Chapter 6
Design of Ramp Signal Installations
6.1. Overview of the Design Process

The main components of the ramp signal design process at an entry ramp are capacity analysis, ramp storage design and then developing the design plan showing the ramp layout geometry and location of devices. The main components of the design process are summarised in Figure 6.1. The design at each ramp generally follows an investigation along the freeway to understand freeway performance and to identify potential bottlenecks along the route that affect traffic flow and capacity.

Figure 6.1: Design Process Overview

Note:
There are examples where ramp signals were installed on freeway ramps and then did not meet operational objectives due to poor design, inadequate detailed analysis and/or understanding of ramp metering principles. Performance problems may involve producing no benefits or producing adverse effects. A good control algorithm may not be able to compensate for an installation with inadequate design.
6.2. General Approach

A system approach with an investigation along a significant length of freeway is desirable to gain an overall understanding of freeway performance, infrastructure characteristics and traffic flow issues affecting the design of improvements. The investigation for upgrading of an existing route should include collection of data, data analyses and on-site observations to determine:

- The mainline and entry ramp flows at all entry ramps including locations of critical bottlenecks due to merging traffic
- Bottleneck locations due to other geometric features which may be at lane drops, steep upgrades, tight curves, width restrictions or sight restrictions
- Areas with weaving movements or significant lane changing
- Exit ramps where queues over-spill into the through carriageway. This problem cannot be treated with ramp metering and requires consideration of other improvements to avoid counteracting the planned benefits of ramp metering
- The possible emergence of new critical bottlenecks after the planned ramp metering installation, e.g., the increased throughput at a bottleneck being treated by ramp metering may trigger a new active bottleneck further downstream.

The metering rate and storage requirements at an entry ramp will vary according to the freeway flow, the entry ramp demand and the operational regime within the system. The objective of the design process is to ensure that adequate consideration is given to the capacity and functional geometric layout of the ramp so that satisfactory operation is achieved after the ramp signals are installed. Consideration also needs to be given to the capabilities and operational needs of the proposed algorithm that will control the signals.

The capacity and storage analyses need to be considered for the AM and PM peak periods to determine the worst case, i.e., in some instances the entry ramp flows and desirable storage may be greater in the counter peak direction, even though the mainline flows may be less, e.g., at an entry ramp from a location of significant employment which is in the opposite direction to the peak flow.

For design information not provided in this Handbook, refer to the VicRoads road design guidelines, the Traffic Engineering Manual Volumes 1 and 2 and the Austroads guidelines, as appropriate.

**Note:**

While capacity analysis in the design process generally focuses on traffic volumes, in operation the dynamic ramp signal system uses occupancy to optimise freeway flow.

6.3. Capacity Analysis and Storage Design

The analysis of data to determine design flows, the number of lanes at the stop line and the ramp storage needs is an essential first step in the overall design process. The preparation of signal plans without this analysis can lead to inadequate infrastructure or ineffective operation.

6.3.1. Freeway and Ramp Design Flows

A system approach along the route considering all ramps is desirable to determine the locations of critical bottlenecks that will enable the maximum entry flows to be determined at specific locations in a coordinated system. The overall objective of the analysis is to ensure that flow breakdown will not be triggered due to satisfying excess demand, i.e., in some locations provision can only be made for traffic entering the freeway without causing flow breakdown, rather than satisfying the entry ramp demand.

The design flows to be used for the entry ramp and the freeway need to be estimated then checked against the capacity of the associated merge point and any other potential downstream bottleneck. The ramp flows are also used to determine the number of lanes to be provided on the entry ramp at the stop line and the length of storage for queued vehicles. The objective is to confirm that the entry ramp design flows can be accommodated by the mainline design flow and that the likelihood of flow breakdown is minimised under the expected operation.
Satisfying the ramp demand flow is the desirable situation. In cases where the entry ramp demand flow cannot be accommodated within the freeway bottleneck capacity, the metered entry ramp flow could be less than the demand flow and would result in significant queuing and possible trip diversion.

A coordination group of ramps within a system for the purpose of design may need to extend upstream from the critical bottleneck for up to 10 entry ramps. Within a coordination group the locations where entry flows need be restricted or balanced across a number of adjacent ramps may need to be identified.

6.3.1.1. Upgrading of an Existing Freeway or a New Ramp / Freeway

Freeway and entry ramp demand flows may be determined by considering factors such as:

- Capacity increases for an upgraded freeway
- Current traffic demands and travel patterns adjusted according to appropriate traffic growth trends and likely changes to travel patterns
- Traffic generation of areas serviced by a new ramp
- Traffic modelling of the new/upgraded road network links.

6.3.1.2. Existing Freeway

Peak period traffic flows need to be determined for each entry ramp under consideration as well as the freeway mainline flow at each interchange and critical bottleneck. To determine an entry ramp design flow, the following data collection and analysis is generally required.

1. Assess traffic flow data during each peak period for the freeway direction under consideration to determine:
   - Current entry ramp flow and flow profile, and
   - Freeway flow at the interchange immediately upstream of the entry ramp, i.e. between exit and entry ramps within the interchange.

