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Smart Freeways Supplement to Victoria's Managed Motorway Design Guide Volume 2: Design Practice – Parts 2 and 3

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Smart Freeways
Supplement to Victoria's Managed Motorway Design Guide Volume 2: Design Practice – Parts 2 and 3

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Smart Freeways
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Revision

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Nov 2013	Main Roads' Supplement to VicRoads Managed Freeways – Freeway Ramp Signals Handbook Original document	All
September2020	Smart Freeways - Supplement to Victoria's Managed Motorway Design Guide Volume 2: Parts 2 and 3, Design Practice Major revision	All
March 2021	Part 3 Section 4.4.4: Methodology added. Title changed in table for VMS guidelines.	Part 3 – Section 4.4
August 2022	Drawings 201231-0027, 201231-0028, 201231-0029, 201231-0030, 201231-0031, 201231-0032 and 201731-0028 amended.	Part 3 Sections 6.4 to 6.8
October 2022	Supplementary notes to Part 3, Sections 3.1, 3.2.2, 3.3.4.3.3 amended. Supplementary notes to Part 3, Section 4.3.1 added.	Part 3 - Sections 3 and 4
February 2023	Spreadsheet link (Part 3 Section 4.4.4: Methodology) updated. Drawings 201731-028, 201231-0028, 201231-0029 updated. Reference to priority lane drawing updated (Sec 6.10.10)	Part 3 - Section 4.4.4, 6.4 to 6.8, 6.10.10

Foreword

Smart Freeways policy and guidelines

Main Roads Western Australia (Main Roads) has established a Smart Freeways policy and series of guidelines to guide overall planning, project development, delivery and ongoing operation of Smart Freeways in Western Australia.

The Smart Freeways documents were originally developed as part of the Managed Freeways policy framework in 2012. At that time Main Roads used the term 'Managed Freeways', which has now changed to 'Smart Freeways' with the implementation of the first Smart Freeways project on Kwinana Freeway northbound in 2019/20. The 2020 updated documents supersede the previous Managed Freeways documents.

While historically, the consideration of ITS on freeways was typically on a case-by-case basis, the current Main Roads' approach as outlined in the Smart Freeways Policy is that all freeways shall be considered for ITS provision at either foundation or higher order standard according to these Provision Guidelines.

The Main Roads' Smart Freeways policy and guidelines providing direction and guidance include the documents listed in the table below. This document, Smart Freeways Supplement to Victoria's Managed Motorway Design Guide, Volume 2: Parts 2 and 3 is shown highlighted.

Document	Description
Smart Freeways Policy	One page high-level policy statement setting out Smart Freeways objectives and principles.
Smart Freeways Policy Framework Overview	Smart Freeways context, principles, corporate governance, processes and intended outcomes to achieve policy objectives.
Smart Freeways Provision Guidelines	Guidelines and warrants for application of Smart Freeways traffic management treatments and ITS devices.
Smart Freeways Operational Efficiency Audit Guidelines	Guidelines for formal examination of traffic analysis and design of all freeway projects.
Guidelines for Variable Message Signs	Guidelines for the design and use of variable message signs for traveller information for safe and efficient travel for road users.
Supplement to Victoria's Managed Motorway Design Guide, Volume 2: Design Practice, Parts 2 and 3	Main Roads Supplement relating to: • Network optimisation tools (benefits and operation of coordinated ramp signals). • Planning and design for mainline, entry ramps (including ramp signals), exit ramps and interchanges.
Supplement to Victoria's Managed Freeways Handbook for Lane Use Management and Variable Speed Limits	Main Roads Supplement relating to: • Lane use management system (LUMS). • Variable speed limits (VSL).

Smart Freeways concept

Smart Freeways make the best use of the existing freeway network, particularly during times of high demand and traffic incidents. We use an ITS and operational strategies that enable dynamic network management and operation in real-time. Smart Freeways traffic management initiatives, complemented by appropriate mainline and ramp geometric improvements, work together as an integrated system to achieve and maintain optimal freeway traffic conditions, with minimal delays and congestion.

Over recent years, Victoria's approach to managed motorways in Melbourne has achieved unparalleled, sustainable benefits to freeway operations for safety, productivity, efficiency and reliability. We have applied the same holistic principles and learnings, while also working towards national consistency.

Supplement to Victoria's Managed Motorways Design Guide

Main Roads has been authorised by the Department of Transport Victoria (previously VicRoads) to use the following parts of the 'Managed Motorway Design Guide' (MMDG), as a primary reference for Smart Freeway understanding and design. The referenced parts of the MMDG relate to mainline planning and design as well as freeway optimisation and design, particularly of coordinated ramp signals:

- Volume 2: Design Practice, Part 2: Managed Motorway – Network Optimisation Tools.
- Volume 2: Design Practice, Part 3: Motorway Planning and Design.

Accordingly, this Supplement has been developed to be read in conjunction with the Victoria's design guides, copies of which can be obtained via the Department of Transport (VicRoads) website:

https://www.vicroads.vic.gov.au/business-and-industry/technical-publications/traffic-engineering

This Supplement follows the same structure as Victoria's MMDG documents. The MMDG is applicable to Main Roads unless this Supplement provides either additional guidance, or information which replaces MMDG requirements.

In Western Australia, Main Roads' policies, guidelines and standards take precedence over Austroads' Guides and Standards Australia Standards.

Abbreviations

AADT	Annual average daily traffic
AAWDT	Annual average weekday traffic
ALR	All lane running
AHS	ALINEA HERO Software use for the HERO-LIVE coordinated ramp signals
ANPR	Automatic number plate recognition
AP	Access point (for wireless detectors)
AID	Automated incident detection
AIDS	Automated incident detection system
CCTV	Closed circuit television
CMS	Changeable message sign
CIC	Customer Information Centre
CRS	Coordinated ramp signals
DMS	Dynamic message sign
ESL	Emergency stopping lane
GPS	Global positioning system
ICT	Information and communications technology
IRS	Incident response service
ITS	Intelligent transport systems
JUMA	Joint use mast arm
LED	Light emitting diode
LUMS	Lane use management system
MMDG	Victoria's managed motorway design guide
MSFR	Maximum sustainable flow rate
pc/h/ln	Passenger cars per hour per lane
PMTZ	Partially managed transition zone
PTA	Public Transport Authority
PTZ	Pan, tilt and zoom
RC1	Ramp control sign (ramp signals on, freeway closed, no right/left turn)
RC2	Ramp control sign (ramp signals on, prepare to stop)
RC3	Arterial road VMS (ramp control sign)
RNOC	Road Network Operations Centre
RP	Repeater point (for wireless detectors)
RRPM	Retro reflective pavement marker
RTMT	Real-time monitoring team
RTTO	Real-time traffic operations
SCATS	Sydney Coordinated Adaptive Traffic System

SF	Smart Freeways
STREAMS	ITS control system currently in use by Main Roads
TCSN	Traffic control system network
TIRTL	The Infra-Red Traffic Logger
UPS	Uninterrupted power supply
VDS	Vehicle detection station
veh/h	Vehicles per hour
veh/h/ln	Vehicles per hour per lane
VKT	Vehicle kilometres travelled
VMS	Variable message sign or signs. This generic term may include dynamic message signs (DMS) and changeable message signs (CMS).
VSL	Variable speed limit
WA	Western Australia
WAPOL	Western Australia Police
WIM	Weigh-in-motion

Contents

Summary of Main Roads Guidance

These comparison tables are provided for information only. The user of this Supplement shall ensure they make appropriate reference to the correct reference material.

Legend

✓ no additional Main Roads' Smart Freeways guidance
+ additional Main Roads' Smart Freeways guidance
× Main Roads' Supplement overrides this section in the Victoria's Guides

Section	Victoria's Managed Motorway Design Guide Volume 2: Design Practice Part 2: Managed Motorway – Network Optimisation Tools Section Headings	Main Roads Guidance
1	Network Optimisation Control Tools	
1.1	Overview	+
1.2	Past Experience in Melbourne	✓
1.3	Overview of Managed Motorways Tools	+
2	Ramp Metering as a Network Optimisation Tool	✓
2.1	Principles of Motorway Traffic Flow	✓
2.2	Ramp Metering – An Overview	✓
2.3	Principal Aims of Motorway Ramp Metering	✓
2.4	Context and Effectiveness	✓
2.5	Ramp Metering as a Management Tool	✓
		✓
3	Ramp Metering Control	✓
3.1	Independent Control	✓
3.2	Dynamic Coordinated (Route-Based) Control	✓
3.3	Managing Ramp Demands	✓
3.4	Control Strategies and Algorithms	✓
3.5	Why Occupancy is Used to Manage Motorway Flow	✓
3.6	Managing Heavy Congestion and Incidents	✓
3.7	Management of Entry Flows to Assist in Flow Recovery	✓
3.8	Closing Entry Ramps and/or the Motorway	✓
3.9	Traffic Diversion by Providing Traveller Information	✓
3.10	When Ramp Metering has Limited Effectiveness	✓

Section	Victoria's Managed Motorway Design Guide Volume 2: Design Practice Part 2: Managed Motorway – Network Optimisation Tools Section Headings	Main Roads Guidance
4	The Operation of Ramp Meters	
4.1	Legal Basis for Ramp Meters	✗
4.2	Control Algorithms Used by VicRoads	+
4.3	Ramp Meter Operational Modes	✓
4.4	Switching on/off Signs and Signals	✓
4.5	Operating Sequence and Cycle Times (not used for design)	✓
5	Ramp Signals Integration with other Managed Motorway Operations	✓
5.1	Ramp Signals Response to a Lane Closure	✓
5.2	Ramp Signals Response to Changing Speed Limits	✓
5.3	Ramp Signals Response to a Freeway Closure	✓
5.4	Emergency Vehicle Access when Ramp Signals are Operating	✓
		✓
6	Benefits of Ramp Metering	✓
6.1	Qualitative Benefits	✓
6.2	Quantitative Benefits for the Motorway – Monash Freeway Example	✓
7	Exit Ramp Management System	+
7.1	Managing traffic leaving the motorway	+
8	Interface at Surface Road Interchanges	✓
8.1	Interchanges	✓
8.2	Entry Ramps	✓
8.3	Exit Ramps	✓
9	Ramp Metering Myths and Misunderstandings	✓
9.1	Introduction	✓
Appendix A	Ramp Metering – Information Bulletin	✓
Appendix B	A Short History of Ramp Metering and Ramp Metering in Melbourne	✓
Appendix C	Paper presented at the Fifth Australian Computer Conference, Brisbane, May 1972	✓

Section #	Victoria's Managed Motorway Design Guide Volume 2: Design Practice Part 3: Motorway Planning and Design Section Headings	Main Roads Guidance
1	General Introduction	
1.1	Context	✓
1.2	Background	✓
1.3	VicRoads Approach to Planning, Design and Operations	+
1.4	Performance-Based Design	+
1.5	Design Intent	+
1.6	Project Planning and Interaction	✓
1.7 (new)	Additional Information relating to Design Drawings Presentation	+
2	Motorway Planning	
2.1	General Principles	✓
2.2	Iterative Design Process	✓
2.3	Other Project Planning Considerations	✓
3	Motorway Concept Design	
3.1	Preliminary Design Volumes (Mainline and Ramps)	+
3.2	Enhancing Existing Motorways (Including Retrofit or Ramp Metering Signals)	+
3.3	Upgrading Motorway Capacity or New Motorway Projects	+
3.4	Volume / Capacity Model Outputs	✓
3.5	Mainline Carriageways	+
3.6	Interchange Location and Spacing	+
3.7	Ramp-related Access Arrangements	+
4	Mainline Analysis and Functional Design	
4.1	General Process	✓
4.2	Design Volumes (Mainline and Ramps)	✓
4.3	Mainline Capacity Analysis and Design	+
4.4	Mainline Design Volume / MSFR Analysis	+
5	Design of Mainline Vehicle Detector Locations	
5.1	Principles for Detector Locations	+
5.2	Collector-Distributor Road Detector Locations	+
5.3	Detector Locations in Tunnel Segments	+
5.4	Vehicle Detection and Grouping of ITS Assets	+
6	Design of Ramp Signals and Entry Ramps	
6.1	Overview of the Design Process	✓
6.2	Ramp Discharge Capacity for Design	+

Section #	Victoria's Managed Motorway Design Guide Volume 2: Design Practice Part 3: Motorway Planning and Design Section Headings	Main Roads Guidance
6.3	Ramp Storage Analysis and Requirements	✓
6.4	Geometric Design and Layout of Entry Ramps	+
6.5	Two Lane Metered Entry Ramp	+
6.6	Three Lane Metered Ramps	+
6.7	Four Lane Metered Ramps	+
6.8	Priority Access Lanes	+
6.9	Designing for Future Retrofitting Ramp Signals	+
6.10	Layout of Ramp Signal Devices and Traffic Management	+
7	Motorway-to-Motorway Ramp Metering Signals	
7.1	Introduction	✓
7.2	Control of Motorway-to-Motorway Ramps	✓
7.3	Ramp Geometry and Signal Layout	✗
7.4	RC2-C Warning Signs	✓
7.5	Speed and Lane Management	✓
7.6	Mainline RC3-C Warning Signs	✓
7.7	Vehicle Detection	✓
7.8	Other Signs	✓
7.9	Pavement Marking	✓
7.10	CCTV Cameras	✓
8	Surface Road Access Management	
8.1	General Principles	✓
8.2	Interchange Capacity and Design Performance	✓
8.3	Managing Entry Ramp Queue Overflows	✓
9	Exit Ramp Design and Management	
9.1	Principles for Managing Traffic at Exit Ramps	✓
9.2	Treatment Options	✓
9.3	Exit Ramps Design Storage	✓
9.4	Exit Ramp Management System	+
Appendix A	Extended Design Domain	✗
Appendix B	Photometric Tests of LED Lanterns	✓
Appendix C	Glossary of Traffic Terms and Relationships	✓

Overview

Smart Freeways policy framework

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Other parts of Victoria's MMDG are also available as background relating to Smart Freeway traffic analysis, operation and design. In particular, analysis for the determination of Maximum Sustainable Flow Rates (MSFR) for design volume/capacity analyses is available in:

- Managed Motorway Design Guide (MMDG), Volume 1: Role, Traffic Theory & Science for Optimisation, Part 3: Motorway Capacity Guide.

The MSFR determination methodology is explained in section 3.3.2 - Approach 2, Variant b and section 3.3.3 'Capacity' Approach 2, Probability of flow breakdown. In this context, occupancy rather than flow rate is to be used for the determination of flow breakdown probability curves.

Other parts of Victoria's MMDG may also be used as reference documents but are not specifically endorsed for design in Western Australia.

In Western Australia, Main Roads' policies, guidelines and standards take precedence over Austroads Guides and Standards Australia Standards.

Supplement structure and terminology

This Supplement has the same structure as the MMDG and only additional requirements, clarifications, or practices different from Victoria appear. Where appropriate, this Supplement may also contain additional sections and figures not covered by the MMDG, but the numbering sequence found in the MMDG remains. Where indicated, the figures and tables in this Supplement replace those in the MMDG. Information in the MMDG should also be read in the context of Main Roads' information in the Smart Freeways Policy Framework Overview, Provision Guidelines and other design guidelines.

The Smart Freeways terminology used in this Supplement is to have an equivalent meaning to Managed Motorways in the MMDG and Managed Freeways in previous Main Roads' guides.

References to VicRoads (now part of Department of Transport Victoria) shall be understood to have equivalent application to Main Roads Western Australia. Where specific aspects of design require endorsement or approval within VicRoads, reference shall be made to the Main Roads' governance requirements provided in the Smart Freeways Policy Framework Overview.

Part 2: Managed Motorway - Network Optimisation Tools

Part 2 Section 1.1: Overview

The City Wide Coordinated Ramp Metering (CWCRM) terminology used throughout the MMDG shall be understood to be equivalent to Main Roads terminology for Coordinated Ramp Signals (CRS).

