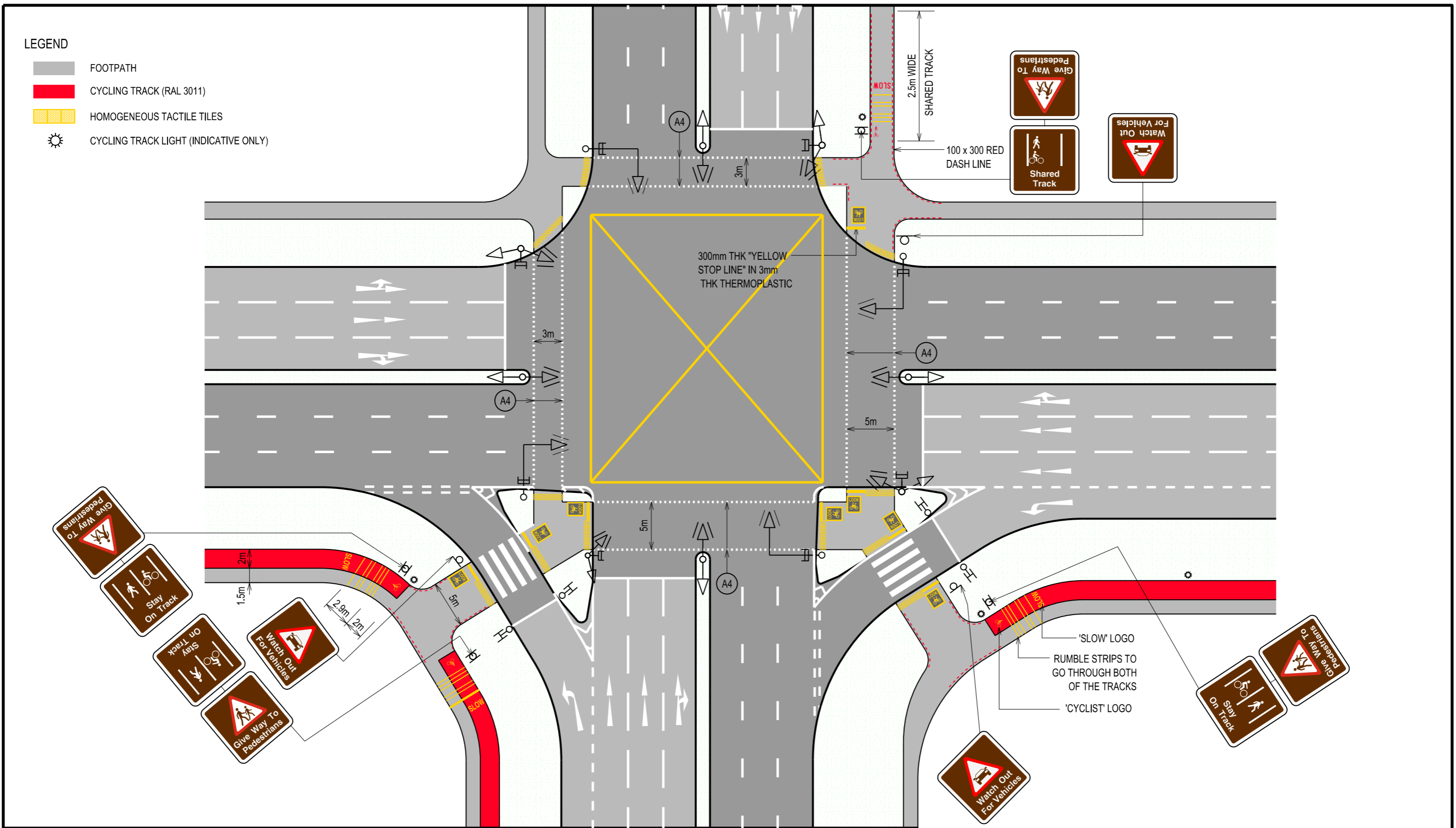
B	SEP 2017
A	OCT 2015
REV.	DATE



DRAWING NO. LTA/SDRE14/3/KER12		REV. B
DATE OF ISSUE 1st APR 2014	SCALE AS SHOWN	SHEET NO. 1 OF 1

LEGEND


-  FOOTPATH
-  CYCLING TRACK (RAL 3011)
-  HOMOGENEOUS TACTILE TILES
-  CYCLING TRACK LIGHT (INDICATIVE ONLY)