Note: This information is available from freeway data stations or a specific traffic survey. Alternatively, the freeway flow and profile at the merge can be calculated from:
   - Freeway flow upstream of the interchange, and
   - Subtracting the exit ramp flow.

2. Assess freeway flow data (flow, speed and occupancy) to determine if flow breakdown is occurring during peak periods at:
   - The entry ramp merge points, or
   - Any other downstream bottlenecks, e.g., tight curves, steep upgrades or high weaving areas.

If flow breakdown is occurring, the peak period raw traffic data may mask the true demand, particularly if the freeway breaks down for an extended period. In such cases the designer may need to use the flow rate during the brief period prior to breakdown then apply an appropriate peak hour factor (PHF) to determine the true hourly design flow.

Note: On existing freeways examining flow data at 15 minute intervals provides a preliminary indicator to identify the periods where flow breakdown occurs. To examine the locations and probable causes of flow breakdown, one minute data generally provides the detail required during the unstable periods.

3. Determine the critical bottleneck location for the section of freeway, based on information gained in Step 2.

Note: The critical bottleneck along the route, i.e., where flow breakdown first occurred, can generally be identified from a FIRM tool plot.
6.3.2. Ramp Demand Relative to Mainline Capacity

When the freeway and ramp flows have been determined the following steps aim to compare the ramp demand flow with the capacity of the freeway at the downstream bottleneck location.

1. Determine the design capacity, $q_{\text{cap}}$, at the freeway critical bottleneck (merge or downstream bottleneck). This is determined by an assessment of the flow at which flow breakdown is expected to occur. Figure 6.2 shows the parameters involved and for the purpose of analysis, the bottleneck design capacity would generally be:
   - A maximum of 2,100 pc/lane/h averaged over all freeway lanes, assuming favourable freeway mainline conditions, or
   - A lower value if geometric factors affect capacity at the merge or downstream section of freeway before the next exit, e.g., steep grade or tight radius curve, or
   - Where existing flow data is available, generally 95% of the 5 minute flow prior to breakdown, assuming free flow conditions before capacity flow is reached, i.e., the site is a critical bottleneck and that flow breakdown is not due to a shockwave from downstream – refer Section 2.3.2.

**Note:**
Although a notional capacity is used in the initial design, in operation the ramp metering system will endeavour to optimise flow by controlling occupancy.

2. Compare the maximum entry ramp flow that is able to enter the freeway, $q_r$, with the ramp arrival (demand) flow, $q_{ra}$, i.e., the design flow is to match the capacity of the bottleneck at the merge or other downstream bottleneck (refer Section 3.4.1).

3. Where a comparison of maximum metered volumes at a ramp with the arrival flow identifies a location where ramp demands may not be accommodated, consideration should be given to:
   - The potential for redistribution of some traffic to other routes. The implications of unsatisfied demand require an assessment of the arterial road network to determine possible routes for traffic diversions within the arterial road network, e.g., for short trips, or for diversion to another freeway entry ramp which is likely where longer trips may be involved. An adjustment of entry ramp flows at a particular location may result in an acceptable design where trip diversion is feasible. In this situation it may be necessary to modify the signal phasing at the arterial road/entry ramp intersection to encourage trip diversion. Many parts of arterial road networks are generally relatively permeable and can disperse congestion. In some instances the arterial roads may also have sufficient capacity to accommodate redistributed traffic.
The provision of real time information signs to display travel time information to assist drivers in making a route choice (refer Section 6.4.12.3)

Providing for ramp queue overflow onto the arterial road (refer to Section 6.3.5 and Section 8.2)

Also metering upstream ramps, if this matter is encountered at a proposed isolated ramp meter installation

Increasing downstream freeway capacity.

6.3.3. Number of Traffic Lanes at the Stop Line

The number of lanes at the stop line is related to the ramp arrival flow, \( q_{ra} \), adopted for design, the number of vehicles per green per lane and an appropriate average cycle time, \( c_r \) to provide the metering of traffic into the mainline. This can be determined from Equation 6-1 or the values collated in Table 6.1.

\[
\frac{c_r}{q_{ra}} = \frac{3600 \times \text{No. lanes at the stop line} \times \text{No. veh/g/l}}{\text{q}_{ra}}
\]

Equation 6-1

Note:
The number of lanes may be assumed and then the resulting cycle time checked relative to an appropriate minimum average cycle time.

On high demand freeways, the desirable minimum cycle time adopted for design and capacity analysis averaged over the design peak hour should typically be in the order of 7.5 seconds for one and two lane ramps. For three or four lane ramp meters with an added lane, 6.5 seconds is a typical minimum average value over the design hour. These average cycle time values over the design hour allow for real time operational flexibility. In practice, as outlined in Section 7.5.2 and as shown in the example in Figure 6.3, longer and shorter cycle times will occur within the dynamic system over the peak period based on traffic conditions at the bottleneck and coordination relative to other ramps. If a cycle time in the desirable range cannot be achieved in design, this may result in ineffective metering of ramp demands during operation.

Figure 6.3: Example of Average and Varying Cycle Times

Cycle times lower than 7.5 seconds (6.5 seconds for three and four metered lanes) as shown orange in Table 6.1, could be appropriate when the capacity analysis indicates ramp demands are accommodated with spare capacity on the mainline, e.g., where there is low mainline flow or an added lane.