Part 2 Section 1.3: Overview of Managed Motorway Tools

The overview of managed motorway tools and associated functions as well as the toolkit in Table 1 is generally applicable and may be read as background to Smart Freeways technologies. The Main Roads' summary and descriptions of ITS technologies and devices is provided in the Smart Freeways Provision Guidelines.

The reference to VicRoads warrants in Volume 2, Part 1, shall be replaced by Main Roads' warrants in the Provision Guidelines.

Part 2 Section 4.1: Legal Basis for Ramp Meters

This section shall be replaced with the following information.

Freeway ramp signals in Western Australia are traffic lights as defined in the *Road Traffic Code 2000*. Regulation Nos. 39, 40 and 41 defines a driver's responsibilities when approaching, or at a green, red or yellow traffic light. Other rules define responsibilities relating to the stop line and other regulatory signs and pavement markings associated with freeway ramp signals. The Executive Director Network Operations of Main Roads must give approval to erect, establish, display, maintain or remove freeway ramp signals.

Part 2 Section 4.2: Control Algorithms Used by VicRoads

Main Roads is also using the HERO-LIVE suite of coordinated ramp signals algorithms - known as AHS in Main Roads central control system STREAMS.

Part 2 Section 7: Exit Ramp Management System

Main Roads may consider adopting design and operational requirements for Victoria's exit ramp management system in the future. In the interim, along with appropriate ramp geometric design, Main Roads has been using other strategies such as SCATS Strategy Manager for managing exit ramp queues, which may need to be considered in Smart Freeway designs where excessive exiting queues are experienced in operations or anticipated during design.

Part 3: Motorway Planning and Design

Part 3 Section 1.3: Approach to Planning, Design and Operations

The principles in this Supplement and the MMDG can be applied to the following generalised work types:

- **Existing freeway improvement** - to retrofit a new coordinated ramp signalling system to improve safety and productivity from existing infrastructure. Other localised works would generally be needed, including vehicle detection stations and geometric improvements at entry ramps to provide required discharge capacity and storage.
- **Existing freeway upgrading** - where additional mainline capacity (widening) and improved interchanges are being provided to upgrade capacity and improve travel time reliability.
- **New freeway design** - for a new major link in the freeway network.

Part 3 Section 1.4: Performance-based Design

The performance-based design principles in these sections are supported in Main Roads' Smart Freeways Policy Framework Overview (Section 5.4) which includes the following information.

Main Roads' Smart Freeways policy and guideline documents aim to highlight road safety and operational principles, which both require a high priority during design. Therefore, the design intent shall be to produce a Smart Freeway and ITS design that will maximise the completed project's performance outcomes, i.e. Smart Freeway design is not just about ITS devices but a well-designed freeway complemented with appropriate ITS, which works to optimise safety and operational performance.

The design principles to achieve these outcomes are provided in Victoria's MMDG and in this Main Roads' Supplement to that guide.

Part 3 Section 1.5: Design Intent

The concepts of design intent and designing for operations in this section require project design performance targets that directly relate to achieving the Smart Freeway performance objectives as outlined in the Smart Freeway Policy Framework Overview.

While high-level performance objectives are important for project and network evaluation, they can only be realised for a specific project if appropriate attention is given to all details in the design to ensure it is designed for operations. Table 2 provides guidance and summary of typical design targets needed for operational performance of Smart Freeway projects.

Table 2: Project design performance targets for Smart Freeway projects

Objective	Design performance target (at design year)
Mainline: with adequate capacity and minimum potential for traffic turbulence	Ratio of forecast design volume/maximum sustainable flow rates ≤ 1 (or ≤ 100%) during peak periods A sufficient number of entry ramps are controlled with ramp signals to manage the mainline Lane arrangements entering the mainline from entry ramps meet design guidance Lane arrangements leaving the mainline to exit ramps meet design guidance
Entry ramps: with adequate discharge capacity and storage	Ramp signal cycle time for design ramp flow not less than: • 7.5 seconds for ramps merging with the mainline • 6.5 seconds for ramps with an added lane, added lane plus merge or two added lanes entering the mainline Storage for design ramp flow to be a minimum desirable of 4 minutes
Exit ramps: to prevent queues impacting the mainline lanes	Exit ramps with adequate length and width (number of lanes) to accommodate storage requirements for the design traffic for 95th percentile queues plus distance for deceleration, (consideration of interchange performance is also relevant)
Interchanges: with adequate capacity	Practical degree of saturation based on forecast design volumes not greater than: • 0.90 for signals control • 0.85 for roundabout control • 0.80 for Stop or Give Way control.

Part 3 New Section 1.7: Additional Information for Design Drawings Presentation

Design drawings need to conform to Main Roads' guidance and requirements for drawing presentation as indicated on the Main Roads' website. Where changes are made during construction, 'as-constructed' drawings shall also be provided by the project.

Mainline Design Drawings

The mainline layout drawings for Smart Freeways shall include the following design features and devices **on the same layout / alignment drawings** for ease of design review and setting up the freeway in the central control system:

- Chainages along the carriageway.
- Layout of pavement and lane markings, including ramp connections, tapers, lane reductions (exclusive exit lanes, lane drops), etc.
- Locations of signs including direction signs and variable message signs (VMS), etc.
- Layout and positions of all vehicle detector stations (VDS).
- Locations of LUMS gantries, if applicable.

Ramp Signal Plans

Each ramp shall be shown on a dedicated ramp signals drawing, generally along the lines of the Main Roads' guideline drawings for ramp signals (refer Part 3 Section 6.4.4 below), i.e. not be part of the mainline alignment drawings design grid. For long ramps two drawings may be needed, or up to three drawings for long freeway-to-freeway ramps. Inserts may be provided for assets at a distance from the ramp signals, if necessary.

The following design features and devices shall generally be shown **on the same layout drawings** for ease of design review and setting up the ramps and ramp signals in the central control system:

- Ramp layout (lane lines, edge lines, continuity lines, pavement arrows, etc.), including number of lanes at the ramp entrance, stop line, at ramp nose, and the layout entering the mainline (consistent with mainline alignment drawings).
- Either a chainage line along the ramp (to enable calculation of lane / ramp storages) or specific dimensions (or tabulation) of the lane / ramp storages upstream of the stop line.
- Location of stop line dimensioned to ramp nose and/or ramp entrance.
- Vehicle detector locations along the ramp including dimensions to the stop line and start of ramp as well as AP and RP locations, etc., if applicable.
- Controller location.
- Ramp control signs and locations (RC1, RC2, RC3 etc.), and other electronic signs, if applicable, e.g. overhead lane control signs, VSL signs, etc.
- Location and type of signal posts or structure.
- Associated static traffic signs.
- Conduit locations for the ramp, including connections to electrical power supply and the telecommunications network, including location, size and number of conduits and pits.
- Other assets as may be relevant, e.g. safety barriers.

Part 3 Section 3.1: Preliminary Design Volumes (Mainline and Ramps)

Additional guidance relating to determination of design volumes for the three work types listed in Part 3 Section 1.3 are summarised in Table 3. Additional information and further guidance is provided in the MMDG Vol. 2, Part.3, Section 3.2.2, and related sections of this Supplement.

Determining realistic design volumes is generally an iterative process considering travel patterns and traffic demands as well as the scope of works and other project-specific considerations.

Table 3: Additional guidance for considering design volumes

Determining design volumes	Existing freeway improvement [1]	Existing freeway upgrading	New freeway design
Mainline:			
Existing maximum 15 min. flow x 4 (i.e. maximum 15 min. demand factored up to an hour) with balanced flows along the route (mainline and ramps)	●	○	
Traffic growth and/or suppressed demand	●	●	
One-hour volumes from calibrated 24 hour strategic model volume outputs - with appropriate K-factor (see MMDG section 3.3.4.3.3 below)		●	●
Entry ramps: (during periods when ramp signals are expected to be operational. The entry ramp peak hour must be the same as the mainline peak hour at that location.)			
Existing maximum 15 min. flow x 4 x 1.05 (i.e. factored up to an hour plus 5%)[3] or Existing maximum 5 min. flow x 12 (i.e. factored up to an hour) if there is a short, sharp increase[2] within the hour.	●		
Traffic growth and/or suppressed demand	●	●	
Forecast Peak hour volumes from calibrated strategic modelling (derived from forecast daily volumes with an appropriate K-factor), adjusted to design flows by dividing by a Peak Hour Factor given in Table 3a.		●	●

Notes:

● Shall be considered

○ May be considered

[1] Work types are defined in Part 3 Section 1.3 of this document.

[2]As a rule of thumb, a short sharp increase in volume is defined as 12.5% or more of the hourly volume occurring in 5 minutes for two consecutive 5-minute periods during peak periods.

[3]The 5 minute flow x 12 or 15 minute flow x 4 x 1.05 does not apply to the mainline as the 15 minute mainline flow is consistent with the MSFR used for the design.

Part 3 Section 3.2: Enhancing Existing Motorways

This section specifically refers to Smart Freeway works on an existing freeway improvement (no mainline widening). These Smart Freeway works include improved capacity and performance from existing infrastructure by managing the mainline traffic with coordinated ramp signals.

Therefore, it is essential that a reliable understanding of existing traffic demands is achieved through investigation, particularly in the context of traffic demand for entry ramp design. Understanding of traffic demand for design of entry ramps is particularly important when retrofitting an existing freeway, as it can be difficult to satisfy traffic demand with existing entry ramp designs, where demand management is needed to achieve improved mainline productivity.

The MMDG includes guidance on a number of relevant matters that may need to be considered. The following additional comment and guidance is provided for Main Roads application.

Part 3 Section 3.2.2: Design Traffic Volumes

Part 3 Section 3.2.2 - 3rd dot point

This guidance relates to understanding varying ramp demands within the peak hour for existing freeway improvement projects (no widening). It shall also be applied to 'existing freeway upgrade' projects where there is minimal extent of widening (localised widening only to accommodate ramp improvements.) and where no strategic modelling is carried out to determine forecast design volumes. Where mainline widening interacts with more than one interchange it should fall into the freeway upgrade category as it would have the ability to change traffic patterns. It indicates that the highest five-minute flow rate (or 15-minute flow rate factored up by five per cent) should be used as the basis for considering the minimum ramp demand for discharge and storage, rather than an hourly flow which may not reflect varying ramp demands during the peak period.

The purpose of this guidance is to ensure adequate design for operations where the average peak hour flow does not represent the flow rate that occurs over a shorter period of time within the peak hour. For many entry ramps with relatively constant demand through the peak hour, the five-minute flow rate, 15-minute flow rate and the hourly flow rate will be similar (e.g. traffic leaving a signalised intersection with similar cycle times through the peak).

It is expected that most of the entry ramps within the Perth metropolitan area will fall within this traffic demand regime with relatively constant demand throughout the peak hour. In such cases, the 15-minute flow rate factored up by five per cent is recommended to be used as the basis for hourly design volumes to ensure the maximum likely demand during the peak is used for design for existing freeway improvement works (no widening), plus any other factors relating to traffic growth and suppressed demand as outlined below.

However, at some ramps this may not be the case. For example, a ramp in an industrial area or a local road with a school where road users generally leave at about the same time can result in a sharp increase in traffic demand over a short period. In this case the flow rate over a shorter period of time that occurs within the peak hour should be the basis for ramp signal design for ramp discharge and storage (refer MMDG Volume 2, Part 3, Section 6 and Table 6.1 regarding the basis of calculations). In such cases, the existing maximum 5 min. flow x 12 (i.e. factored up to an hour) shall be used as the basis for ramp design.

Simple examples to demonstrate the above principles are provided below:

- Entry ramp from an arterial road with constant traffic demand: An 840 veh/h design flow would result in a ramp discharge design with two-lanes and minimum of 476 metres of storage.
- Entry ramp from an industrial area: A 400 veh/h design flow would normally result in a ramp discharge design with one-lane and 227 metres of storage. However, if the majority of the flow occurs within a short period, e.g. 70 veh/5-min, these flows should be factored up to 70 x 12 = 840 veh/h for design if excessive delays are to be avoided during operations when ramp demand is higher than the average hourly volume, i.e. the design needs to satisfy requirements of two-lanes and 476 metres of storage (may also need factoring up if there is a significant proportion of trucks).
- This matter shall be considered by designers when working with existing flow data and the hourly average ramp flow does not represent traffic demand over a short period during the peak.

Existing Freeway Upgrading and New Freeway Design projects

ROM strategic modelling is to be carried out for 'existing freeway upgrading' (with widening) and 'new freeway design' projects to determine forecast daily ramp volumes for an appropriate design life (see Provision Guidelines section 4.1.2). These daily forecasts are used to determine peak hour ramp volumes by using an appropriate K-factor.

For upgrading of an arterial road, e.g. with signalised intersections, to a freeway standard roadway, this would generally include significant change to capacity, design volumes and traffic patterns. The design would also be targeting a relatively long design life and forecast volumes. Therefore, this upgrade would be defined as a new freeway.

For the above projects, ramp design shall be based on design volumes based on a maximum 15-minute flow rate using a Peak Hour Factor (PHF) obtained from Table 3a. The peak hour ramp volumes are divided by the PHF to determine the design volumes (veh/h) for ramp signal design. These are then converted to passenger cars (pc/h) for calculation of discharge capacity and storage as required in the MMDG.

Table 3a: Peak Hour Factors (PHF) to be used to determine Design Flows

Freeway / Roadway Section	PHF	
	AM Peak	PM Peak
Kwinana Freeway Northbound	0.93	0.93
Mitchell Freeway Southbound	0.93	0.93
All other road sections with CRS	0.95	0.95

Part 3 Section 3.2.2 - 5th dot point
This guidance relates to understanding the nature of existing traffic and traffic growth with a view to determining forecast traffic volumes for design of existing freeway improvements.

This is important if ramp capacity is to be provided for future traffic demand (e.g. anticipated changes to land use or development), or to accommodate additional traffic resulting from the managed mainline. This will have implications for ramp design relating to discharge capacity and storage.

This matter shall be considered by designers when working with existing flow data in the context of determining design traffic volumes for the peak hour. Options may include applying an appropriate growth factor, or in some cases, using traffic modelling to assist in refining design volumes.

Part 3 Section 3.2.2 - 6th dot point
This guidance relates to understanding the nature of suppressed traffic demand.

This will be important to consider where it is expected that existing volumes do not represent actual traffic demand (suppressed demand). It can also be related to anticipated traffic increases (induced demand) on the ramp resulting from improved freeway throughput due to the operation of coordinated ramp signals.

This matter shall be considered by designers when working with existing flow data in the context of determining design traffic volumes for the peak hour. Options may include applying an appropriate growth factor, manual redistribution of traffic, or using traffic modelling to assist in refining design volumes.

Part 3 Section 3.2.2 - 7th dot point
This guidance relates to understanding the traffic demand outputs from strategic models and where projects may not be able to accommodate demand. Related guidance is provided in the MMDG Section 3.3.4 and 4.4.7.

This matter shall be considered by designers (together with other Main Roads' guidelines) if there is a project requirement to carry out strategic modelling as part of the process to determine peak hour design volumes.

Where the project development process indicates that the design is not able to meet traffic demand, this needs to be documented as part of the process – refer MMDG Section 4.4.7. In this case additional storage (e.g. ramp redesign and/or storage on the arterial road) can facilitate system operation to optimise productivity by accommodating excess queues. Where feasible, this shall be provided to prevent queues interfering with arterial road operation.

Part 3 Section 3.3: Upgrading Motorway Capacity or New Motorway Projects

This section specifically refers to existing freeway upgrading (includes mainline widening) or a new freeway. These Smart Freeway works relate to achieving improved capacity and network performance with additional mainline infrastructure as well as by managing the mainline traffic with coordinated ramp signals (if warrants are satisfied – see the Smart Freeways Provision Guidelines).

The MMDG also provides guidance relating to staging strategies, limits of control within the project scope, and determining design traffic volumes from strategic models. While the guidance provides valuable background and awareness, it is not intended to provide details of how to carry out traffic modelling where reference shall be made to Main Roads' current guides.