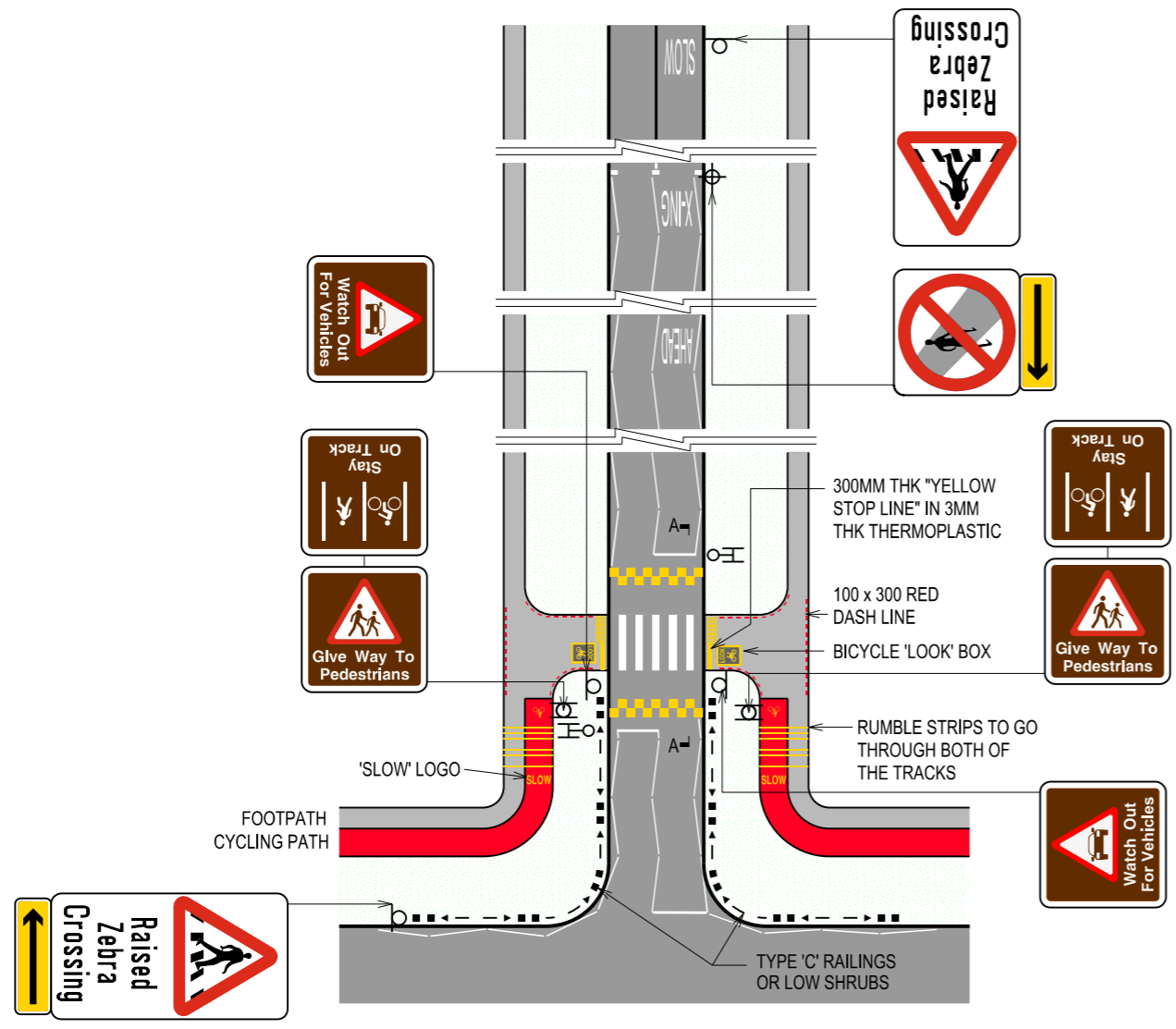


NOTES:

1. Cyclist logo & signage provided at the first entry point to cycling track from a pedestrian crossing.
2. Additional strips and other signage shall be applied if there is further need to slow down and warn the cyclist.
3. If cycling track intersects a pedestrian route, the cycling track shall terminate before the pedestrian route and continue after the route.
4. Wherever cyclists are likely to join the cycling track, additional cyclist logo shall be added.
5. Where the cycling track crosses a covered linkway, a reflective strip shall be pasted on the walkway roof/column to warn the cyclists.
6. All markings that are off carriageway shall use coloured high strength coating system (RAL 1003) or (RAL 3011) unless otherwise stated.