Designs with average cycle times outside the limits in Table 6.1 shall be approved by the Executive Director – Policy and Programs.
### Table 6.1: Lanes at the Stop Line and Ramp Storage Requirements

The capacity and operation related to high volume ramps requires particular consideration of the number of lanes and the storage lengths available. In some situations additional lanes required at the stop line for capacity reasons can be provided by using localised flaring to create an auxiliary lane, particularly if a long ramp provides adequate storage. Examples are shown in Figure 6.4 and the standard drawings referred to in Section 6.4.
Note: VicRoads previous ramp metering guidelines (2005), provided options for metering with 2 (or 3) vehicles per green per lane. This form of operation has not been trialled successfully in Australia, although it is used in some overseas jurisdictions with limited success. While theoretically 2 veh/g/l may seem to provide double the flow compared with 1 veh/g/l, the actual increase is significantly less at low cycle times due to the following:

a) Based on overseas experience it is understood that 2 veh/g/l is rarely achieved in practice as driver indecision leads to a lower actual metered rate, typically in the order of 1.7 veh/g/l.

b) Generally two seconds longer green time is required with 2 veh/g/l to provide sufficient time for two vehicles to cross the stop line.

An example of a two lane ramp with a cycle time of 6 seconds for 1 veh/g/l, compared with 8 seconds for 2 veh/g/l is shown below. Generally, it is preferable to release a single vehicle per green per lane, even if shorter cycle times need to be adopted.

<table>
<thead>
<tr>
<th>No. veh/g/lane</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green time (sec)</td>
<td>1.3</td>
<td>3.3</td>
</tr>
<tr>
<td>Yellow time (sec)</td>
<td>0.7</td>
<td>0.7</td>
</tr>
<tr>
<td>Red time (sec)</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Cycle time (sec)</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>Flow (veh/h)</td>
<td>1200</td>
<td>1530</td>
</tr>
</tbody>
</table>

In exceptional circumstances when 1 veh/g/l is not workable, e.g., a high flow freeway to freeway situation or where widening for auxiliary lanes is not feasible or cannot provide sufficient capacity, then 2 veh/g/l operation may need to be considered. In these circumstances, until more information is available, a design discharge rate of 1.7 veh/g/l is appropriate.

In other situations, a longer green period to release 3 or more veh/g/l, i.e., short platoons, may be an option if the ramp entry becomes an added lane on the intersecting freeway. In this case an appropriate time for the green phase is used without reference to a particular number of vehicles per green, i.e., no signs are needed.

Freeway ramp metering designs which use more than 1 veh/g/l shall be approved by the Executive Director – Policy and Programs.
6.3.4. Ramp Storage Requirements

6.3.4.1. Desirable Standard

The desirable standard is to provide for a total length of storage between the stop line and the ramp entrance to accommodate traffic with a wait time of 4 minutes, i.e., the ramp queue delay. This standard shall be provided by lengthening existing ramps when it is economically feasible within design constraints, e.g. downstream bridge or exit taper. This facilitates operational flexibility to provide for the following situations:

- To limit vehicle entry to the freeway when the ramp merge or downstream freeway is at or approaching capacity
- To balance queues between adjacent ramps in a coordinated system
- To reduce the likelihood of overflow queues extending onto the arterial road
- To provide for short term variations in traffic demand within the peak period
- To accommodate traffic growth or future change in travel patterns, and
- To limit vehicle entry to the freeway during an incident and to facilitate recovery after an incident (refer Section 3.7).

The length of the desirable ramp storage, $L_{rDes}$ is calculated from the number of vehicles in the maximum wait time queue, $n_{rMax\text{-}wait}$, the maximum wait time, $t_{Max\text{-}wait}$, and the average length of the ramp queue vehicle storage space, $L_{vs}$ as shown in Equation 6-2.

$$L_{rDes} = n_{rMax\text{-}wait} \times L_{vs}$$

where: $L_{vs}$ is typically 8.5 metres or 9 metres with high ramp truck volumes

Equation 6-2

The number of vehicles in the queue based on the maximum wait time, $n_{rMax\text{-}wait}$ is calculated from the ramp arrival (demand) flow, $q_{ra}$ and the maximum wait time, $t_{Max\text{-}wait}$ (generally 4 minutes) as shown in Equation 6-3.

$$n_{rMax\text{-}wait} = \frac{q_{ra} \times t_{Max\text{-}wait}}{60}$$

Equation 6-3

If more than 4 minutes storage is available on a long ramp, this provides advantages as the additional storage will provide greater operational flexibility.

Table 6.1 provides a guide to entry ramp storage lengths to be provided for various operational arrangements on the ramp. The total storage requirement is divided by the number of lanes along the ramp to determine if adequate storage is available, or compared with the total lane length if lanes are of different lengths.

The ramp storage achieved in the design has implications for the operational management of the freeway (as outlined above), as well as the arterial network as a whole. Therefore, the storage achieved relative to the desirable guideline needs to be documented during scope approval of the project. In some instances the ramp may need to be lengthened, e.g., by extending the nose, or widened to increase storage.