For example, this will be important to consider if a planning investigation indicates that a two-lane freeway requires upgrading to an ultimate four-lane freeway in each direction over the full route. This investigation would need to consider the ultimate forecast traffic volumes and capacity requirements as well as warrants for higher order ITS (see the Smart Freeways Provision Guidelines) in the long-term planning. However, if staging of the ultimate project includes initial upgrading to three-lanes in each direction, and different section lengths for construction packages, then each of the medium-term projects should also be considered for standalone satisfactory traffic operation, including forecast volume/design capacity warrants for higher order ITS (see the Smart Freeways Provision Guidelines).

In situations where CRS are needed, there is also the possibility that the required extent of ramp signals will extend beyond the formal limits of a widening project. Decisions would also need to be made relating to interchange layouts for medium and longer-term needs.

Part 3 Section 3.3.4.3.3: 24-hour models

This guidance relates to understanding the ratio and relationship of peak period traffic demand relative to the 24-hour traffic demand, and its application to outputs from 24-hour strategic models.

For 24-hour models, the peak / 24-hour ratio (K-factor) varies significantly depending on the nature of the traffic demand, level of congestion (due to loss of throughput) and whether it is a radial or circumferential route. The choice of K-factor can have the following implications:

- If the ratio used is too low this can result in infrastructure being under-designed with the facility not meeting traffic demand after construction.
- If the ratio used is too high, the infrastructure could be over-designed with potential for wasting money and resources.

Where analysts or designers are determining ratios from existing flow data, this shall be based on the real short-term demand, i.e. the 15-minute flow rate factored up to an hourly flow rate shall be used for this purpose, rather than the one-hour flow.

As an example, the volumes forming the basis of Figure 3-1 in the MMDG (Vol. 2, Part.3), together with the differing K-factor values are:

- Max. hourly flow (which includes periods of congestion) at a freeway section with four lanes in one direction is measured to be 7,528 veh/h and a daily flow rate of 88,035 veh/day.
  - Therefore, the K-factor based on a peak hour flow = 7,528/88,035 = 8.5%.
- At the same site the maximum 15-min. flow (i.e. peak demand) was measured to be 1,980 veh.
  - Therefore, based on the 15-min peak demand, the hourly flow rate is = 4 x 15-min flow rate = 4 x 1,980 = 7,920 veh/h, and
  - The K-factor based on the 15-min flow rate = 7,920/88,035 = 9.0%.
- The K-factor at the above location should, therefore, be taken as 9.0%.

For heavily trafficked freeways (includes high traffic volumes during the inter-peak period), the K-factor value is typically in the order of nine per cent. The use of a K-factor less than nine per cent for Smart Freeway planning and/or design requires detailed justification (refer Smart Freeway Policy Framework Overview section related to governance).

When converting 24-hour model forecasts to peak period design volumes for a new freeway design the same K-factor would generally be applied to the mainline, interchanges and ramps. For an existing freeway improvement or upgrading where modelling is carried out, different K-factors can be applied to interchange traffic movements where this can be justified from existing data. In this case, the K-factor for the ramps would generally be consistent with the mainline value to maintain flow balance relative to entering and exiting volumes. Where there are pronounced peaks and the volumes outside peaks are relatively low as with some roads in the fringes of the metropolitan area, using existing data may lead to inappropriately high K-factors. In such situations, K-factors should be capped at 10 per cent for urban freeways and turning movements at a systems interchange, and 12 per cent for individual turning and through movements at a service interchange.

Part 3 Section 3.5: Mainline Carriageways

This section provides additional geometric ramp spacing guidance relative to both traffic safety outcomes and capacity. This guidance shall be considered for freeway planning and design as well as other geometric design matters considered under the Austroads guides and Main Roads' Supplements.

Part 3 Section 3.6.3: Ramp Spacing

This section provides additional geometric ramp spacing guidance relative to both the Austroads' Guide to Traffic Management and the Austroads' Guide to Road Design. Typically, ramp spacing is defined as the distance between the centrelines of successive crossroads with interchanges on the motorway.

The section introduces new 'taper separation' terminology and provides guidance relating to the taper separation distance that is related to entry ramp design, exit ramp design, spacing for safety, spacing for traffic operations and spacing for exit ramp signage.

This guidance shall be considered for freeway planning and design as well as other geometric design matters considered under the Austroads' guides and Main Roads' Supplements.

Part 3 Section 3.7.2: Mainline / Ramp Entry Layout Configurations

The principles in this section shall be read in conjunction with other Main Roads' guidance. Information in MMDG Table 3.1 shall be replaced with guidance in Main Roads' Supplement to the Austroads' Guide to Traffic Management Part 3: Traffic Studies and Analysis. Entry ramp horizontal geometry shall be designed in accordance with Main Roads' Supplement to Austroads' Guide to Road Design - Part 4C and the Drawings listed in Section 6.4.1 of that Supplement.

Part 3 Section 3.7.3: Mainline / Ramp Exit Layout Configurations

The principles in this section shall be read in conjunction with Main Roads' guidance. Information in MMDG Table 3.2 shall be replaced with guidance in Main Roads' Supplement to the Austroads' Guide to Traffic Management Part 3: Traffic Studies and Analysis. Exit ramp horizontal geometry shall be designed in accordance with Main Roads' Supplement to Austroads' Guide to Road Design - Part 4C and the Drawings listed in Section 6.4.1 of that Supplement.

Part 3 Section 4.3: Mainline Capacity Analysis and Design

The Maximum Sustainable Flow Rate (MSFR) to be used for design capacity varies according to the type of control (managed, partly managed, or unmanaged), number of lanes, grade and proportion of trucks, due to the flow effects of these factors on capacity. The MSFR values in the MMDG may also need to be adjusted according to other factors indicated in Section 4.3.2.

For existing freeway improvement (no widening) projects (refer Part 3, Section 1.3 above), an assessment of actual capacity may be considered for design. In this case the measured capacity (adjusted for Smart Freeway operation design) or applicable MSFR may be used for mainline design, whichever is lower.

For existing freeway upgrading projects with widening, the capacity will change due to the additional lane(s), and possibly other improvements, so generally the applicable MSFR should be used for design. However, if the existing measured capacity is considered for these projects, it would need adjustment for the additional capacity being provided. In this case the adjusted existing capacity or applicable MSFR would be used for design, whichever is lower.

When existing capacity is being assessed the methodology shall be consistent with Victoria's MMDG Volume 1: Part 3, section 3.3.2 (Approach 2, Variant b), and section 3.3.3 'Capacity' (Approach 2, Probability of flow breakdown) to determine the MSFR capacity and flow breakdown probability curves.

Part 3 Section 4.3.1: Maximum Sustainable Flow Rates for Mainline Design

The MSFR values in Tables 4.1, 4.2 and 4.3 in Victoria's MMDG Vol 2, Part 3 are listed in veh/h. Since all Smart Freeways assessments are undertaken using PCU/h values, the following tables for MSFR are to be used in lieu:

No of Lanes on Mainline	Gradient, s			
	s<=2%	2% < s <= 3%	3% < s <= 4%	4% < s <= 5%
1	2100	1975	1875	1725
2	4175	3950	3750	3450
3	6050	5750	5450	5025
4	7800	7400	7025	6475
5	9275	8800	8350	7700

Table 4.1: Managed Motorway Sections - MSFR design values (PCU/h)

No of Lanes in Tunnel	Gradient, s			
	s<=2%	2% < s <= 3%	3% < s <= 4%	4% < s <= 5%
1	1900	1850	1750	1600
2	3800	3625	3425	3150
3	5725	5425	5150	4750
4	7625	7250	6850	6325

Table 4.2: Managed Motorway Tunnel Sections - MSFR design values (PCU/h)

No of Lanes on Mainline	Gradient, s			
	s<=2%	2% < s <= 3%	3% < s <= 4%	4% < s <= 5%
1	1800	1700	1600	1500
2	3550	3375	3200	2950
3	5150	4875	4625	4275
4	6625	6300	5950	5500
5	7875	7475	7100	6550

Table 4.3: Un-Managed Motorway Sections - MSFR design values (PCU/h)

Part 3 Section 4.3.2: Adjustments to MSFR Values in Design

Refer subsections below.

Part 3 Section 4.3.2.4: Lane Drops and Section 4.3.2.5: Exclusive Exit Lanes

In Western Australia, where a lane drop is required at a freeway ramp exit, the practice has traditionally been to carry the lane past the ramp nose and then instigate the lane drop (see MMDG Figure 4-2). The rationale behind this is to avoid a "trapped lane" that may result in drivers changing lanes at the last second, or worse, driving across the gore area.

A lane drop is a source of turbulence and research has shown that a midblock lane drop can cause a capacity drop in an unmanaged freeway of 10 to 20 per cent. There is a lack of research on this matter in relation to lane drops after an exit; however, it is not unreasonable to assume a capacity drop of 10 per cent.

It has been found that if the lane drop is provided as an exclusive exit lane (see MMDG Figure 4-3), provided sufficient advance warning of the exclusive exit is given, (enabling drivers to move into the correct lanes well in advance of the exit), then the loss of capacity is minimised. Therefore, from a design point of view, it is important that consideration be given to capacity implications of lane layout arrangements and how a lane drop is affected to minimise turbulence and optimise the freeway capacity. For appropriate ramp spacing guidelines, the designer should refer to the MMDG Section 3.6.3.

In the case of weaving sections, reference shall be made to MMDG Section 4.3.2.9, subject to the other guidance below. The Highway Capacity Manual generally over-estimates capacity so these analyses are discouraged.

In any analysis for both weaving sections and exit-ramps, in the case of lane drops after the exit, the through-traffic volume shall not exceed 90 per cent of the applicable MSFR (unmanaged or managed) for the downstream freeway due to the expected turbulence and potential for flow breakdown.

The following guidelines may be used to determine whether or not an effective lane drop could be achieved through the provision of an exclusive exit lane.

For all lane reductions

The mainline design volume / MSFR analysis (see MMDG Section 4.4) shall be carried out to assess the capacity of the proposed layout. Where the lane reduction is from an auxiliary lane or an exclusive exit lane, appropriate reductions in the MSFR upstream of the exit shall be included in the evaluation in accordance with MMDG Sections 4.3.2.3 and 4.3.2.5 respectively. The following guidance may also be appropriate.

In the case of a three-lane freeway upstream of the exit, if the exiting traffic volume is approximately 33 per cent or more of the approach volume, then an exclusive exit lane may be appropriate based on Main Roads' Supplement to the Austroads' Guide to Traffic Management Part 3: Traffic Studies. If the exiting volume is greater than 1,350 veh/h then a two-lane exit may be more appropriate).

In the case of a four-lane freeway upstream of the exit, if the exiting traffic volume is approximately 25 per cent or more of the approach volume, then an exclusive exit lane may be appropriate.

The lane to be dropped is an auxiliary lane[1]

If the distance between the adjacent upstream entry-ramp and the exit is short (< 450 metres between "edges meet" points) *and* the weaving volumes are relatively light (< 1000 veh/h) then an exclusive exit lane may be appropriate.

If the distance between the adjacent upstream entry-ramp and the exit is short (< 450 metres between "edges meet" points) *and* the weaving volumes are relatively heavy (> 1000 veh/h), the majority of which originates from the adjacent upstream entry-ramp, then an exclusive exit lane may not be appropriate.

The lane to be dropped is not an auxiliary lane

If the distance between the adjacent upstream entry-ramp and the exit is short (< 450 metres between "edges meet" points) *and* the entering ramp weaving volumes are relatively light (< 500 veh/h) then an exclusive exit lane may be appropriate.

If the distance between the adjacent upstream entry-ramp and the exit is short (< 450 metres between "edges meet" points) *and* the entering ramp weaving volumes are relatively heavy (> 1000 veh/h) then an exclusive exit lane may not be appropriate.

[1] An auxiliary lane in the freeway context is a lane that starts at an entry-ramp (normally as an added lane) and ends at the adjacent downstream exit-ramp (as a lane-drop or exclusive exit lane).

If the provision of an exclusive exit lane means that traffic entering from an adjacent upstream entry-ramp or traffic entering from the ramp immediately upstream of that has to make more than one lane change in order to proceed beyond the exit ramp and the distances between the ramps are relatively short (< 750 metres between nose of entry-ramp to exit ramp nose), then an exclusive exit lane is not appropriate (refer to Figure 1).

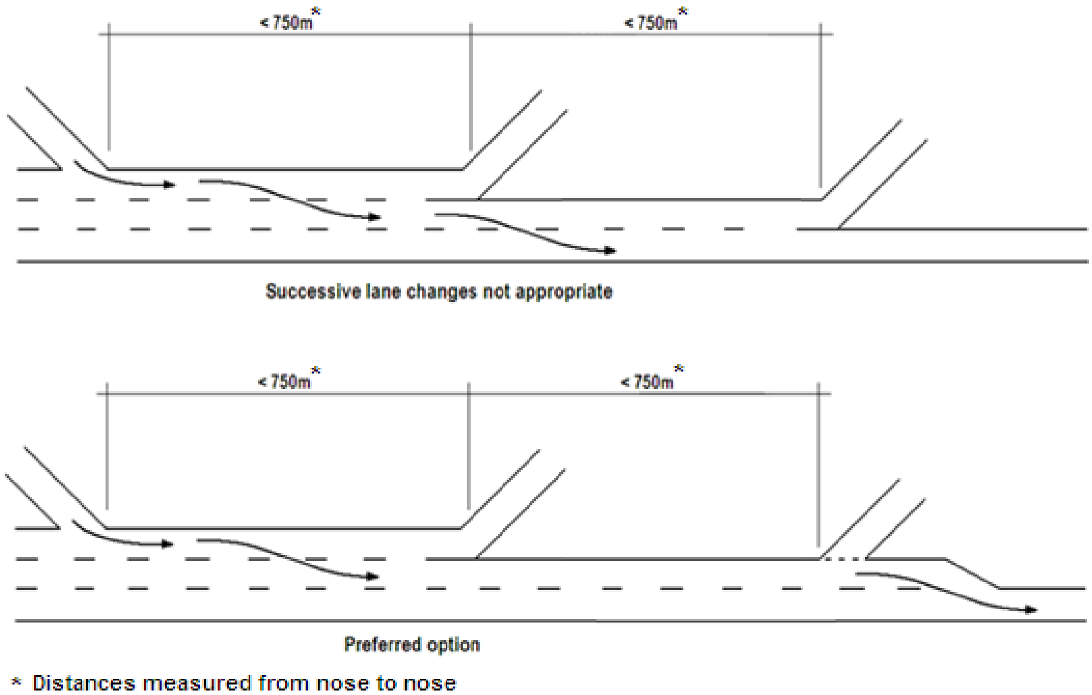


Figure 1: Example of inappropriate exclusive left-turn lane

Part 3 Section 4.3.2.9: High Lane Changing Segments including Weaving

Weaving sections shall be evaluated in accordance with this section and the following additional guidance:

- The Highway Capacity Manual generally over-estimates capacity so the use of these analyses is discouraged.
- Microsimulation analyses may be used for complex or high lane change / weave areas. In this case, the model shall be appropriately calibrated to give comparable outputs relative to similar on-road weaving situations, i.e. to generally replicate real traffic data and traffic operational performance (traffic turbulence and stability etc.).

Part 3 Sections 4.3.2.12 and 4.3.2.13: Mainline / Entry and Exit Ramp Layout Configurations

The principles in these two sections shall be read in conjunction with Main Roads guidance above relating to MMDG Sections 3.7.2 and 3.7.3.

Part 3 Section 4.4: Mainline Design Volume / MSFR Analysis

This section provides guidance on mainline design volume / MSFR (capacity) route analysis which is an enhancement to previous analyses carried out by Main Roads. The analysis methodologies include the use of Maximum Sustainable Flow Rate (MSFR) to be used for design capacity (see MMDG Section 4.3.1) together with adjustments for a number of factors as indicated in MMDG Section 4.3.2.