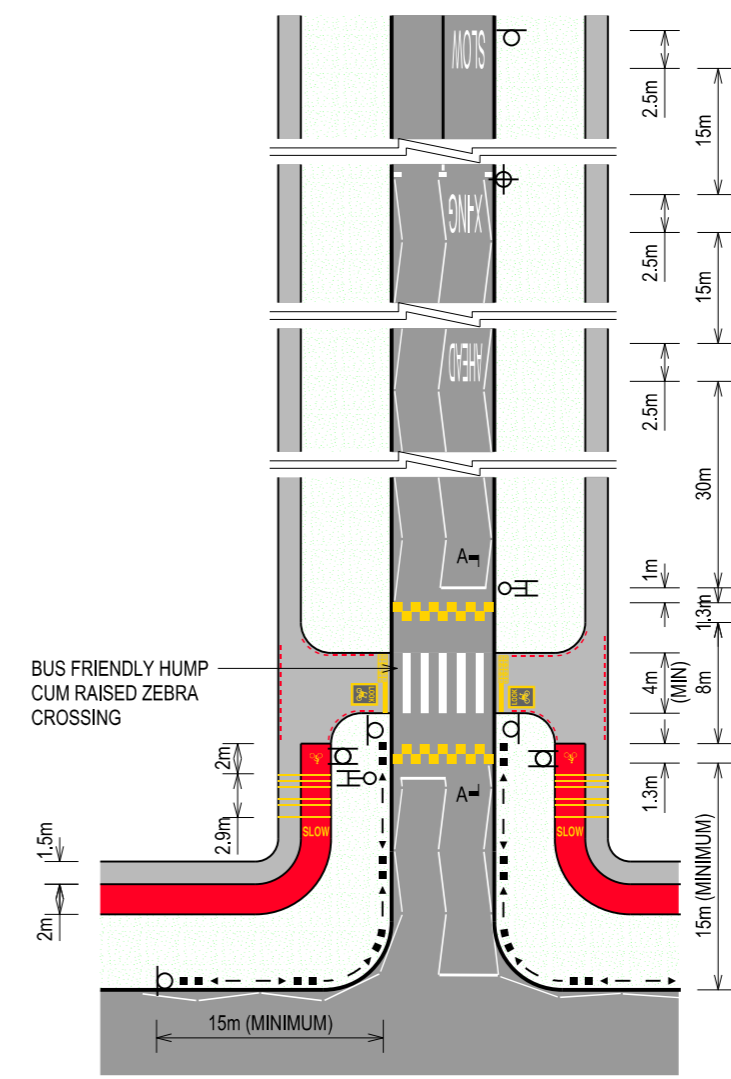
7. Cycling track signages shall be installed on cycling track lighting poles if the intended location of the signages are next to it.
8. Gratings/sumps that are on cycling track or shared track are to use pedestrian grating with mild steel plate unless otherwise stated. Details to follow drawing No. LTA/SDRE14/4/GRA1 to 3.
9. Pavement details of cycling track to follow drawing No. LTA/SDRE14/3/KER11B.
10. For cycling track lighting reference shall be made to LTA/SDRE17/21/CYC10.
11. For all road markings reference shall be made to LTA/SDRE14/8/RMS1-3.

REV.		DATE		STANDARD DETAIL	TREATMENT AT MAJOR JUNCTION			
		DRAWING NO. LTA/SDRE17/21/CYC1				REV. -		
REV.		DATE		DATE OF ISSUE SEP 2017		SCALE 1:400	SHEET NO. 1 OF 1	