6.3.4.2. Storage Difficulties

In locations where providing the desirable storage, i.e., 4 minute wait time, is not feasible, a lower storage value may need to be considered. This may be appropriate when the analysis indicates that entry ramp demand flows are satisfied (refer Section 3.5). Operational constraints are generally created if ramps have minimal storage. An arterial road network with good connectivity can facilitate re-routing of trips to adjacent ramps to compensate for a low storage ramp. Balancing of queues by the coordinated ramp signal system to ramps with surplus storage, if available, will also assist.
Therefore, where ramp storage is compromised in design, other ramps immediately upstream should be provided with at least the desirable standard and preferably more, to compensate for the loss of overall system storage. If inadequate overall storage is not achieved it is to be expected that operation will be compromised.

Where the desirable standard of storage cannot be provided, consideration should be given to the implications of queue overflow into the arterial road (refer Section 6.3.5 and Section 8.2), as well as the potential for motorists to change their travel route to other ramps. In this situation, the arterial network needs to have the capacity and connectivity to provide the opportunity for motorists to change their travel patterns.

In a situation where the desirable storage cannot be provided, typically a minimum 3 minutes queue length may need to be adopted for design. This queue length between the ramp entrance and the ramp signals stop line will generally be sufficient to accommodate storage for turning vehicles arriving in a platoon from the arterial road/ramp intersection signals. However, it would restrict the system’s ability to build a queue in order to manage mainline traffic and prevent flow breakdown.

6.3.4.3. Example of Capacity and Storage Calculations

Capacity and storage calculations along a route can be undertaken in a spreadsheet. An example is shown in Figure 6.5.

Figure 6.5: Example of Capacity and Storage Calculations
6.3.5. Considering Ramp Queue Overflow onto the Arterial Road

As a general principle, freeway ramps should be designed to provide the desirable storage indicated in Section 6.3.4.1. In circumstances that prevent this being achieved, ramp overflow onto the arterial road needs to be considered. This may include:

- Consideration of improvements at the arterial road/entry ramp intersection, such as extending or providing right or left turn lanes to increase effective storage for the entry ramp traffic (refer Section 8.2)
- SCATS system integration. This may include implementation of leading and lagging right turn phases at the arterial road intersection to reduce the potential for overfilling of a short ramp, i.e., two short right turn phases within the cycle rather than a single longer phase
- Provision of arterial road queue detectors (refer Section 6.4.9)
- Considering potential for trip diversion
- Considering equity between left and right turn movements into the ramp, e.g., signalising a left turn slip lane.

Section 8.2 provides further information relating to the management of ramp overflow queues.

6.4. Geometric Design and Layout of Devices

6.4.1. General Ramp Layout

The general layout of freeway ramp signals at various entry ramp configurations are shown on the Standard Drawings outlined in Section 6.4.1.2. The layouts in the standard drawings are based on the geometric standards for freeway entry ramps in VicRoads road design guidelines. This is to ensure that the ramp geometry and merging distances are satisfactory when the metering signals are operating as well as when the signals are not operating.

When retrofitting an existing entry ramp with ramp signals the length available for acceleration and merging needs to be checked to ensure the overall design is satisfactory and meets current design standards.

The number of lanes to be provided at the stop line and the storage length for vehicles are based on analysis as described in Section 6.3.

6.4.1.1. Stop Line Location

The positioning of the stop line needs to achieve a balance between safety for merging traffic and maximising ramp storage. As a general principle, the stop line distance from the nose should be as indicated on the Standard Drawings and these guidelines so that the storage is maximised, even if the ramp is longer than the calculated desirable distance. This provides greater flexibility in operation when the freeway is experiencing congestion (refer Section 6.3.4).

In situations where increased storage is needed, consideration may need to be given to extending the ramp nose together with extending the length of the overall merge length to maintain the desirable standards.

The stop line location varies for the two, three and four lane ramp configurations as outlined in the following sections. As general design principles:

- The merging of traffic leaving the stop line is completed by the ramp nose to match the entry arrangement onto the mainline. Separated decision making points are provided where multiple merge manoeuvres are required
- The shoulder width is fully developed adjacent to the nose. This acts as a ‘run-out’ area and provides additional width for safety in the event that merging manoeuvres are not completed by the nose.
6.4.1.2. Standard Drawings

The general layout of freeway ramp signals at various entry ramp configurations are shown on the standard drawings listed in Table 6.2 with further details provided in Sections 6.4.2 to 6.4.5. The choice of treatment is based on capacity and storage considerations outlined in Section 6.3 as well as strategic objectives, such as the desirability of priority access lanes.

<table>
<thead>
<tr>
<th>Ramp Type</th>
<th>Drawing No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two lanes of metered traffic</td>
<td>453771</td>
</tr>
<tr>
<td>Two lanes of metered traffic plus a priority lane</td>
<td>541797</td>
</tr>
<tr>
<td>Two lanes of metered traffic plus a metered priority lane</td>
<td>541798</td>
</tr>
<tr>
<td>Three lanes of metered traffic</td>
<td>541795</td>
</tr>
<tr>
<td>Four lanes of metered traffic</td>
<td>541796</td>
</tr>
<tr>
<td>Freeway to freeway interchange</td>
<td>453912</td>
</tr>
</tbody>
</table>

Note: Electronic copies of the drawings for printing in A3 size are available.