The enhanced analysis methodology also introduces new concepts and guidance relating to:

- Partially managed transition zones within a section of freeway managed with coordinated ramp signals, i.e. the capacity at the start of a managed section gradually increases from unmanaged to managed operational capacity.
- Uncontrolled entry ramps within a managed section. In this case, the downstream capacity is considered as unmanaged.

Part 3 Section 4.4.4: Methodology

An Excel spreadsheet to calculate capacity and ramp storage requirements along a route may be downloaded here.

If the above link does not work, the spreadsheet can be accessed by searching for 'Smart Freeways Ramp Storage Assessment' in the Technical Library on the Main Roads WA website.

Part 3 Section 4.4.7: Traffic Demand Greater than Mainline Capacity

While this section provides high level principles, it does not provide detail for design, e.g. it indicates: '*Entry ramp storage provisions become more critical in this situation and need to be designed accordingly*', but it does not indicate the design methodology. The following guidance is additional to information in the MMDG.

Figure 2 shows an analysis where the mainline design volume (traffic demand) exceeds the maximum sustainable flow rate (capacity). In this example when considering the worst case segment along the route, the excess unmanaged traffic demand is 900 veh/h averaged over the design hour.

To manage this situation in design, the preferred approach is to reconsider the project design and/or scope so that mainline traffic can be managed within the route capacity.

If a change in mainline design is not feasible, the entry ramp storage provisions need to be reconsidered to provide additional storage to accommodate the excess traffic. This may be spread across a number of upstream entry ramps so that traffic can be held back from entering the mainline during operations (in this example 510 metres additional storage as per MMDG Vol. 2 Part 3, Table 6.1). This may include entry ramps that have surplus storage i.e. greater than desirable minimum four minutes (except low flow ramps, i.e. < 600 veh/h), and preferably at the ramps which are closest to the problem. For this situation, there also needs to be project handover advice and guidance for the ramp signal operator, e.g. to indicate in the route management strategy that traffic demand management is needed to manage the mainline (minimise flow breakdown), and that this may require longer waiting times on entry ramps in the system for management of operations.

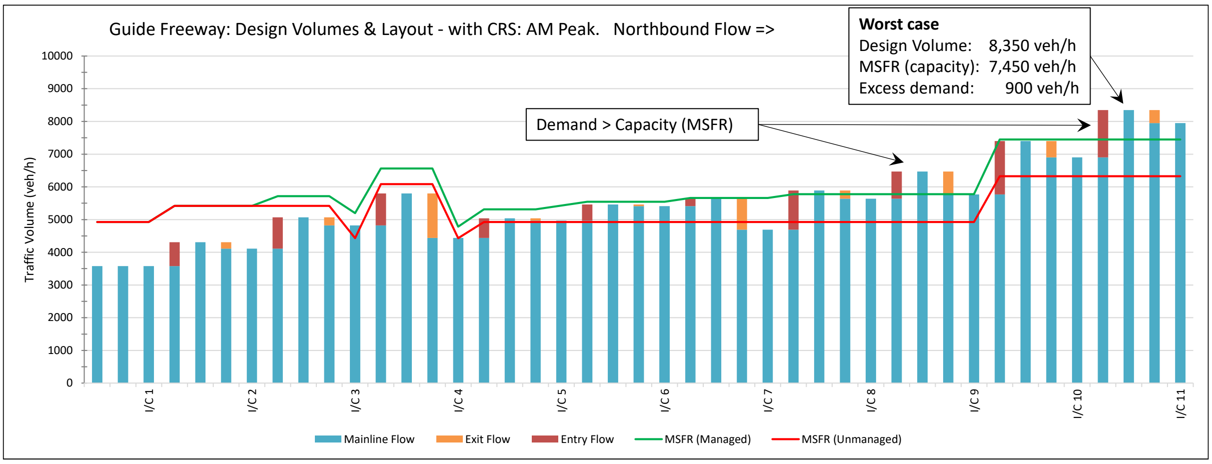


Figure 2: Example of mainline design volume exceeding the MSFR (capacity)

Part 3 Section 5: Design of Mainline Vehicle Detector Locations

The principles in this section shall be read in conjunction with Main Roads' guidance for installation of vehicle detector stations (VDS) in Main Roads' Specification 708.

The Main Roads' guideline drawings listed in Annexure 708A of the specification show typical layout arrangements for VDS detection systems. The specification drawings can be downloaded from the Main Roads' website.

Part 3 Section 6.2: Entry Ramp Discharge and Section 6.3: Storage Design

The focus of the designer should be on providing adequate ramp discharge capacity (number of lanes at the stop line) and ramp storage. These provisions are essential for achieving effective ramp signals operation to manage the mainline operation and to minimise adverse impact on the adjacent arterial road network. It should be noted that the ramp design flow for storage calculations (Table 6.1) is in passenger cars per hour (pc/h).

Smart Freeway proposals that do not meet requirements for ramp discharge capacity and/or ramp storage are subject to the approval processes in the Smart Freeways Policy Framework Overview.

Part 3 Sections 6.4 to 6.8: Geometric Design and Layout of Entry Ramps

Part 3 Section 6.4.4: Standard Drawings

The principles in this section shall be read in conjunction with the following Main Roads' guidance for the geometric layout of entry ramps, ramp signals and associated devices. The Main Roads' guideline drawings in Table 4 replace MMDG Table 6.4 and the VicRoads standard drawings.

Table 4: Main Roads' ramp signals guideline drawings

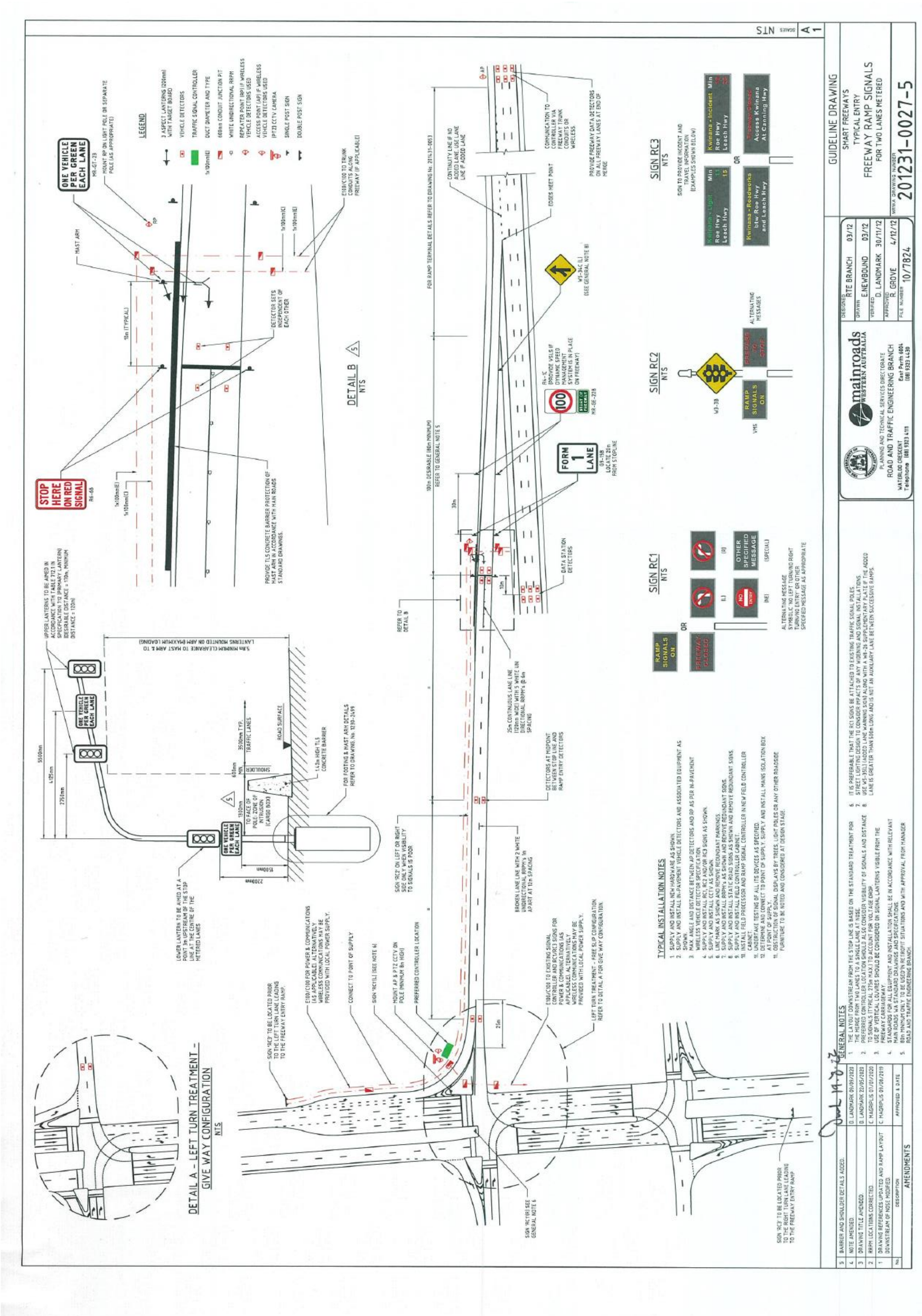
Ramp Type	Drawing No.
Two lanes of metered traffic	201231-0027
Two lanes of metered traffic plus a metered priority lane: Option P1	201231-0028
Two lanes of metered traffic plus a metered priority lane: Option P2	201231-0029
Three lanes of metered traffic to one lane at the nose	201231-0030
Four lanes of metered traffic to two lanes at the nose	201231-0031
Three lanes of metered traffic to two lanes at the nose	201231-0032
Freeway to freeway interchange	201231-0053
Two Lanes Metered Plus Dynamic Metered Lane	201731-0028

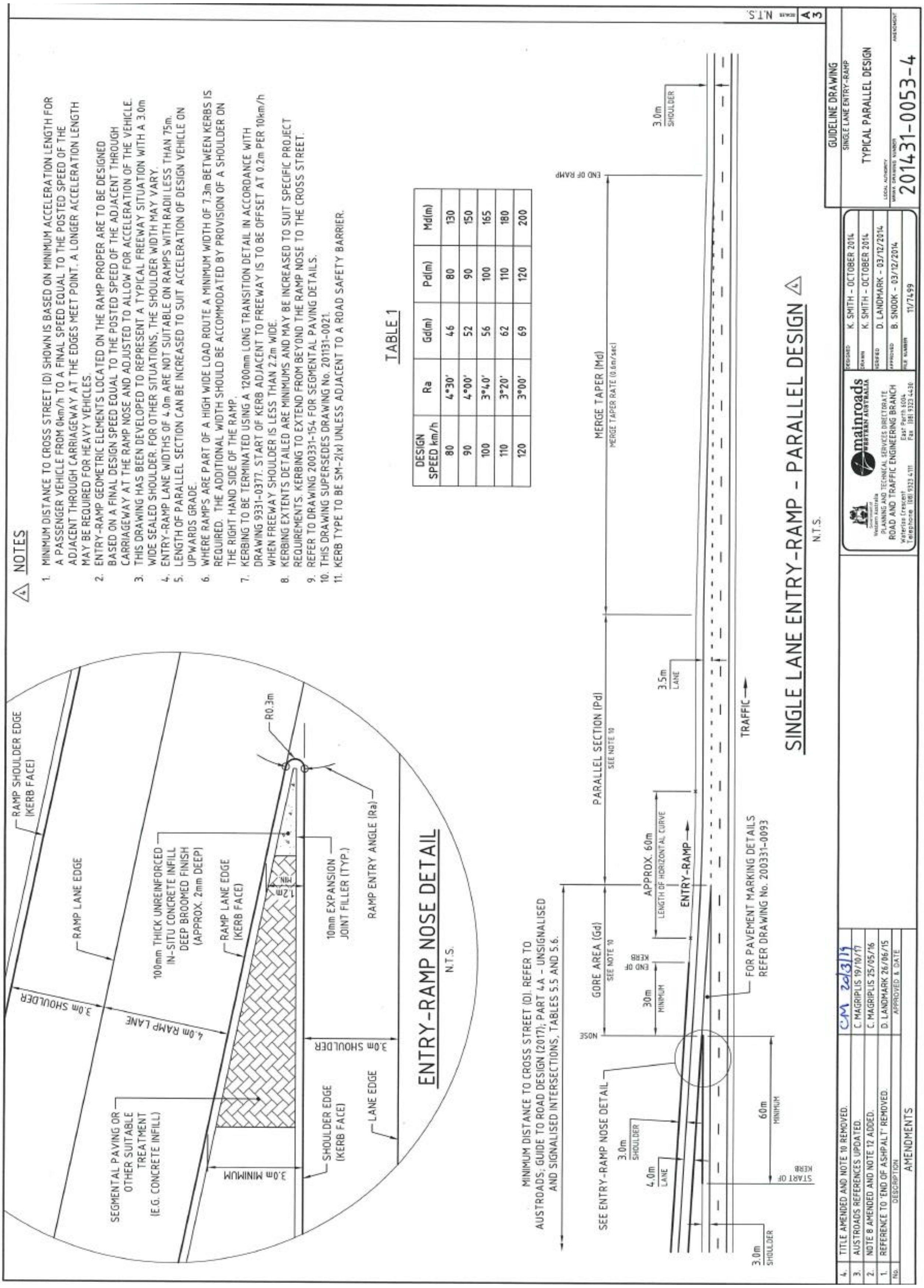
Part 3 Section 6.5: Two Lane Entry Ramp

The principles in this section shall be read in conjunction with the following guidance.

For two-lane ramps, the stop line is located a desirable minimum distance of 100 metres upstream of the ramp nose as shown in Guideline Drawing No. 201231-0027 below, which replaces the VicRoads drawing. In retrofit situations (existing freeway improvement and existing freeway upgrade projects), where ramp storage is an issue, an absolute minimum of 80 metres may be used, subject to approval as indicated in the Smart Freeways Policy Framework Overview. Specific site conditions where the distance from the stop line to the nose may need to be increased should be considered as per the MMDG.

While the general principles in MMDG Section 6.5 and Figure 6-3 are supported the Main Roads' geometry for acceleration and merging is different as shown in Main Roads' Drawing No. 201431-0053 below.


GUIDELINE DRAWING
SMART FREEWAYS
TYPICAL ENTRY
FREEWAY RAMP SIGNALS
FOR TWO LANES METERED
201231-0027-5



NOTES

1. MINIMUM DISTANCE TO CROSS STREET (D) SHOWN IS BASED ON MINIMUM ACCELERATION LENGTH FOR A PASSENGER VEHICLE FROM 0km/h TO A FINAL SPEED EQUAL TO THE POSTED SPEED OF THE ADJACENT THROUGH CARRIAGEWAY AT THE EDGES MEET POINT. A LONGER ACCELERATION LENGTH MAY BE REQUIRED FOR HEAVY VEHICLES.
2. ENTRY-RAMP GEOMETRIC ELEMENTS LOCATED ON THE RAMP PROPER ARE TO BE DESIGNED BASED ON A FINAL DESIGN SPEED EQUAL TO THE POSTED SPEED OF THE ADJACENT THROUGH CARRIAGEWAY AT THE RAMP NOSE AND ADJUSTED TO ALLOW FOR ACCELERATION OF THE VEHICLE.
3. THIS DRAWING HAS BEEN DEVELOPED TO REPRESENT A TYPICAL FREEWAY SITUATION WITH A 3.0m WIDE SEALED SHOULDER. FOR OTHER SITUATIONS, THE SHOULDER WIDTH MAY VARY.
4. ENTRY-RAMP LANE WIDTHS OF 4.0m ARE NOT SUITABLE ON RAMPS WITH RADII LESS THAN 75m.
5. LENGTH OF PARALLEL SECTION CAN BE INCREASED TO SUIT ACCELERATION OF DESIGN VEHICLE ON UPWARDS GRADE.
6. WHERE RAMPS ARE PART OF A HIGH WIDE LOAD ROUTE A MINIMUM WIDTH OF 7.3m BETWEEN KERBS IS REQUIRED. THE ADDITIONAL WIDTH SHOULD BE ACCOMMODATED BY PROVISION OF A SHOULDER ON THE RIGHT HAND SIDE OF THE RAMP.
7. KERBING TO BE TERMINATED USING A 1200mm LONG TRANSITION DETAIL IN ACCORDANCE WITH DRAWING 9331-0377. START OF KERB ADJACENT TO FREEWAY IS TO BE OFFSET AT 0.2m PER 10km/h WHEN FREEWAY SHOULDER IS LESS THAN 2.2m WIDE.
8. KERBING EXTENTS DETAILED ARE MINIMUMS AND MAY BE INCREASED TO SUIT SPECIFIC PROJECT REQUIREMENTS. KERBING TO EXTEND FROM BEYOND THE RAMP NOSE TO THE CROSS STREET.
9. REFER TO DRAWING 200331-154 FOR SEGMENTAL PAVING DETAILS.
10. THIS DRAWING SUPERSEDES DRAWING No. 201131-0021.
11. KERB TYPE TO BE SM-2(x) UNLESS ADJACENT TO A ROAD SAFETY BARRIER.