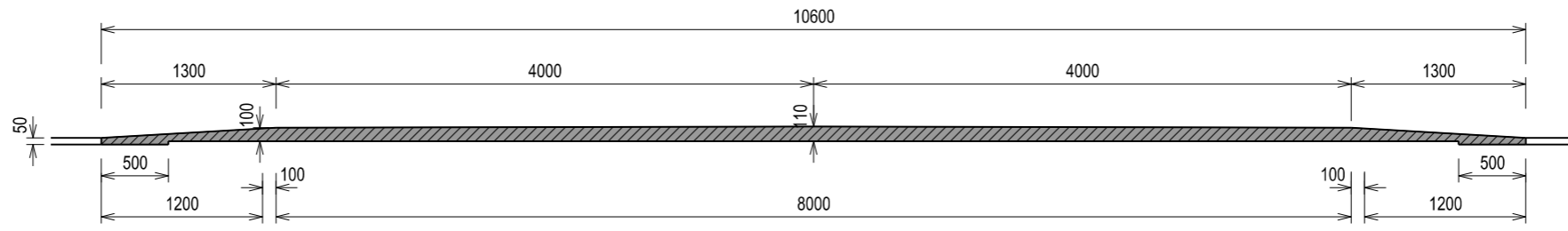
TREATMENT AT UNSIGNALISED JUNCTION

(TRAFFIC SIGNS)
SCALE 1:500



TREATMENT AT UNSIGNALISED JUNCTION

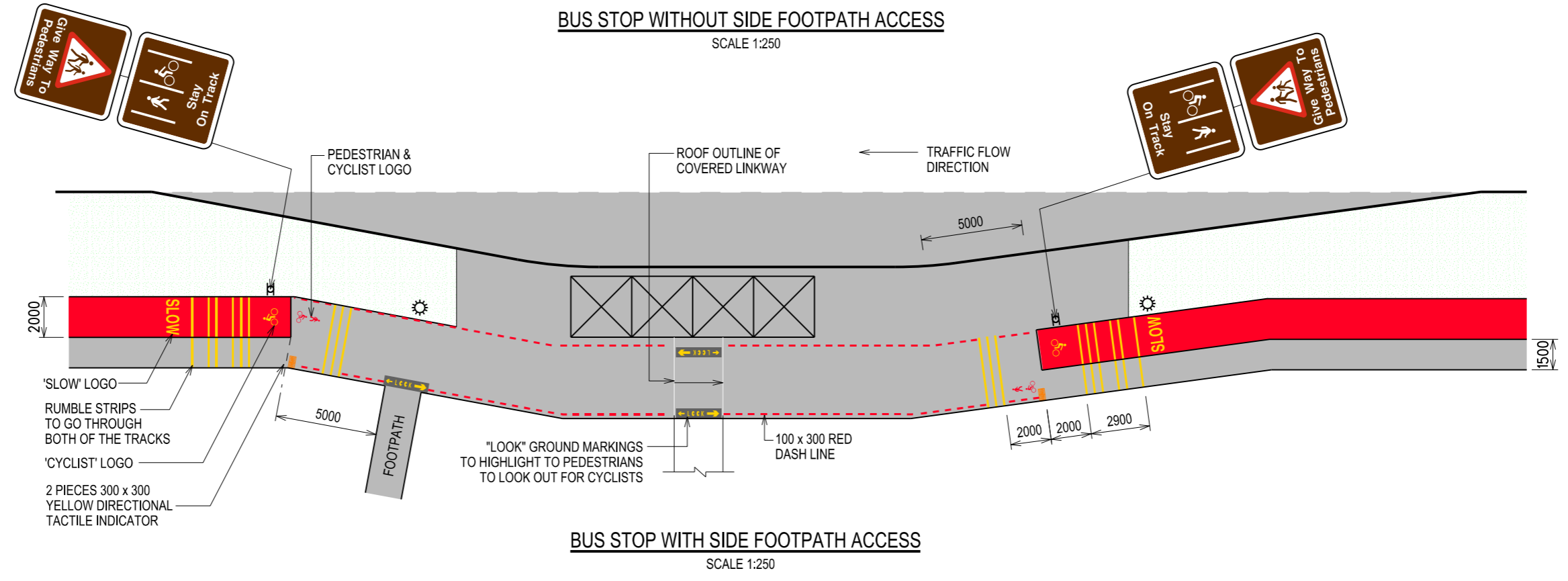
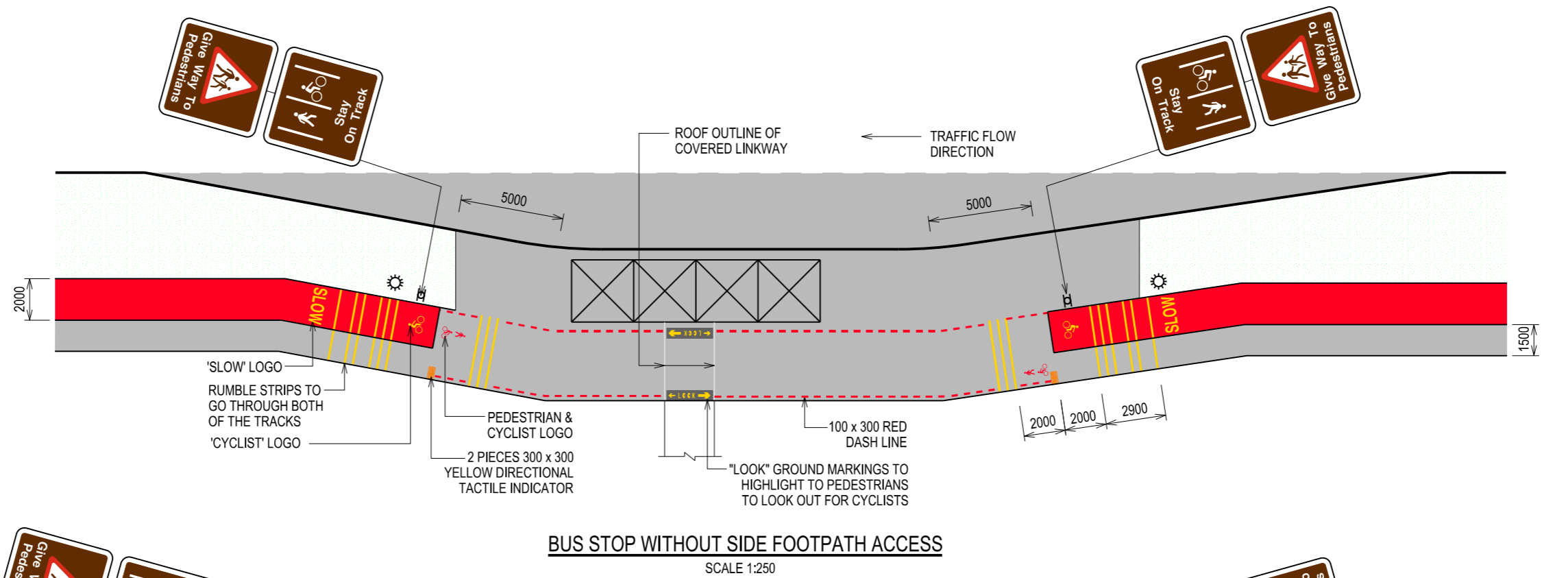
(DIMENSION)
SCALE 1:500



SECTION A-A
SCALE 1:50

- NOTES:**
- Notes refer to Drawing No. LTA/SDRE16/21/CYC1.
 - Refer for other details for bus friendly hump cum raised zebra crossing.
 - To add zebra crossing at unsignalised junction with minimum setback of 15m.