Table 6.2: Standard Drawings for Freeway Ramp Signals

6.4.2. Two Lane Entry Ramp (Drg. No. 453771)

The typical entry ramp layout for a ramp with two metered lanes is shown in Figure 6.6. The layout for two lane ramps is the general minimum for entry ramps. However, a similar layout would be adopted for low flow ramps only requiring a single lane.

For two lane ramps, the stop line is generally located 80 metres upstream of the ramp nose. When the signals are operating, this distance aims to maximise ramp storage while still providing an overall acceleration and merging distance of 400m (80m plus the standard 320m entry lane merge distance) which is sufficient distance for cars to accelerate from 0 to 80 km/h when merging with the left lane of the freeway. For grades of 5 or 6% the acceleration distance includes part of the final merge taper.

A speed of 80 km/h in the left lane of the freeway is appropriate for merging during periods of high flow when the ramp meters are operating. This figure is also consistent with the speed threshold used for activation of the ramp signals. Based on the operation of current ramp signals installed, the above standard has been satisfactory for trucks. Nevertheless, on ramps with high truck volumes a greater merging distance could be considered as indicated below.

The stop line location also provides satisfactory operation for the two lanes to one lane taper before the nose when the signals are not operating. When the signals are off, 80 metres provides adequate distance near the end of the ramp for ramp traffic travelling at 80km/h to merge to a single lane before the nose, based on the standard for an acceleration lane merge (1m/s lateral shift). Further acceleration to match the speed of traffic in the main carriageway can then be undertaken.

The stop line distance may need to be increased for site specific conditions such as:

- Where the merge area is on a steep upgrade, particularly on grades over 5% where otherwise the acceleration distance includes part of the final merge taper
- To improve the visibility to the signals due to a crest, curve, vegetation or other restriction
- Where a curved ramp alignment restricts sight distance to the two-to-one lane merge area
- Where the ramp traffic includes a significant number of trucks, or
- On long high standard ramps that may operate at high speeds.
Figure 6.6: Typical Freeway Ramp Signals Layout - 2 Metered Lanes
6.4.3. Priority Access Lanes

To provide an access advantage to selected vehicles, an additional entry ramp lane may be installed to allow those vehicles to bypass the ramp queue. An example providing truck priority is shown in Figure 6.7.

A priority access lane may be provided to improve the service level for:

- Trucks - in recognition of the economic value of efficient movement of freight or to allow heavy vehicles to reach freeway operational speeds on uphill grades
- Vehicles occupied by more than one person such as buses, taxis or specified high occupancy (HOV) vehicles, e.g., a Transit Lane to provide priority and incentive for people to share vehicle usage. Motor bikes may also use Transit Lanes;
- Public transport priority where the entry ramp is part of a bus route.

With appropriate regulatory signing as outlined in Section 6.4.13, a priority lane is enforceable under Road Safety Road Rules 2009 (Rules 154, 156, 157 and 158).

Where a freeway is managed to optimise traffic flow, maximum utilisation of the mainline infrastructure is provided to keep all lanes operating efficiently and in reducing overall trip times. Therefore, when compared with the use of a dedicated priority lane on the mainline that is generally underutilised, the use of priority access lanes on an entry ramp, in association with freeway entry ramp signals to manage flow on the mainline for all vehicles, is an effective option for maximising the use of the freeway.

The types of bypass lanes include:

- Free flow bypass lane. These lanes provide an uncontrolled movement of priority vehicles along the ramp and avoid the need for vehicles to stop. However, the uncontrolled entry flow can cause problems for management of the mainline when there are heavy freeway demands. Therefore, uncontrolled free flow bypass lanes should only be used in the absence of a critical bottleneck in the downstream sections of the freeway.
- Partially controlled / free flow bypass lane. In the context of managing freeway flow it is generally preferable to control all entry flows. This priority lane operation has a free flow bypass lane which is controllable with ramp signals that switch on separately to the general traffic ramp signals. This arrangement has the advantage of only activating the bypass lane signals when the freeway is approaching a high level of occupancy. The bypass operates as an uncontrolled / free flow lane when traffic conditions permit, e.g., when the freeway is below capacity and ramp queues are under control, and then the lane operates as a controlled bypass during times of critical mainline flow management. This layout has the same geometry as a free flow bypass lane.
Controlled by metering signals. Although priority vehicles are metered, the separate priority access lane provides an advantage as the queues will be shorter for the priority lane.

Preference should be given to providing metered priority access lanes or partially controlled bypass lanes rather than full time free flow access. This improves freeway control and maximises the potential for sustaining desirable freeway performance.

Given the importance of ramp capacity and storage, priority access lanes should only be provided where there is a significant strategic need and provision of the additional lane does not compromise the width, number of traffic lanes and storage required for general traffic.

Guidance for situations where priority access lanes may need to be considered includes:

- Sites where a bus route uses the ramp
- Ramps on the Principal Freight Network (PFN)
- Other ramps not on the PFN but with high truck volumes
- In response to policy to encourage car occupancy greater than one person. This would usually be applicable to high volume ramps where the proportion of high occupancy vehicles could justify a separate lane. The Transit Lane benefit is more often a fringe benefit where the priority access is provided primarily for trucks or public transport
- Where analysis indicates a marginal need for another metered lane on the ramp, i.e., a better alternative may be to provide a priority access lane rather than an extra metered lane.