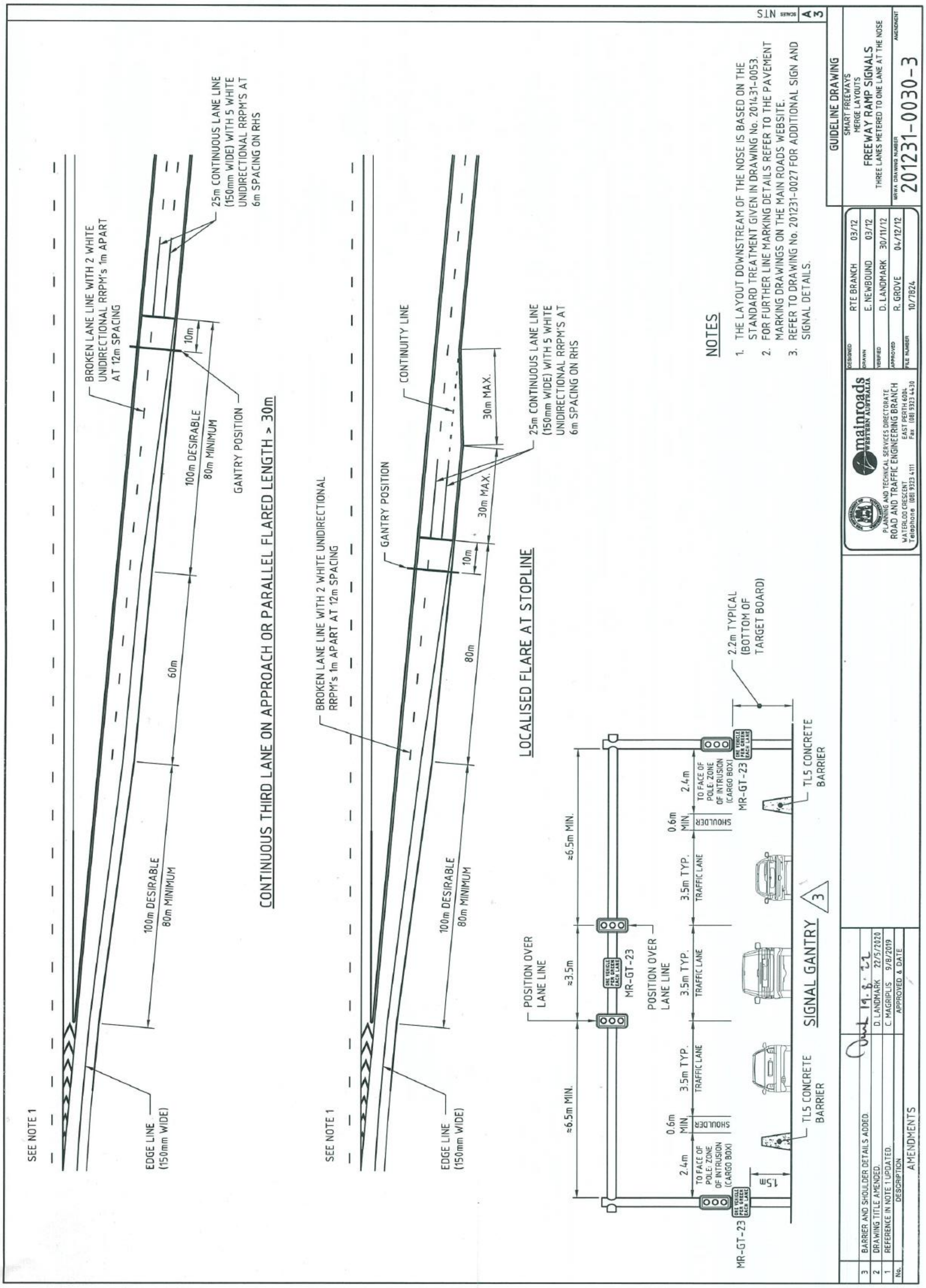
TABLE 1

DESIGN SPEED km/h	Ra	Gd(m)	Pd(m)	Md(m)
80	4°30'	46	80	130
90	4°00'	52	90	150
100	3°40'	56	100	165
110	3°20'	62	110	180
120	3°00'	69	120	200

Part 3 Section 6.6: Three Lane Metered Ramps

The principles in this section shall be read in conjunction with the following Main Roads' guidance.

For three-lane ramps at the stop line, the layout shall be as shown in Main Roads' Guideline Drawing Nos. 201231-0030 (1-lane at ramp nose) and 201231-0032 (2-lanes at ramp nose) below, which replace the VicRoads drawing.


CONTINUOUS THIRD LANE ON APPROACH OR PARALLEL FLARED LENGTH > 30m
LOCALISED FLARE AT STOPLINE
SIGNAL GANTRY
NOTES
1. THE LAYOUT DOWNSTREAM OF THE NOSE IS BASED ON THE STANDARD TREATMENT GIVEN IN DRAWING No. 201431-0053.
2. FOR FURTHER LINE MARKING DETAILS REFER TO THE PAVEMENT MARKING DRAWINGS ON THE MAIN ROADS WEBSITE.
3. REFER TO DRAWING No. 201231-0027 FOR ADDITIONAL SIGN AND SIGNAL DETAILS.
SEE NOTE 1
EDGE LINE (150mm WIDE)
100m DESIRABLE 80m MINIMUM
60m
80m
10m
30m MAX.
GANTRY POSITION
CONTINUITY LINE
BROKEN LANE LINE WITH 2 WHITE UNIDIRECTIONAL RRPM's 1m APART AT 12m SPACING
25m CONTINUOUS LANE LINE (150mm WIDE) WITH 5 WHITE UNIDIRECTIONAL RRPM'S AT 6m SPACING ON RHS
POSITION OVER LANE LINE
MR-GT-23
2.2m TYPICAL (BOTTOM OF TARGET BOARD)
TL5 CONCRETE BARRIER
≈6.5m MIN.
≈3.5m
3.5m TYP.
0.6m MIN.
2.4m TO FACE OF POLE / ZONE OF INTRUSION (CARGO BOX)
1.5m
SHOULDER
TRAFFIC LANE
GUIDELINE DRAWING
SMART FREEWAYS MERGE LAYOUTS
FREEWAY RAMP SIGNALS
THREE LANES METERED TO ONE LANE AT THE NOSE
201231-0030-3
NTS
mainroads WESTERN AUSTRALIA
3 BARRIER AND SHOULDER DETAILS ADDED.
2 DRAWING TITLE AMENDED. D. LANDMARK 22/5/2020
1 REFERENCE IN NOTE 1 UPDATED. C. MAGRIPLIS 9/8/2019
AMENDMENTS

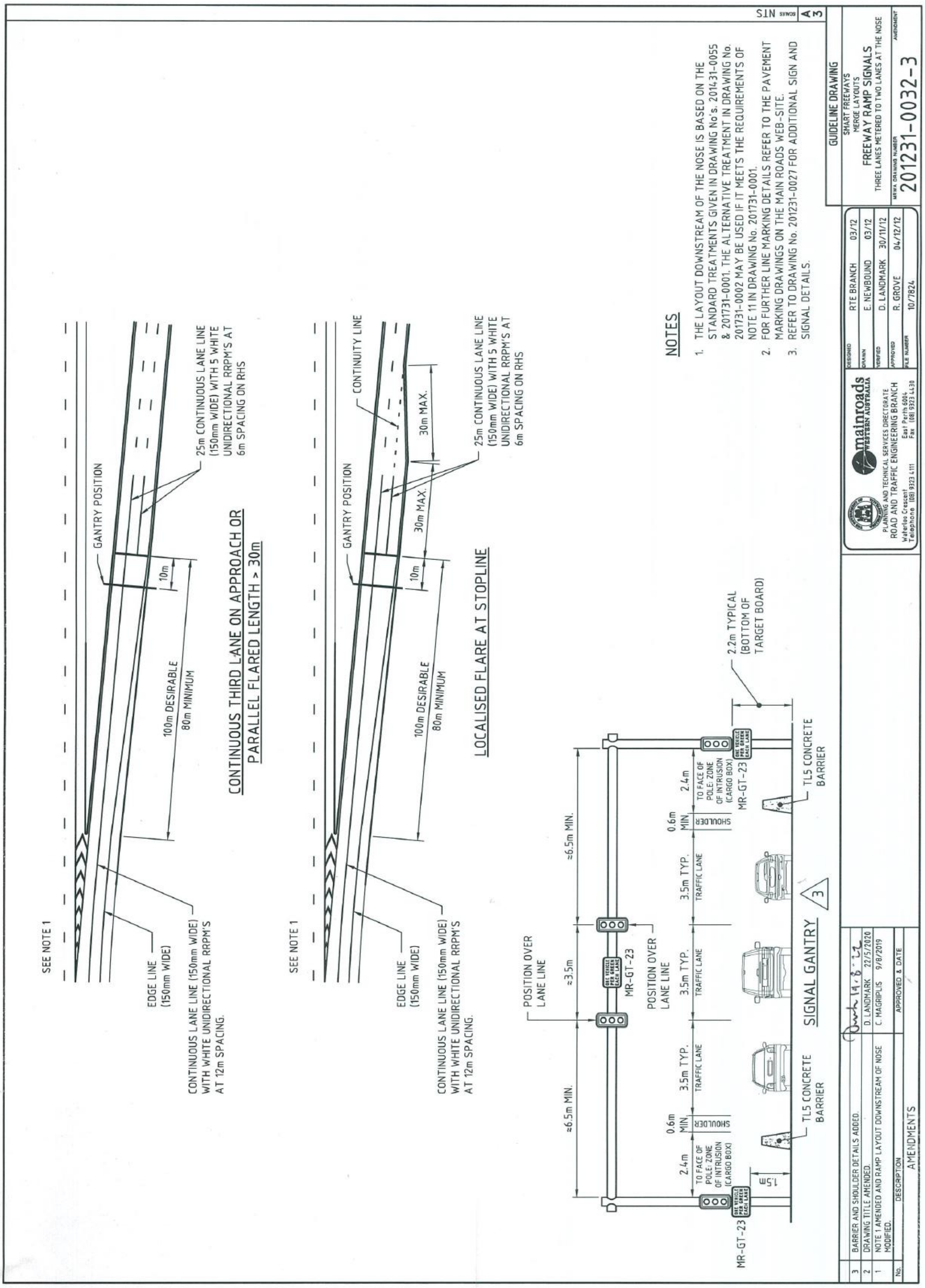

CONTINUOUS THIRD LANE ON APPROACH OR PARALLEL FLARED LENGTH > 30m
LOCALISED FLARE AT STOPLINE
SIGNAL GANTRY
SEE NOTE 1
GANTRY POSITION
EDGE LINE (150mm WIDE)
CONTINUOUS LANE LINE (150mm WIDE) WITH WHITE UNIDIRECTIONAL RRPM'S AT 12m SPACING.
25m CONTINUOUS LANE LINE (150mm WIDE) WITH 5 WHITE UNIDIRECTIONAL RRPM'S AT 6m SPACING ON RHS
100m DESIRABLE
80m MINIMUM
10m
30m MAX.
CONTINUITY LINE
MR-GT-23
POSITION OVER LANE LINE
TL5 CONCRETE BARRIER
2.2m TYPICAL (BOTTOM OF TARGET BOARD)
NOTES
1. THE LAYOUT DOWNSTREAM OF THE NOSE IS BASED ON THE STANDARD TREATMENTS GIVEN IN DRAWING No's. 201431-0055 & 201731-0001. THE ALTERNATIVE TREATMENT IN DRAWING No. 201731-0002 MAY BE USED IF IT MEETS THE REQUIREMENTS OF NOTE 11 IN DRAWING No. 201731-0001.
2. FOR FURTHER LINE MARKING DETAILS REFER TO THE PAVEMENT MARKING DRAWINGS ON THE MAIN ROADS WEB-SITE.
3. REFER TO DRAWING No. 201231-0027 FOR ADDITIONAL SIGN AND SIGNAL DETAILS.
GUIDELINE DRAWING
SMART FREEWAYS
MERGE LAYOUTS
FREEWAY RAMP SIGNALS
THREE LANES METERED TO TWO LANES AT THE NOSE
201231-0032-3
AMENDMENTS

Figure 3 is a special case alternative to the layouts for ramps with three metered lanes and replaces Figure A-1 in the MMDG Part 3 Appendix A. The layout consists of three metered lanes merging to one over a desirable distance of 100 metres (80 metres minimum). The use of the continuity line and the stop line set back of three metres for the left-hand lane ensures that the vehicle in the left-hand lane merges behind the other two vehicles. This layout shall only be used in the following circumstances:

- The option of merging two lanes together first (over 80 metres) and then merging with the third lane (over 100 metres desirable, 80 metres minimum) as shown in Guideline Drawing No. 201231-0030 is not possible due to storage constraints.
- The third lane shall be developed at the stop line using a localised flaring layout.
- Approval for use of this layout shall be as indicated in the Smart Freeways Policy Framework Outline.