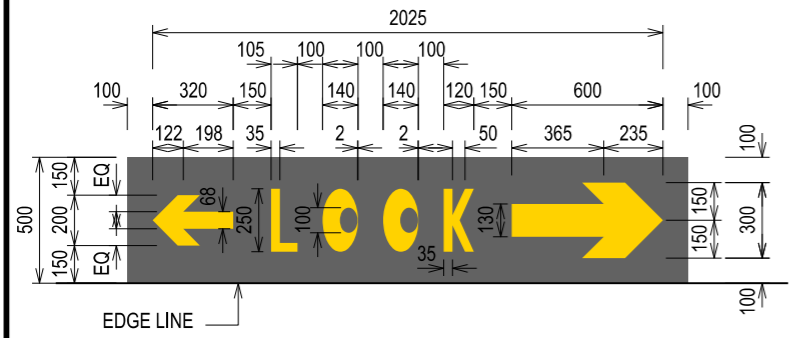
REV.		DATE		STANDARD DETAIL	TREATMENT AT OTHER JUNCTIONS				
		DRAWING NO. LTA/SDRE17/21/CYC2					REV. -		
REV.		DATE		DATE OF ISSUE SEP 2017		SCALE AS SHOWN		SHEET NO. 1 OF 2	



NOTES:

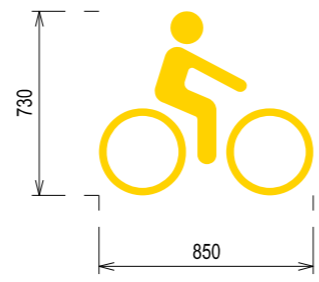
1. Notes refer to Drawing No. LTA/SDRE16/21/CYC1.

REV.		STANDARD DETAIL			
		TREATMENT AT BUS STOP WITH BUS BAY			
DRAWING NO.		LTA/SDRE17/21/CYC6		REV.	
DATE OF ISSUE		SCALE		SHEET NO.	
SEP 2017		AS SHOWN		1 OF 2	



"LOOK" MARKING

SCALE 1:30
COLOUR CODE: RAL 1003 (YELLOW)
RAL 9011 (BLACK)



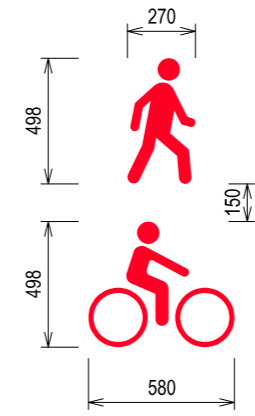
CYCLIST LOGO

SCALE 1:30
COLOUR CODE: RAL 1003 (YELLOW)
RAL 3011 (RED)
NOTE: YELLOW COLOUR MARKINGS ON RED COLOUR PATH FINISHES. RED COLOUR MARKINGS ON OTHER FINISHES.



SLOW LOGO

SCALE 1:30
COLOUR CODE: RAL 1003 (YELLOW)
RAL 3011 (RED)
"SLOW" FONT IN HELVETICA / HELVETICA BOLD
NOTE: YELLOW COLOUR MARKINGS ON RED COLOUR PATH FINISHES. RED COLOUR MARKINGS ON OTHER FINISHES.



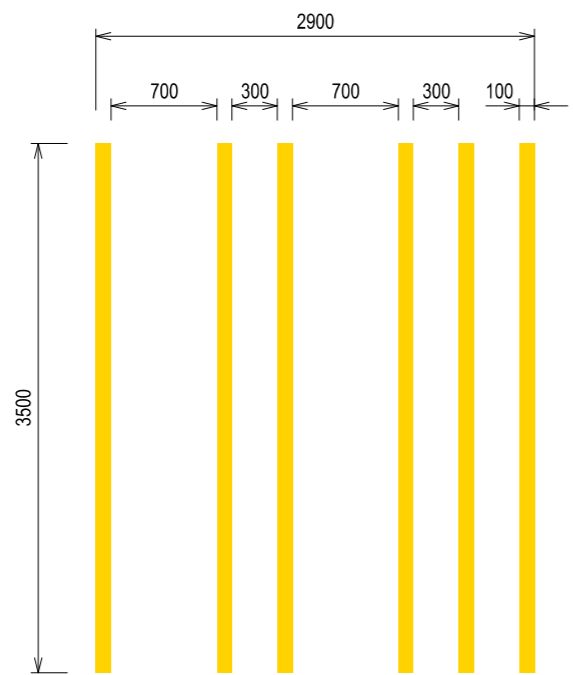
PEDESTRIAN & CYCLIST LOGO

SCALE 1:30
COLOUR CODE: RAL 3011 (RED)
RAL 1003 (YELLOW)
NOTE: YELLOW COLOUR MARKINGS TO BE APPLIED ON RED COLOUR FLOOR FINISHES ONLY.