6.4.3.1. Freeflow and Partially Controlled Priority Lane (Drg. No. S41797)

The freeflow priority lane layout has advantages that the priority vehicles do not need to stop then accelerate to merge, and the geometry is suitable for use at all times, i.e., when the signals are operating and not operating. The freeflow priority lane layout requires a second merge distance when entering the mainline and may involve more extensive road works when compared to a metered priority lane layout.

A disadvantage of a free flow priority lane is that there is reduced control over the volume of traffic entering the freeway and hence the ability to manage flow at the mainline bottlenecks. However, the ramp metering algorithm does consider the bypass traffic at the bottleneck and may reduce the metering flow rate for other traffic accordingly. Therefore vehicle detectors are provided in the priority lane as shown in the standard drawings. A partially controlled access lane provides control when necessary.

The entry ramp layout for ramp with a free-flow priority bypass lane is shown in Figure 6.8. The geometry is based on the following design principles:

- The stop line is 80m from the nose for the two vehicles leaving the stop line to merge
- A separation (generally 0.7m) is provided between the bypass lane and the metered vehicle lane. This separation tapers to a single line over the 80m merge distance
- The distance of 180m from the nose to the start of the bypass merge taper is consistent with the standard merge length from the nose to start of the merge taper. This distance allows vehicles to merge with the freeway traffic or choose to stay in the auxiliary lane and allow bypass vehicles to merge
- The 140m bypass lane merge taper is the standard freeway merge length
- The 100m parallel auxiliary lane is based on 4 seconds travel at 100km/h. Where downstream obstructions restrict the available length, this parallel section may be reduced
- The 140m final merge taper is the standard freeway merge length
- Kerb and channel is provided over the total distance of 560m available for the merging movements downstream of the ramp nose to minimise formation width, i.e., with no shoulder. The shoulder develops over the final 140m taper to match into the existing freeway shoulder.
6.4.3.2. Metered Priority Lane (Drg. No. 541798)

A metered priority lane is appropriate under the following circumstances:

- If the freeway management requires that all entering traffic is controlled, or
- If insufficient space is available on the freeway for the unmetered merge length, e.g., if the start of an exit ramp taper is immediately downstream.

Although the priority lane is metered, generally the priority vehicles would still have the advantage of a shorter queue and less delay entering the freeway.

The typical entry ramp layout for ramp with a metered priority bypass lane is shown in Figure 6.9. The stop line with this layout is located 150m from the ramp nose to provide additional merge distance for the three to one lane merge. A disadvantage of the metered bypass layout is reduced storage on the ramp compared with a setback of 80m from the stop line with no priority lane, unless the ramp is lengthened by extending the nose.

With the metered priority lane layout, the priority lane is a part-time lane and not suitable for operation when the metering signals are not operating, i.e., the merge lengths downstream of the stop line are inadequate for merging at higher operating speeds when the signals are off. Lane control signs are provided to restrict use of the priority lane outside metering times.
Figure 6.8: Typical Freeway Ramp Signals Layout - Freeflow Priority Lane
Figure 6.9: Typical Freeway Ramp Signals Layout - Metered Priority Lane

CHAPTER 6 DESIGN OF RAMP SIGNAL INSTALLATIONS
6.4.4. Three and Four Lanes at the Stop Line (Drg. Nos. 541795 & 541796)

The typical entry layouts for ramps with three metered lanes and four metered lanes at the stop line are shown in Figure 6.10 and Figure 6.11 respectively.

Ramp layouts with three lanes at the stop line require greater distances between the stop line and the nose for the merging movements, particularly if three lanes need to merge to a single lane at the nose. For the three to one lane merge, the distance also varies according to whether the third lane along the ramp is continuous (full time use) or an auxiliary lane at the stop line (part time use when the signals are on). If two lanes are provided at the nose, i.e., two lane merge onto the freeway or a single lane merge plus an added lane, the merge distance for vehicles leaving the stop line is similar to the two lane layout.

The metering layouts with four lanes at the stop line require a distance of 120m between the stop line and ramp nose. This distance is desirable in view of the complexity of the decision making involved with a larger number of vehicles being released at the same time.

6.4.5. Freeway to Freeway Ramp Metering (Drg. No. 453912)

The principles for managing freeway to freeway (system interchange) ramps are outlined in Section 4.4.

A typical layout for the freeway ramp signals is shown in Figure 6.12 for situations where freeway to freeway entry ramps are to be metered. There can be significant challenges related to ramp metering of freeway to freeway ramps including presence of structures and widening of embankments. There are also operational implications due to managing high traffic flows, balancing queues and delays between ramps, providing the storage required and safety. The detailed layout and geometry for the ramp signals would be developed according to the standard drawings for two, three or four lanes, as appropriate.