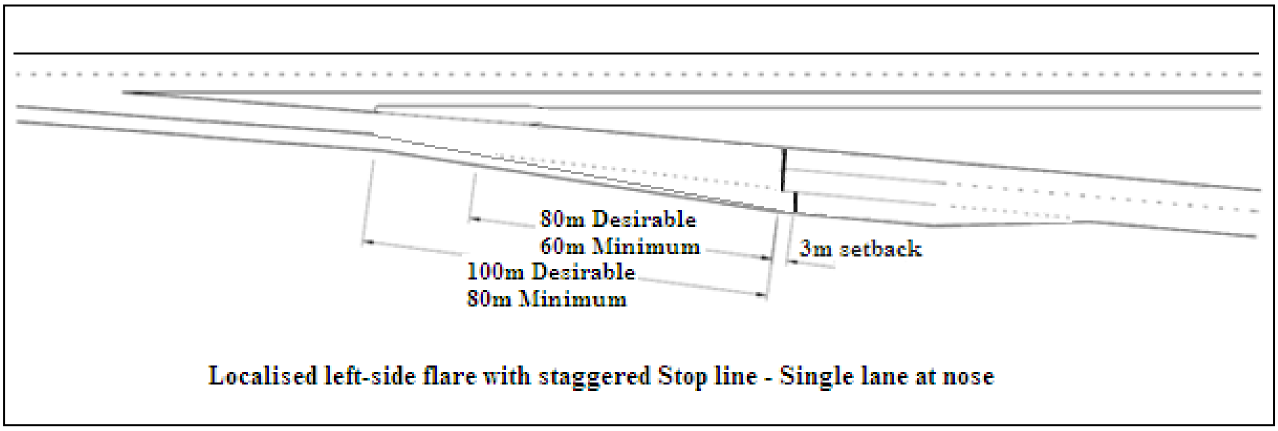
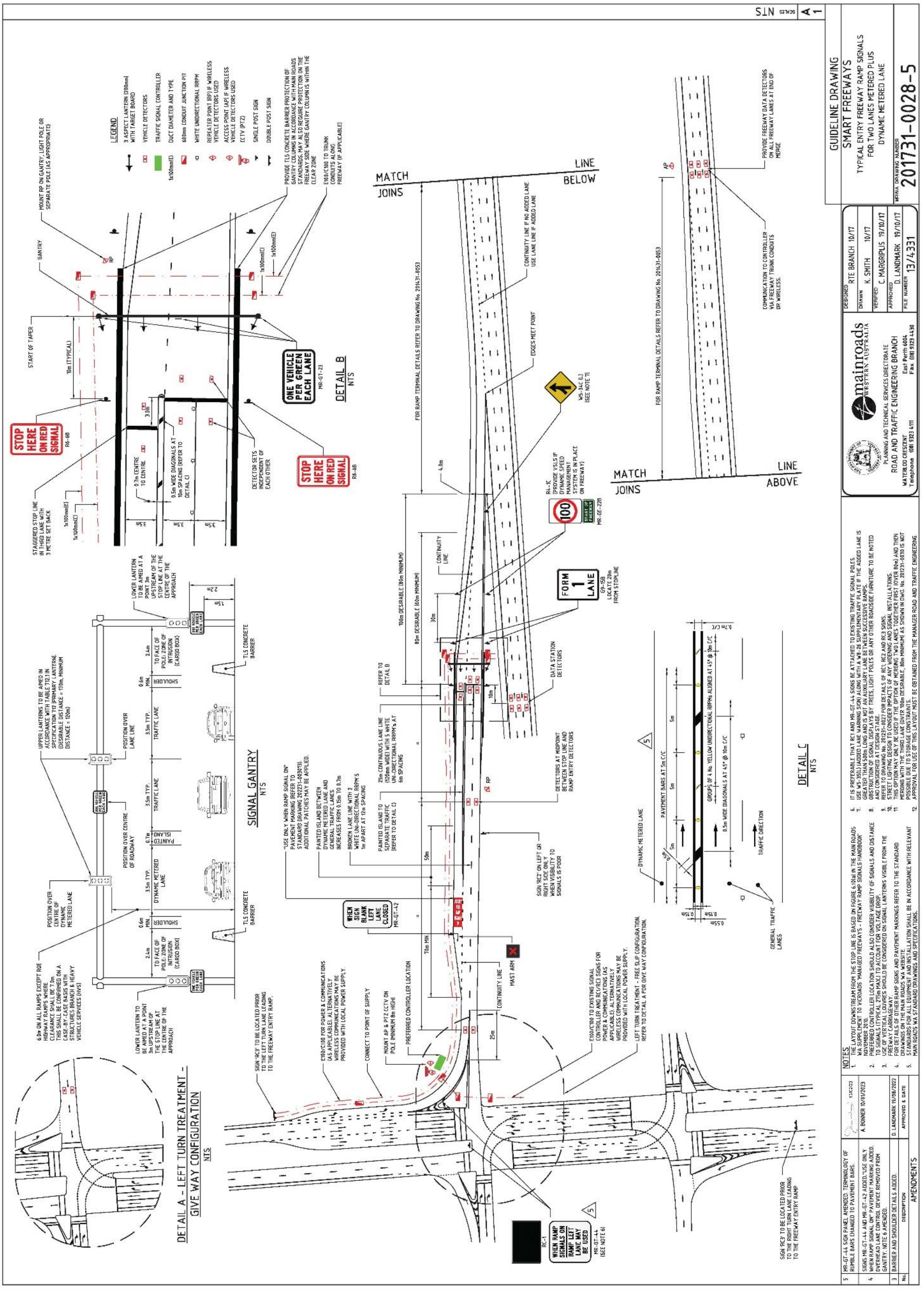


Figure 3: Freeway ramp signals layout – three metered lanes – special case

Guideline Drawing No. 201731-0028 below is also a special case alternative to the layouts for ramps with three metered lanes and is a variation to Figure 3 above. The difference between this option and Figure 3 is that the third lane may extend the full length of the ramp to maximise available storage, but it is controlled by an overhead lane use management sign. This layout shall only be used under the following circumstances:

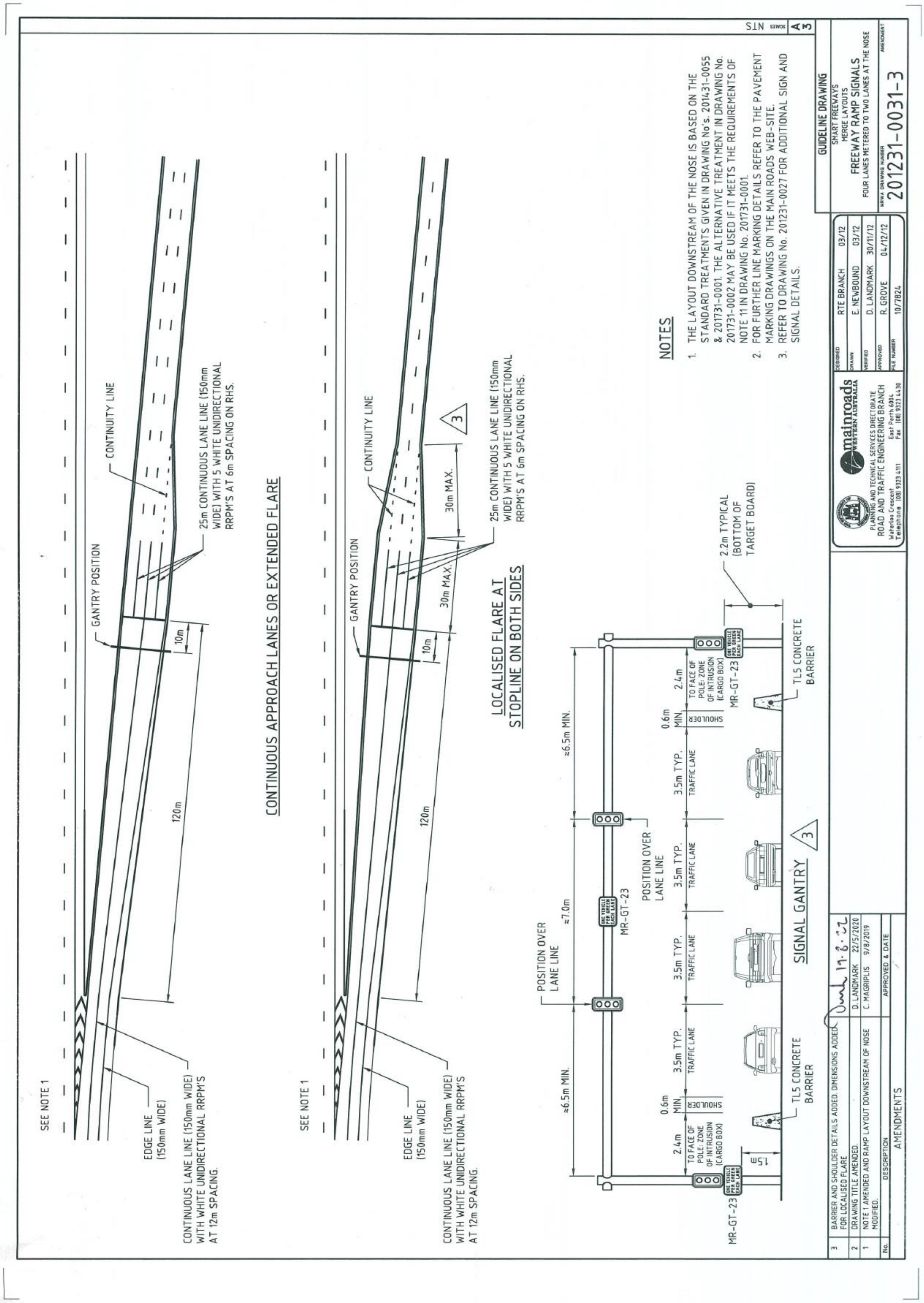
- The option of merging two lanes together first (over 80 metres) and then merging with the third lane (over 100 metres desirable, 80 metres minimum) as shown in Guideline Drawing No. 201231-0030 is not possible due to storage constraints.
- The third lane shall only be used when ramp metering is in operation.
- Approval for use of this layout shall be as indicated in the Smart Freeways Policy Framework Overview.


GUIDELINE DRAWING
SMART FREEWAYS
TYPICAL ENTRY FREEWAY RAMP SIGNALS FOR TWO LANES METERED PLUS DYNAMIC METERED LANE
201731-0028-5
DETAIL A - LEFT TURN TREATMENT - GIVE WAY CONFIGURATION
SIGNAL GANTRY
DETAIL B
DETAIL C
NTS
MATCH LINE BELOW JOINS
MATCH LINE ABOVE JOINS
STOP HERE ON RED SIGNAL
ONE VEHICLE PER GREEN EACH LANE
FORM 1 LANE
100
NOTES
LEGEND
AMENDMENTS

Part 3 Section 6.7: Four Lane Metered Ramps

The principles in this section shall be read in conjunction with the following Main Roads' guidance.

For four lane ramps at the stop line, the layout shall be as shown in Main Roads' Guideline Drawing No. 201231-0031 below, which replaces the MMDG drawing.

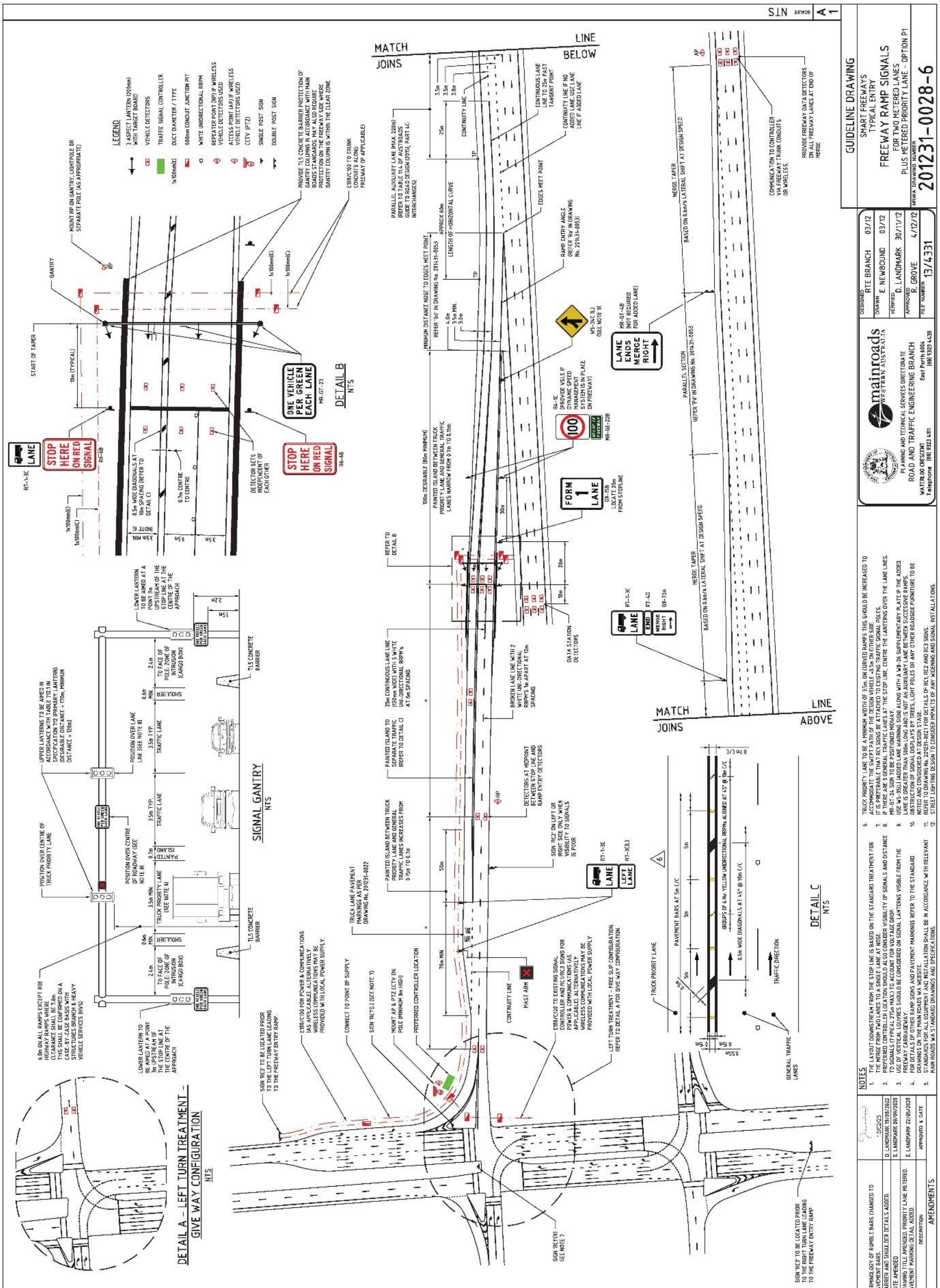

CONTINUOUS APPROACH LANES OR EXTENDED FLARE
LOCALISED FLARE AT STOPLINE ON BOTH SIDES
SIGNAL GANTRY
SEE NOTE 1
GANTRY POSITION
CONTINUITY LINE
25m CONTINUOUS LANE LINE (150mm WIDE) WITH 5 WHITE UNIDIRECTIONAL RRPM'S AT 6m SPACING ON RHS.
EDGE LINE (150mm WIDE)
CONTINUOUS LANE LINE (150mm WIDE) WITH WHITE UNIDIRECTIONAL RRPM'S AT 12m SPACING.
120m
10m
30m MAX.
POSITION OVER LANE LINE
MR-GT-23
≥6.5m MIN.
≥7.0m
2.4m
0.6m MIN.
3.5m TYP.
TRAFFIC LANE
SHOULDER
TO FACE OF POLE ZONE OF INTRUSION (CARGO BOX)
TL5 CONCRETE BARRIER
2.2m TYPICAL (BOTTOM OF TARGET BOARD)
1.5m
NOTES
1. THE LAYOUT DOWNSTREAM OF THE NOSE IS BASED ON THE STANDARD TREATMENTS GIVEN IN DRAWING No's. 201431-0055 & 201731-0001. THE ALTERNATIVE TREATMENT IN DRAWING No. 201731-0002 MAY BE USED IF IT MEETS THE REQUIREMENTS OF NOTE 11 IN DRAWING No. 201731-0001.
2. FOR FURTHER LINE MARKING DETAILS REFER TO THE PAVEMENT MARKING DRAWINGS ON THE MAIN ROADS WEB-SITE.
3. REFER TO DRAWING No. 201231-0027 FOR ADDITIONAL SIGN AND SIGNAL DETAILS.
3 BARRIER AND SHOULDER DETAILS ADDED. DIMENSIONS ADDED FOR LOCALISED FLARE.
2 DRAWING TITLE AMENDED. D. LANDMARK 22/5/2020
1 NOTE 1 AMENDED AND RAMP LAYOUT DOWNSTREAM OF NOSE MODIFIED. C. MAGRIPLIS 9/8/2019
No. DESCRIPTION APPROVED & DATE
AMENDMENTS
mainroads WESTERN AUSTRALIA
PLANNING AND TECHNICAL SERVICES DIRECTORATE
ROAD AND TRAFFIC ENGINEERING BRANCH
DESIGNED RTE BRANCH 03/12
DRAWN E. NEWBOUND 03/12
VERIFIED D. LANDMARK 30/11/12
APPROVED R. GROVE 04/12/12
FILE NUMBER 10/7824
GUIDELINE DRAWING
SMART FREEWAYS
MERGE LAYOUTS
FREEWAY RAMP SIGNALS
FOUR LANES METERED TO TWO LANES AT THE NOSE
201231-0031-3
SCALES NTS
A3