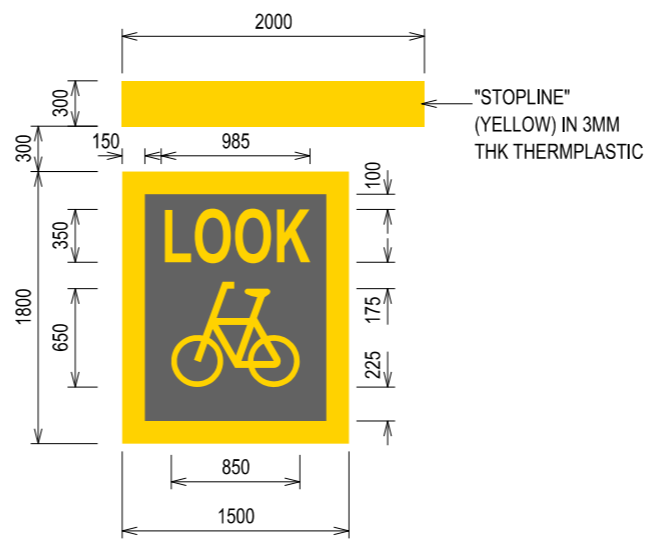
DASH LINE MARKING

SCALE 1:30
COLOUR CODE: RAL 3011 (RED)
RAL 1003 (YELLOW)
NOTE: YELLOW COLOUR MARKINGS TO BE APPLIED ON RED COLOUR FLOOR FINISHES ONLY.



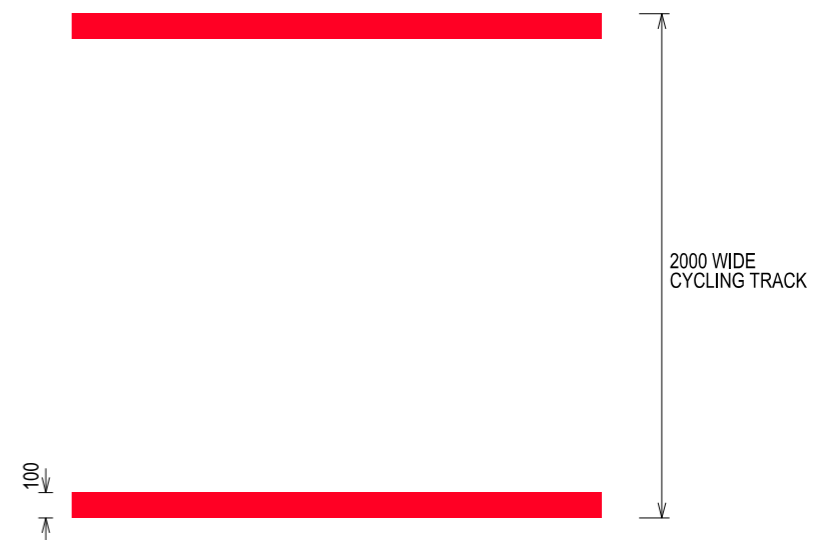
RUMBLE STRIPS

SCALE 1:50
STRIPS THICKNESS: 3mm THERMOPLASTIC



BICYCLE LOOK BOX DETAIL

SCALE 1:50
"LOOK" FONT IN HELVETICA / HELVETICA BOLD
COLOUR CODE: RAL 1003 (YELLOW)
RAL 9011 (BLACK)



SOLID LINE MARKING TO DEMARCAT CYCLING TRACK (AT CENTRAL AREA ONLY)

SCALE 1:30
COLOUR CODE: RAL 3011 (RED)
RAL 1003 (YELLOW)
NOTE: YELLOW COLOUR MARKINGS TO BE APPLIED ON RED COLOUR FLOOR FINISHES ONLY.