Drawing No. 453912 indicates the following two options for the location of the ramp signals:

a) Using separate stop lines for the left and right turning ramp connections just upstream of where they meet within the interchange. This option enables each ramp to be managed separately with queue lengths and/or waiting times balanced between the two ramps

b) Using a single stop line downstream of the merge between the two ramps after they form a single entry ramp onto the intersecting freeway. With this option there needs to be adequate storage within the interchange between the ramp signals and the merge of the upstream ramps.

RC2 warning signs are provided near the start of the ramp to warn drivers when ramp signals are operating. Consideration may also need to be given to freeway VMS prior to the ramp exit for purposes of incident management and ramp closure.

Where the ramp’s design speed is greater than 60 km/h, a variable speed limit sign would generally be appropriate. Generally, a 60 km/h speed limit would operate throughout the metering period. It is desirable for the variable speed limit signs to be capable of displaying speeds between 40 and 100 km/h.

The initial variable speed limit sign is generally located just after the exit ramp nose on the turning roadway being metered. The speed limit would generally terminate immediately after the metering signals to enable the merging vehicles to accelerate to the speed of the freeway they are entering. The variable speed limit within the interchange terminates with the speed limit or the variable speed limit operating on the intersecting freeway.
CHAPTER 6 DESIGN OF RAMP SIGNAL INSTALLATIONS

THREE LAKES TO ONE LANE AT NOSE - MERGE

CONTINUOUS THIRD LANE ON APPROACH OR PARALLEL FLARED LENGTH >30m

LOCALISED FLARING AT STOP LINE

THREE LANES TO TWO LANES AT NOSE - ONE MERGE PLUS ONE ADDED LANE

LEFT-SIDE FLARE OR CONTINUOUS THIRD LANE

SIGNAL GANTRY
FOUR LANES TO TWO LANES AT NOSE - ONE MERGE PLUS ONE ADDED LANE

EXTENDED FLARE OR CONTINUOUS APPROACH LINES

POSITION OVER CENTRE OF LANE TWO

POSITION OVER CENTRE OF LANE THREE

LOCALISED FLARE BOTH SIDES
Figure 6.12: Typical Freeway Ramp Signals Layout – Freeway to Freeway Ramps
6.4.6. Controller Location

The controller location should be a safe location for workers at the cabinet with nearby space for vehicle access and parking. A reasonably flat area (minimum 1900 x 1200) is required for the foundation and paving at the access doors. Access to both sides of the cabinet is required. A location to facilitate connections to power and system communications is necessary. Generally, visibility of the signal lanterns from near the controller is desirable.

A controller location near the ramp entrance provides benefits for worker safety and access. This location also facilitates radio communications, if provided, to ramp control signs on the arterial road as well being relatively close for viewing of the ramp control signs. This location is also convenient for providing a pole near the arterial road to be used for a CCTV camera and the wireless detector access point (refer Sections 6.4.11 and 6.4.15).

An alternative location for the controller is on the left side of the ramp between the traffic signals and the stop line. In this location the signals are visible and the controller is protected behind the guard fence which shields the signal pedestal. Installation near the signals may be difficult due to the available width adjacent to the ramp or the proximity of cut or fill slopes. In some instances the controller may need to be installed part way along the ramp. A controller location between the ramp and the freeway carriageway is generally undesirable.

6.4.7. Signal Pedestals

The signal support pedestal is installed adjacent to the ramp 10 metres downstream of the stop line. The use of a joint use mast arm (JUMA) is the usual standard for 2 lane ramps. The use of a JUMA facilitates fixing of detector and CCTV devices. The use of a 9m JUMA is generally adequate, however, 11m or 13.5m poles may need to be used if additional height is required for reception and/or transmission of detector data, e.g., when line of transmission is obscured by trees or structures.

The use of 2B pedestals each side of the ramp as shown in Figure 1.1 have also been used successfully and may be considered at sites where a JUMA is inappropriate, e.g., due to a height or visibility restriction. Alternatively the use of a 2B pedestal with a joint use pole (JUP) for installation of detector or CCTV equipment may be considered.

Gantries are provided for ramps with 3 or 4 lanes including installations with priority access lanes. The design for the freeway ramp signals gantry structure is available on VicRoads standard drawings. Where overhead lanterns are provided on a JUMA or gantry, the clearance to the underside of the lowest fixture on the structure shall be 5.4m, or 5.9m on an over dimensional (OD) route, in accordance with the VicRoads road design guidelines.

As the traffic signal pedestal (JUMA, JUP, 2B or gantry) is considered a non frangible roadside hazard the installation would generally include a safety barrier, typically guard fence. This barrier also serves to protect the signal controller, if it is installed at this location. An advantage of using a JUMA is that it only results in guard fence on one side of the ramp. Where a pole needs to be located on the freeway side of the ramp, consideration should also be given to the need for a safety barrier on the side adjacent to the main carriageway.

6.4.8. Signal Lanterns

Standard 200mm three-aspect LED lanterns are used for ramp signals. These are provided as high mounted lanterns with good visibility for approaching motorists and as low mounted lanterns for releasing vehicles at the stop line.