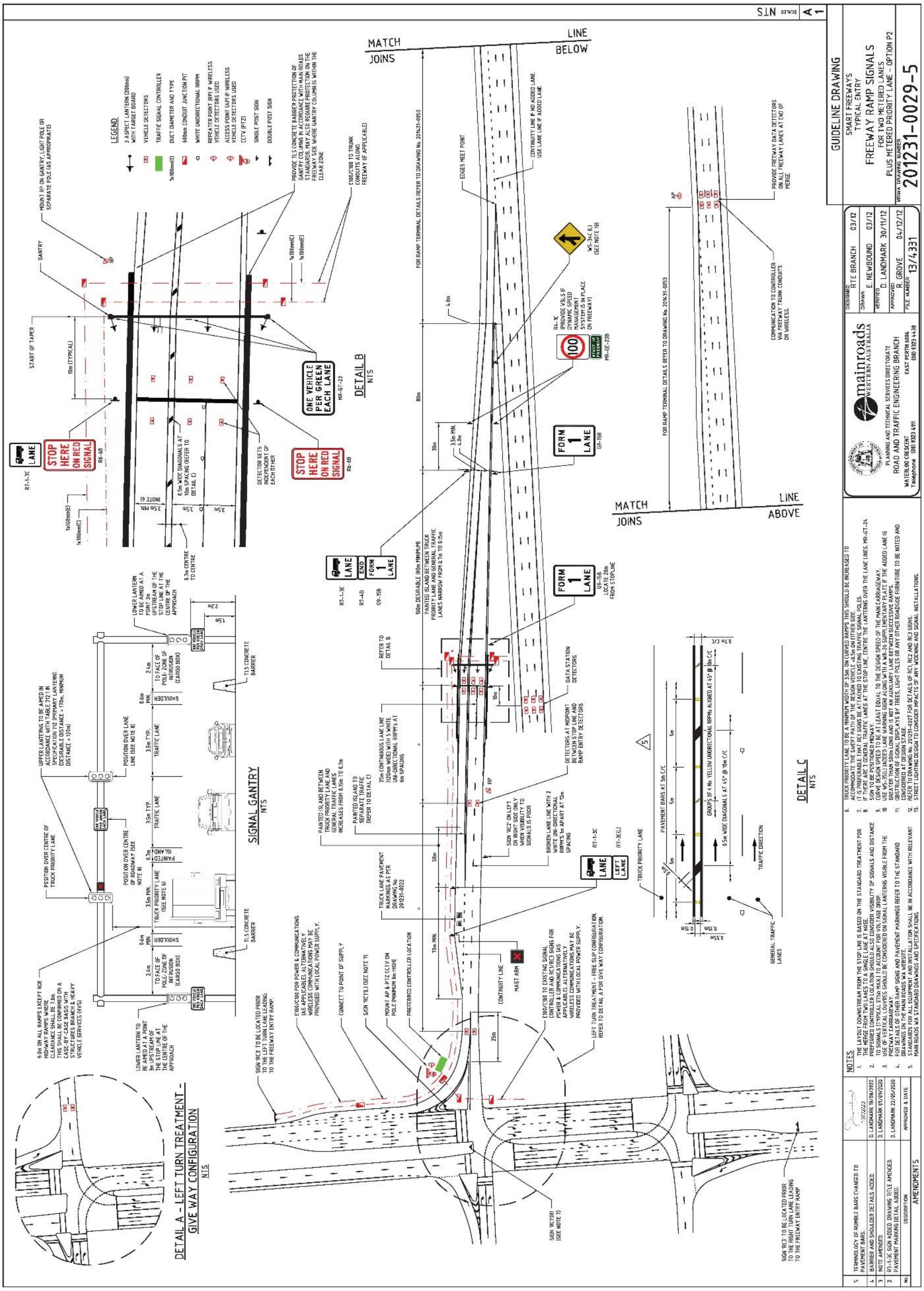
Part 3 Section 6.8: Priority Access Lanes

The principles in this section for all priority access lanes at ramp signals to be metered are supported and shall be read in conjunction with the following Main Roads guidance.

Metered Priority Lanes: Option 1, the layout shall be as shown in Main Roads' Guideline Drawing No. 201231-0028 below, which replaces the MMDG drawing. Option 1 shall be adopted on an uphill grade where it is considered that trucks may not be able to reach an acceptable speed for merging with Option 2 merge geometry.

Metered Priority Lanes: Option 2, the layout shall be as shown in Main Roads' Guideline Drawing No. 201231-0029 below, which replaces the MMDG drawing. Approval for use of this layout shall be as indicated in the Smart Freeways Policy Framework Overview.


GUIDELINE DRAWING
SMART FREEWAYS
TYPICAL ENTRY
FREEWAY RAMP SIGNALS
FOR TWO METERED LANES
PLUS METERED PRIORITY LANE - OPTION P1
201231-0028-6
SIGNAL GANTRY
DETAIL B
DETAIL C
DETAIL A - LEFT TURN TREATMENT - GIVE WAY CONFIGURATION
NOTES
AMENDMENTS
MATCH LINE BELOW
MATCH LINE ABOVE


GUIDELINE DRAWING
SMART FREEWAYS
TYPICAL ENTRY
FREEWAY RAMP SIGNALS
FOR TWO METERED LANES
PLUS METERED PRIORITY LANE - OPTION P2
201231-0029-5
SIGNAL GANTRY
DETAIL B
DETAIL C
DETAIL A - LEFT TURN TREATMENT - GIVE WAY CONFIGURATION
MATCH LINE BELOW
MATCH LINE ABOVE
NOTES
AMENDMENTS

Part 3 Section 6.9: Designing for Future Retrofitting Ramp Signals

The principles in this section shall be read in conjunction with Main Roads' guidance for the geometric layout of entry ramps as well as the layout of ramp signals and associated devices as provided in the guideline drawings in Table 4.

Subject to the design circumstances, the following design features shall also be considered to facilitate the future retrofitting of ramp signals:

- Vehicle detector locations on the entry ramp to suit future stop line location.
- Not providing a shoulder on the ramp, i.e. the ramp would be linemarked as a two-lane ramp with the "Form 1 Lane" sign and merge in its future position, particularly if the implementation of the ramp signals is likely to occur within a short timeframe, e.g. the next few years. If it is considered undesirable to provide the pavement markings in their future position, consider using an approved temporary line marking tape, which meets Main Roads Specification 604 – Pavement Marking.
- The position and spacing of storm water pits should be based on the future allowable spread width, assuming that the shoulder is used as a traffic lane. If the pit spacing becomes uneconomically close, it may be necessary to allow for a nominal future shoulder width to accommodate some of the flow width.
- Verge width requirements for ramp signals and other required roadside furniture, including an allowance for an appropriate pull-off area for maintenance parking.
- The location of poles relative to future ramp signals assets.
- The location of future road safety barriers to protect against crashes with the ramp signal poles. The depth and / or positions of pipes and gullies also needs to be considered in relation to the depth and spacing of barrier posts.

Part 3 Section 6.10: Layout of Ramp Signal Devices and Traffic Management

The principles in these sections shall be read in conjunction with Main Roads' guidance for the geometric layout of ramp signals and associated devices as shown in guideline drawings that replace the MMDG standard drawings (see Table 4).

Part 3 Section 6.10.1: Controller Location

The principles in this section shall be read in conjunction with the following additional Main Roads' guidance.

A controller location between the ramp and the freeway carriageway is generally undesirable unless the controller can be located at the start of the ramp where good visibility to the signals and the freeway beyond is provided. An advantage of this location is that, where the arterial road passes over the freeway, the area is usually protected by a safety barrier. It is important that there is sufficient space to park on the left hand side of the ramp or left-turn splitter island to facilitate safe access to the ITS infrastructure.

Part 3 Section 6.10.2: Signal Pedestals

The principles in this section shall be read in conjunction with the following additional Main Roads' guidance.

In Western Australia, "signal pedestals" or "signal support pedestals" are called "signal posts".

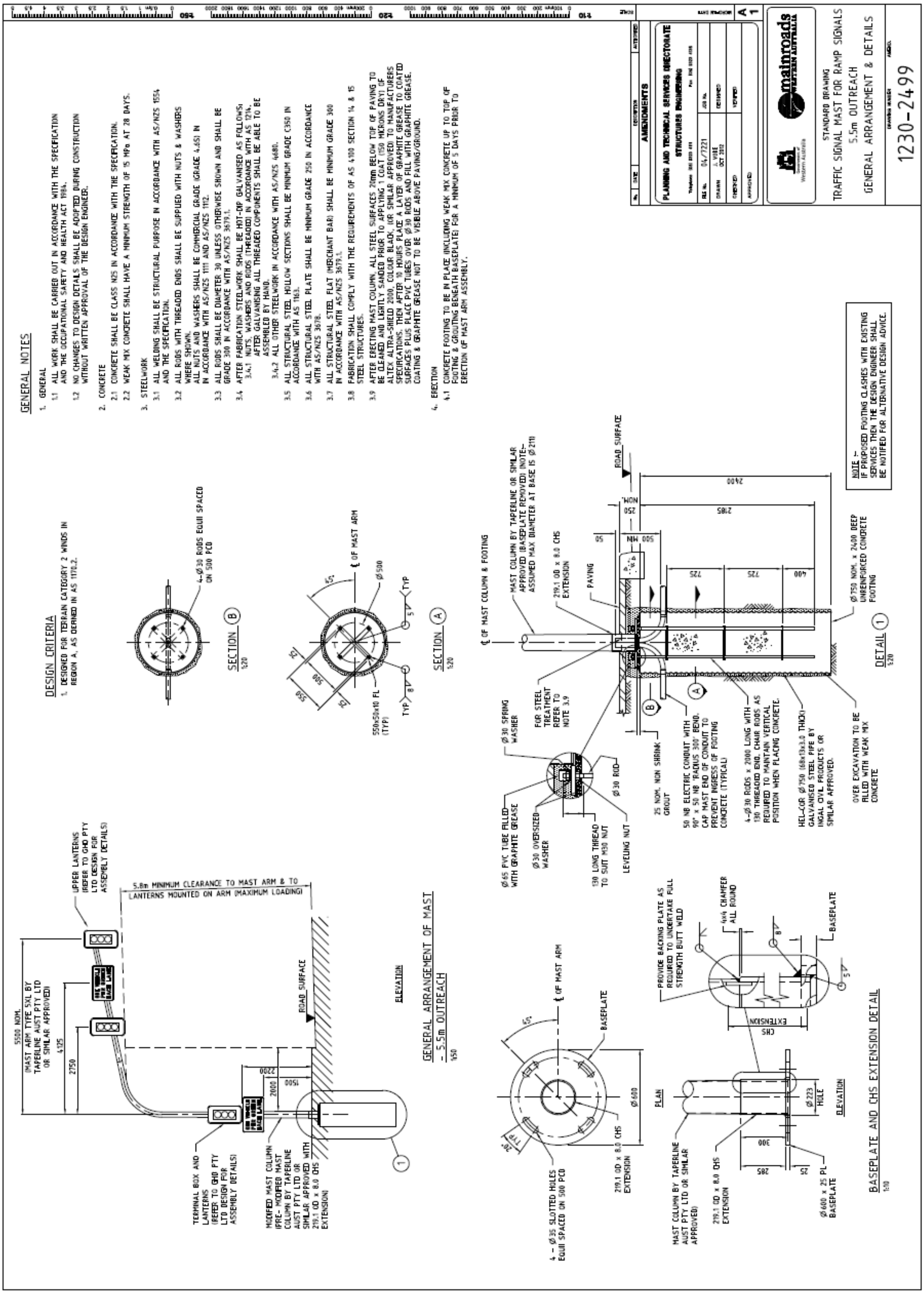
The signal post is installed adjacent to the ramp 10 metres downstream of the stop line. The standard for two-lane ramps is a modified mast arm with an outreach of 5.5 metres and a footing depth of 2.4 metres. This is shown in Standard Dwg. No. 1230-2499 below. The use of joint use mast arms (JUMA) to mount a CCTV camera is not supported in Western Australia since all CCTV installations require a scissor-type accessible extension, rather than access through the use of a mobile platform. However, where wireless vehicle detectors are used, a mast arm extension may be needed for mounting of the RP if a lighting pole is not available.

Gantries are required for ramps with three or four lanes including installations with priority access lanes. The clearance to the underside of the lowest fixture on the structure shall be in accordance with the vertical clearance requirements of the map document D19#246647.

As the traffic signal mast arms and gantry supports are considered non frangible roadside hazards, the installation shall include a safety barrier. For the gantry leg on the right side of the ramp, a safety barrier may be necessary to shield the hazard from mainline traffic as well ramp traffic. The requirements of Main Roads' Supplement to Austroads' Guide to Road Design – Part 6 and Austroads' Guide to Road Design – Part 6: Roadside Design, Safety and Barriers shall be met at all locations.

In positioning the signal mast arms, appropriate allowances should be made for the deflection of the barrier, vehicle roll and the width of the signal lanterns and their target boards. As a general guide the following deflection distances should be adhered to:

- Concrete barrier – no deflection (allow width of the barrier and vehicle roll allowance).
- W-Beam – 1.5 metres from the face of the barrier.
- Wire rope barrier – 2.0 metres from the face of the barrier.


GENERAL NOTES
DESIGN CRITERIA
SECTION A
SECTION B
DETAIL 1
GENERAL ARRANGEMENT OF MAST - 5.5m OUTREACH
ELEVATION
BASEPLATE AND CHS EXTENSION DETAIL
PLAN
mainroads WESTERN AUSTRALIA
STANDARD DRAWING
TRAFFIC SIGNAL MAST FOR RAMP SIGNALS
5.5m OUTREACH
GENERAL ARRANGEMENT & DETAILS
1230-2499

Part 3 Section 6.10.3: Signal Lanterns

The principles in this section shall be read in conjunction with the following additional Main Roads' guidance.

The high mount lanterns are considered the primary lanterns and should be aimed towards the ramp entrance at a distance of 170 metres. This is based on an assumed ramp speed of 80 km/h.

Where traffic signals are installed on standard 5.5 metres outreach mast arms (modified for ramp signal installations), the overhead (primary) lanterns shall be mounted at a minimum height of 5.8 metres (measured from the ground to the bottom of the target board).

Where traffic signals are installed on overhead gantries, the primary lanterns shall be mounted such that the clearance to the underside of the target board, or any associated signage (whichever is the lower), shall be in accordance with the vertical clearance requirements of the map document D19#246647.

The low mount lanterns are considered the secondary lanterns and should be aimed at a point on the centre of the ramp approach, three metres upstream of the stop line. The lower lantern is to be mounted at a height of 2.2 metres (measured from the ground to the bottom of the target board).

Part 3 Section 6.10.7.1: RC1 Warning and Regulatory Sign

The principles in this section shall be read in conjunction with the following additional Main Roads guidance.

The electronic RC1 signs (Ramp Signals On) are installed on the approaches to the arterial road / entry ramp intersection to face traffic turning into the ramp. They are generally installed in the following positions, as illustrated in Figure 4:

- For traffic approaching the on-ramp and turning left into the on-ramp – on the left-hand primary traffic signal post located in the left-turn splitter island if the sign will be within the line of sight for left turning motorists. For large traffic islands, a separate post may be necessary.
- For traffic approaching the on-ramp and turning right into the on-ramp – on the right-hand secondary traffic signal post located in the median.