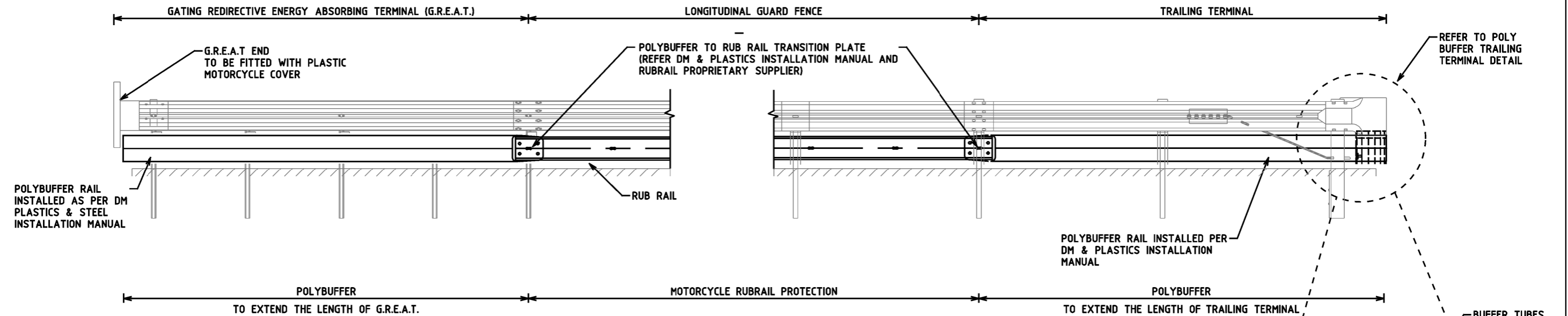
NOTES:

1. Notes refer to Drawing No. LTA/SDRE16/21/CYC1.

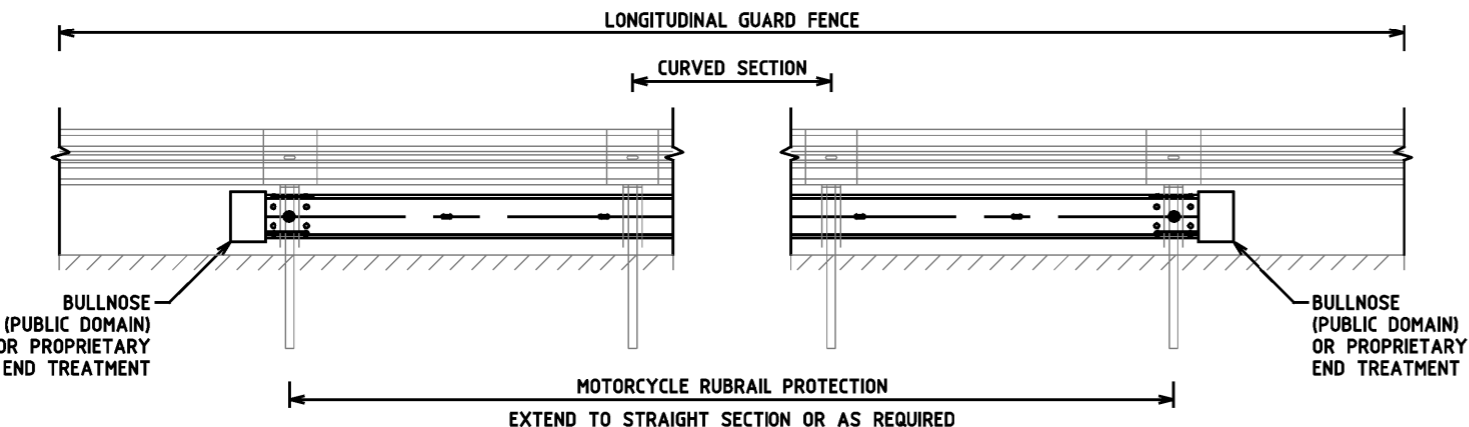
REV.	DATE	STANDARD DETAIL					
		CYCLING PAVEMENT MARKINGS DETAILS				DRAWING NO.	LTA/SDRE17/21/CYC8
				DATE OF ISSUE	SEP 2017	SCALE	AS SHOWN

Appendix B – Guardrail Design Guidance

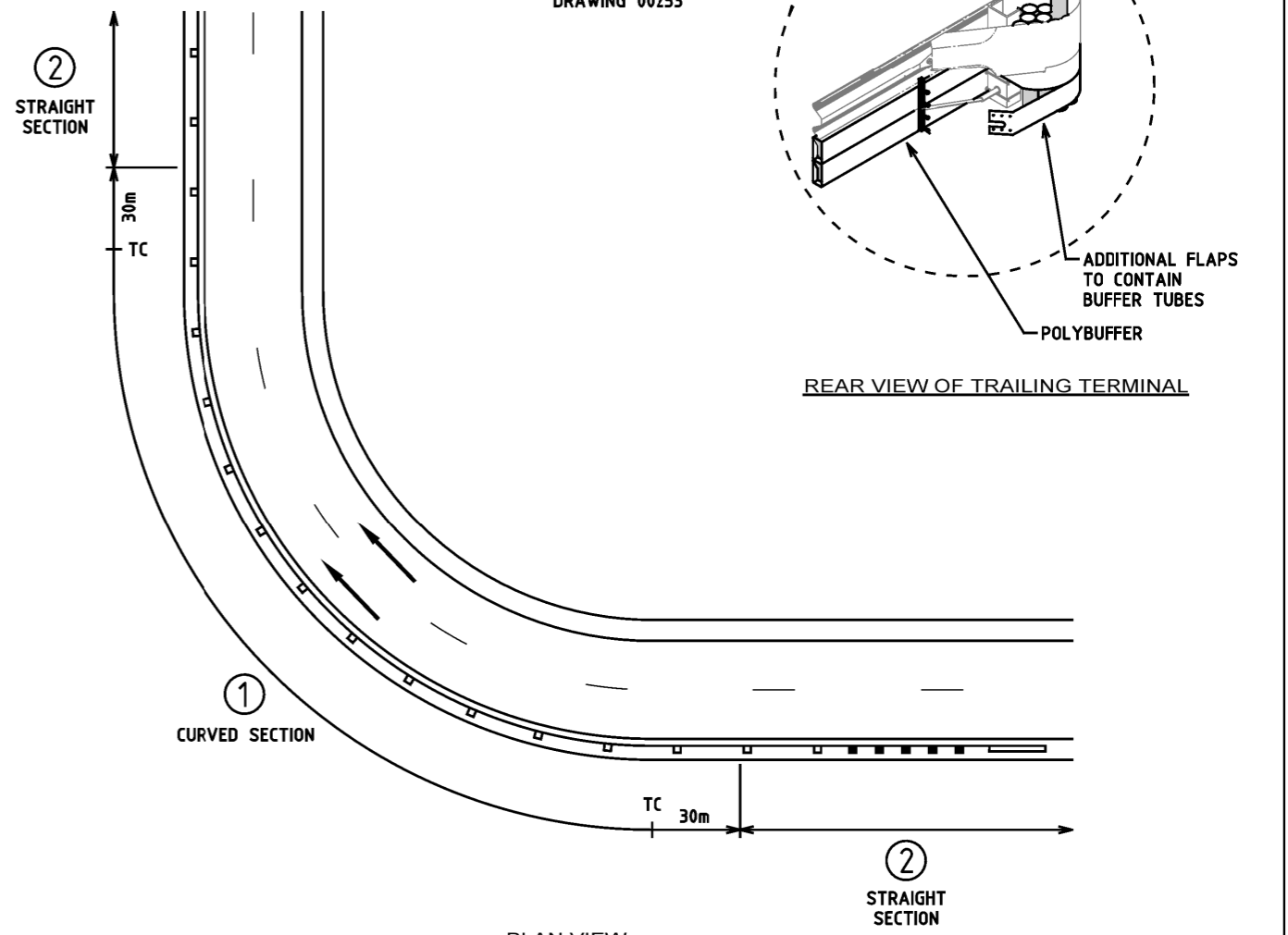
ISSUE	APPROVED BY	DATE	AMENDMENT



① CURVED SECTION - RUB RAIL PROTECTION WITH END TERMINALS



② STRAIGHT SECTION - RUB RAIL PROTECTION



GENERAL INSTALLATION NOTES

- RUB RAIL SHOULD BE INSTALLED ON CURVES LESS THAN 250m RADIUS.
- LARGER CURVES SHOULD BE CONSIDERED WHEN THE CURVES ARE FOLLOWING A LONG STRAIGHT SECTION OF GUARD FENCE.
- G.R.E.A.T. TERMINAL HEAD TO BE FITTED WITH PLASTIC COVER AND THE POSTS TO BE PROTECTED WITH POLYBUFFER OR APPROVED ALTERNATIVE.
- APPROVED RUB RAIL TO BE INSTALLED ALONG THE LONGITUDINAL BARRIER TO SHIELD THE POSTS.
- RUB RAIL TO BE TERMINATED BEFORE TRAILING TERMINAL AND TRANSITIONED TO POLYBUFFER TO SHIELD TERMINAL POSTS.
- BCTAs AND BTCBs CAN BE TREATED WITH POLYBUFFER - REFER DM & PLASTICS INSTALLATION MANUAL.
- WHEN FAUNA CROSSINGS ARE REQUIRED ALONG A ROUTE, FAUNA CROSSINGS MUST NOT BE PROVIDED ALONG CURVED ALIGNMENTS.
- G.R.E.A.T. USED IN LIEU OF TRAILING TERMINAL FOR TWO LANE TWO-WAY TRAFFIC OPERATIONS.
- BULLNOSE RUB RAIL TERMINAL TO BE INSTALLED OUTSIDE OF THE CURVE TO TERMINATE RUB RAIL WHERE GUARD FENCE IS CONTINUOUS.

REFERENCES AND NOTES:

- THIS DRAWING SHOWS RUBRAIL INSTALLATION REQUIREMENTS FOR GUARD FENCE.
- DRAWING PREPARED IN CONJUNCTION WITH INGAL CIVIL PRODUCTS TECHNICAL DRAWINGS & DM PLASTICS & STEEL PRODUCT MANUAL.
- REFER TO RDN 06-04 AND RDN 06-08.

PREPARED BY FOR VICROADS USE

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STANDARD DRAWING

ROAD SAFETY BARRIERS
MOTORCYCLE RUB RAIL
INSTALLATION LAYOUT FOR CURVES

SCALE OF METRES
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