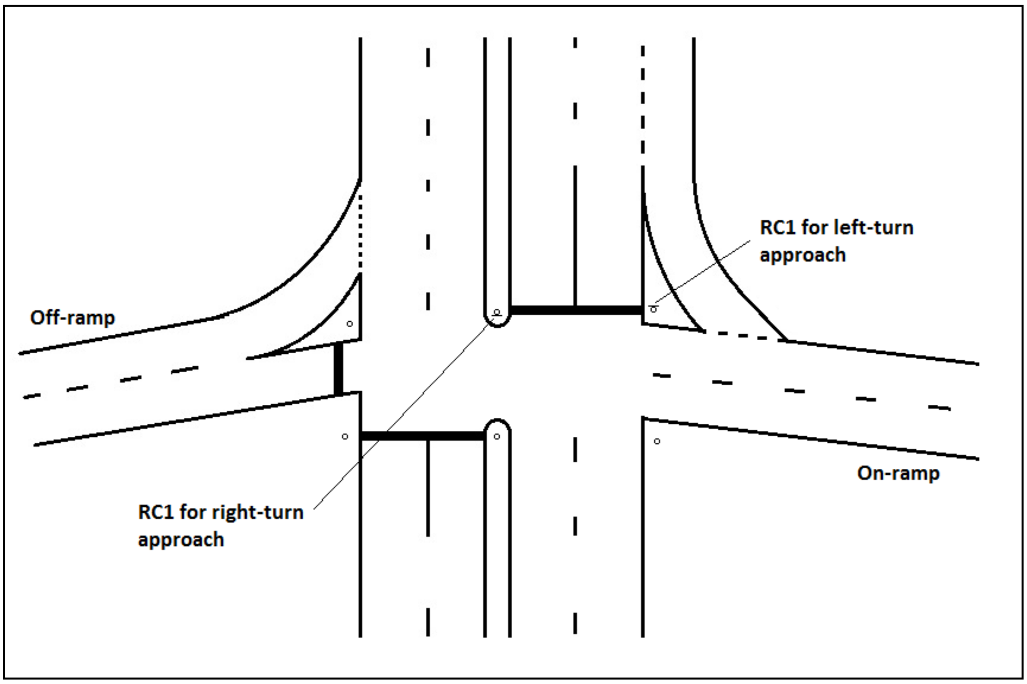


Figure 4: Typical location of RC1 signs

Part 3 Section 6.10.7.3: RC3 Sign – Real Time Information Sign (RTIS)

The Main Roads name for the RC3 real time information sign is an arterial road VMS. The principles in this section shall be read in conjunction with Main Roads' guidance in the Smart Freeways Variable Message Signs Guidelines.

The MMDG RC3 pole and the joint use signal poles (JUP) are not used in Western Australia. Sign posts/supports for arterial road VMS shall be designed for structural integrity according to the number and size of signs and mounting configuration, height, cantilever etc.

Part 3 Section 6.10.9: Other Signs

The principles in this section shall be read in conjunction with the following additional Main Roads' guidance.

Static signs shown on the drawings forming part of the ramp signals installation include:

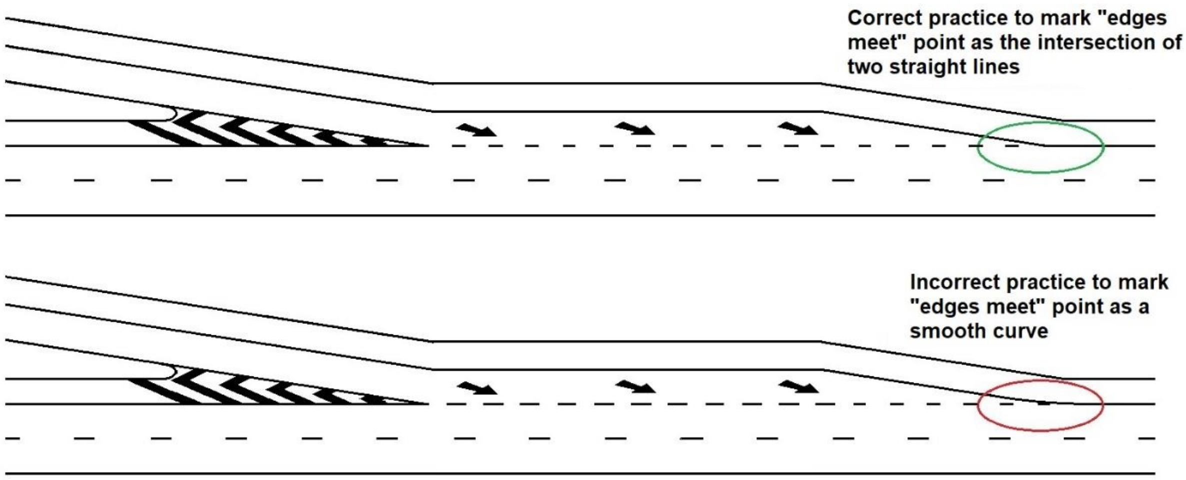
Location	Sign
STOP HERE ON RED SIGNAL (R6-6B) These regulatory signs are required at the stop line as it is remote from the traffic signals (generally 10 m upstream).	
ONE VEHICLE PER GREEN EACH LANE (MR-GT-23) These signs are located underneath the low mount lantern (at a mounting height of 1.5 m to the underside of the sign) and mid-way between the overhead lanterns.	
FORM 1 LANE (G9-15B) These signs are located each side of the ramp 20 m downstream of the stop line. Where the merging from the stop line on 3 or 4 lane ramps is to form two lanes at the ramp nose, FORM 2 LANES signs (G9-16B) shall be used.	
Speed Limit sign (R4-1C) or variable speed limit sign, together with "START OF FREEWAY" (MR-GE-22B) sign. These signs are located 30 m downstream of the last "FORM 1 LANE" or "FORM 2 LANES" signs before the ramp nose.	
Truck lane signs (R7-3-1) to designate the use of the left lane if a priority lane is provided. The use and positioning of these signs is consistent with regulation 135 of the Road Traffic Code 2000. The signs are supplemented with a "LEFT LANE" (R7-3) sign as appropriate. Note: If classes of vehicle other than trucks, or in addition to trucks, are permitted to use the priority lane then the sign shall reflect the appropriate vehicle classes.	

Part 3 Section 6.10.10: Pavement Markings

The principles in this section shall be read in conjunction with the following additional Main Roads' guidance.

The pavement markings and RRPMs associated with the ramp signal designs are shown on the guideline drawings listed in Table 4 and the following principles:

- Longitudinal line marking includes a 25 metres single continuous lane line (150 mm wide) on the approach to the stop line with five white unidirectional RRPM's on the right hand side at six metre spacing.
- A 150 mm wide edge line is provided on the left hand side of the ramp, starting at the stop line to provide guidance for the merging traffic. On the right hand side the 150 mm wide edge line starts approximately 12 metres from the nose in accordance with standard Dwg. No. 200331-093.
- The stop line is located 10 metres upstream of the traffic signal pedestal.
- A continuous lane line, or painted median, shall be installed between two lanes merging and any other lane to "discourage" lane changing into an area where merging may take place.
- Merging manoeuvres within the ramp generally occur as a "zip" merge, i.e. no continuity line is used (see exception in the special case in Figure 3). Merging into the freeway (not applicable to an added lane) is crossing a continuity line so is a lane change manoeuvre.
- The gore markings continue to a point (refer to Figure 5 and standard Dwg. No. 200331-093).
- At the end of the merge taper where the edge line of the ramp joins with the freeway edge line ("edges meet" point), the 150 mm wide edge line should be marked as a clearly defined angle, rather than as a smoothed curve (refer to Figure 5).
- The entry taper to a priority vehicle lane shall be highlighted using appropriate pavement marking messages in accordance with AS1742.12 – Bus, transit, tram and truck lanes. This is illustrated in Guideline Dwg. No. 201231-0029 (shown in Section 6.8 of this document).
- Where a priority vehicle lane is provided, the lane shall be separated from the general traffic lanes by a painted median 0.7 metres wide. The painted median shall have 150 mm wide edge-lines with 0.5 metre wide painted diagonals at 45 degrees at 10 metre spacing as well as yellow rumble bars at five metre spacing. This is supplemented with groups of four yellow unidirectional RRPM's, also aligned at 45 degrees. This is illustrated in Detail C of Guideline Drawing No. 201231-0029.



Not to scale

Figure 5: Line marking at the "Edges Meet" point

Part 3 Section 6.10.11: CCTV Cameras
The general principles in this section shall be read in conjunction with the requirements in Main Roads' Provision Guidelines Section 8.2 in regard to warrants for full and overlapping coverage.

Part 3 Section 6.10.12: Power Supply and Communications
This section shall be replaced with the following Main Roads' guidance.

Power and communication requirements for ITS devices are provided in Main Roads' electrical and ITS standards and specifications.

Part 3 Section 6.10.13: Lighting
This section shall be replaced with the following Main Roads' guidance.

Street lighting is required on all ramps as per Main Roads' Roadway Lighting Guidelines.

Part 3 Section 7: Motorway-to-Motorway Ramp Metering Signals

Part 3 Section 7.3: Ramp Geometry and Signal Layout
Victoria's standard drawing in Figure 7-22 (referenced in section 7.3.1) shall be replaced by Main Roads' Guideline Drawing No. 201231-0053 below.

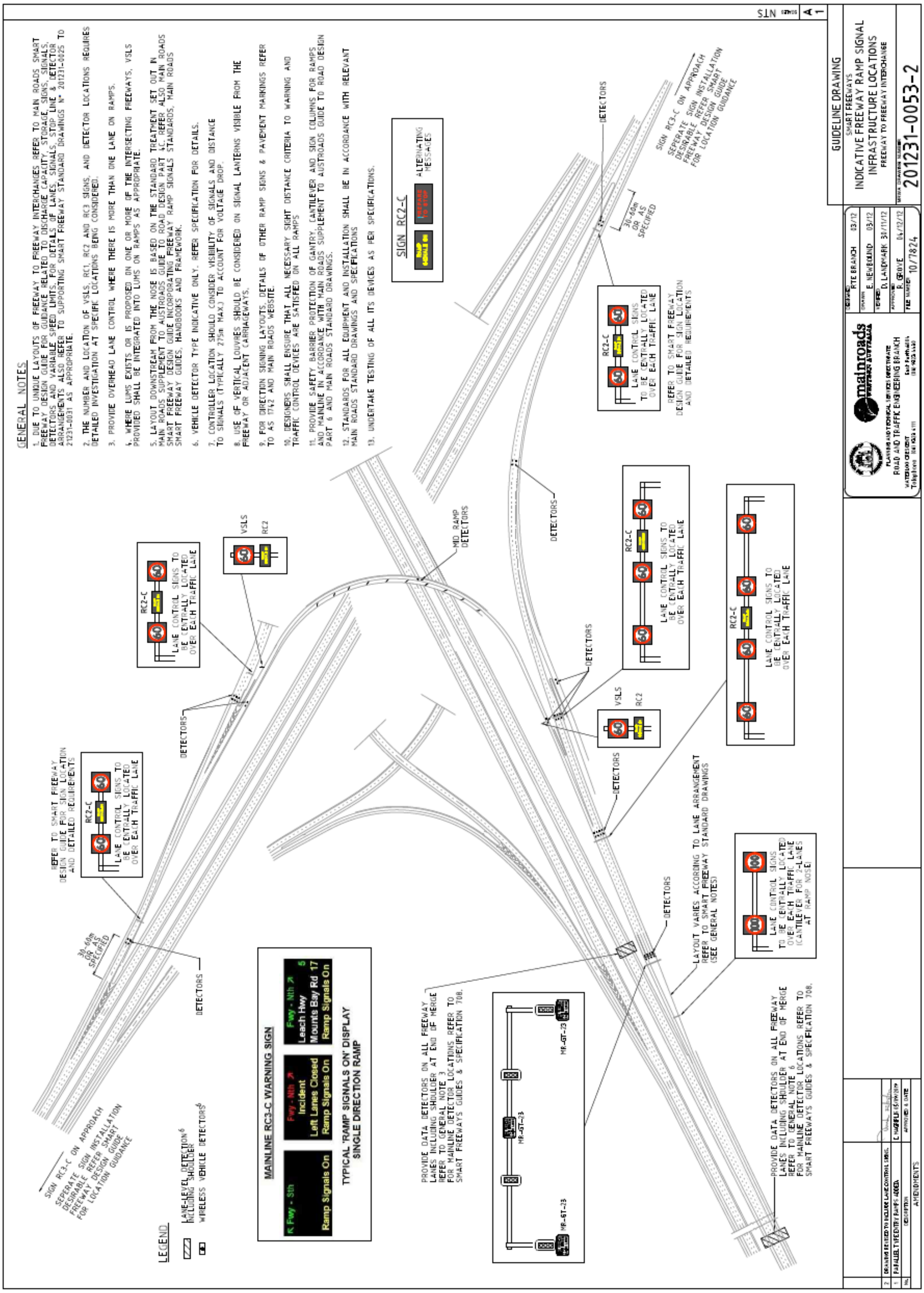
Part 3 Section 7.6: Mainline RC3-C Warning Signs
The Main Roads' name for the RC3-C warning sign is a freeway-to-freeway VMS. Further information is provided in the Smart Freeways Variable Message Signs Guidelines.

Part 3 Section 9.4: Exit Ramp Management System

Main Roads may consider adopting design and operational requirements for Victoria's exit ramp management system in the future. In the interim, along with appropriate ramp geometric design, Main Roads has been using other strategies such as SCATS Strategy Manager for managing exit ramp queues, which may need to be considered in Smart Freeway designs where excessive exiting queues are experienced in operations or anticipated during design.

Part 3 Appendix A: Extended Design Domain

The guidance in this appendix relating to the use of staggered stop line layouts for three-lane ramp metering signals is replaced by the Main Roads' guidance provided for Part 3 Section 6.6: Three Lane Metered Layouts above.


GUIDELINE DRAWING
SMART FREEWAYS
INDICATIVE FREEWAY RAMP SIGNAL INFRASTRUCTURE LOCATIONS
FREEWAY TO FREEWAY INTERCHANGE
201231-0053-2
NTS
GENERAL NOTES
SIGN RC2-C
MAINLINE RC3-C WARNING SIGN
TYPICAL 'RAMP SIGNALS ON' DISPLAY SINGLE DIRECTION RAMP
LEGEND
DETECTORS
VSLS
RC2
RC2-C

References

Austroads Guide to Traffic Management (various parts), Austroads, Sydney, NSW.

Austroads Guide to Road Design (various parts), Austroads, Sydney, NSW.

Main Roads' Supplements to Austroads Guide to Traffic Management (various parts), Main Roads, Perth, WA.

Main Roads' Supplements to Austroads Guide to Road Design (various parts), Main Roads, Perth, WA.

Main Roads' Guideline for Emergency Stopping Bays and Roadside Help Phones, 2018, Main Roads, Perth, WA.

Main Roads' technical publications and specifications available on the website (various): https://www.mainroads.wa.gov.au/BuildingRoads/StandardsTechnical/Pages/home.aspx

Smart Freeways Policy, 2020, Main Roads, Perth, WA.

Smart Freeways Policy Framework Overview, 2020, Main Roads, Perth, WA.

Smart Freeways Provision Guidelines, 2020, Main Roads, Perth, WA.

Smart Freeways Operational Efficiency Audit Guidelines, 2020, Main Roads, Perth, WA.

Smart Freeways Variable Message Signs Guidelines, 2020, Main Roads, Perth, WA.

Supplement to Victoria's Managed Motorway Design Guide, Volume 2: Design Practice, Part 4: Lane Use Management and Variable Message Signs, 2020, Main Roads, Perth, WA.

Transportation Research Board, Highway Capacity Manual 2016, TRB, Washington DC.

VicRoads (Victorian Department of Transport) Managed Motorway Design Guide (MMDG) Volume 2: Design Practice, Part 2: Managed Motorway – Network Optimisation Tools, 2019, Melbourne, VIC.

VicRoads (Victorian Department of Transport) Managed Motorway Design Guide (MMDG) Volume 2: Design Practice, Part 3: Motorway Planning and Design, 2019, Melbourne, VIC.

VicRoads (Victorian Department of Transport) Managed Motorway Design Guide (MMDG), Volume 1: Role, Traffic Theory & Science for Optimisation, Part 3: Motorway Capacity Guide, 2019, Melbourne, VIC.