The high mounted lanterns are to be aimed towards the ramp entrance or to maximise sight distance, e.g., where there is a curved ramp. Subject to the length of the outreach and ramp width involved, a lantern would generally be provided for each lane on the JUMA outreach or on the gantry as indicated on the drawings. Where 2B pedestals (or JUP plus a 2B) are used, the upper lanterns shall be installed in the high mount position (2920mm high).
**Note:** Although only one low mounted signal faces drivers in some layouts, e.g., on a JUMA or on the gantry leg in the priority access lane layout, the overhead LED signal lanterns are also visible at the specified stop line distance from the signals and meet the luminous intensity standards in AS 2144 for the driver’s viewing angle at the stop line (refer to test results in Appendix C).

The desirable layout for overhead signal lanterns is to mount the lanterns directly over each lane. It is recognised that the standard 5.5m JUMA outreach width does not enable this to be achieved, and the current angled outreach is also less than desirable. Consideration is being given to a new horizontal arrangement with increased length of outreach for the future.

On a JUMA, JUP or gantry, the lower lanterns are to be mounted at a height of 2340mm (approx. 2200mm to the underside of the target board). The lower lanterns are to be aimed at a point at the centre of the ramp approach 3m upstream of the stop line to maximise visibility to the signals for drivers waiting at the stop line.

Where a JUP and a 2B pole are used instead of a JUMA, the lower lanterns are to be mounted at a height of 1200mm with the One Vehicle Per Green (G9-V167) and Each Lane (G9-V166) signs installed between the high mounted and low mounted lanterns.

**Note:** VicRoads freeway ramp signals standards for signs and signals are based on best practice which varies from earlier standards as outlined in the Austroads Guide to Traffic Management Part 10: Traffic Control and Communication Devices and AS 1742.14, particularly in relation to the use of three aspect lanterns. Anecdotally motorists’ observance of two aspect lanterns is not good. This may be because they are different to conventional 3 aspect traffic signals and drivers misunderstand the legal significance. Legally there is an advantage to provide a yellow signal because it gives some warning that a red light is coming (for which a driver must stop). Other advantages for using 3 aspect signals based on experience in Victoria include:

- It is beneficial to use a flashing yellow for the start up and close down sequence
- Public acceptance with ramp signals is very good. It is considered that this is because the signals are no different to normal traffic signals, except for the phase and cycle times
- Compliance is a key factor in the operation of a ramp metering system and therefore this alone justifies the use of 3 aspect lanterns.

### 6.4.9 Mainline Detectors

Detectors on the freeway mainline provide traffic data for flow, speed and occupancy to control the ramp signal system.

The freeway detectors in each lane on the mainline provide the principal sources of data for activation/deactivation and operation of the ramp signal system. The detectors are located just beyond the turbulent merging area and provide feedback to the ramp signal system to optimise freeway flow by controlling entering traffic from upstream ramps. The detectors are also used to provide speed, flow and occupancy data for monitoring freeway performance.

For entry ramps with a single lane at the ramp nose, the mainline data detectors are generally provided 320m downstream of the ramp nose, i.e., at the end of the taper. For entry ramps with two lanes at the nose, including layouts with an unmetered priority access lane, the mainline detectors are provided at the end of the final merge taper.

In an added lane situation where there is no merge, the downstream detectors are generally locating at the same distance as for a merge arrangement, i.e. 320m downstream from the physical ramp nose. This location is generally appropriate for measuring occupancy due to weaving of entering traffic and the traffic changing lanes into the added lane for leaving the freeway at the next downstream exit. This distance also provides appropriate spacing relative to the previous upstream detectors which will typically be about 100m upstream of the ramp nose.
As outlined in Section 5.2.1, freeway data detectors are also provided on the mainline upstream of the ramp nose for traffic counting and monitoring of freeway performance, e.g., for travel time and incident management. Freeway data detectors should also be provided on the freeway carriageway at about 500m spacing along the mainline between interchanges for monitoring traffic flow and management of bottlenecks. Detectors upstream of the nose can be used by the ramp signal system if the downstream detectors at the merge become unusable for any reason. Other downstream detectors, particularly at a bottleneck, can also be used by the ramp metering system.

The type of detector should be specified in the design together with locations for other equipment, e.g., repeater points (RP) and access points (AP) for wireless detectors (refer Section 5.2). Specific bottleneck locations where flow breakdown is likely to occur may need to be included for detector installation and monitoring to ensure mainline data is available at appropriate locations for the ramp metering system.

6.4.10. Ramp Detectors

6.4.10.1. Stop Line Detectors

The detectors immediately upstream and downstream of the stop line within each lane perform different functions. The detectors upstream of the stop line (leading detectors) are provided to detect the presence of a vehicle and actuate the green signal. When the upstream detectors are unoccupied the signals are held on red. This prevents the signals cycling when there are no waiting vehicles and helps to avoid driver confusion in relation to timing their arrival and deciding whether to stop or not.

The detectors downstream of the stop line (trailing detectors) are provided for general traffic counting data as well as vehicle counting associated with the metering control algorithm and ramp queue length estimates.

6.4.10.2. Middle of Ramp Queue Detectors

Detectors provided at the midpoint between the stop line and the ramp entrance detectors are used for queue length estimates and queue management in the ramp signal control algorithm. The mid ramp detectors are not required for an unmetered priority access lane.

Mid ramp detectors are not provided on metered priority access lanes as the bypass traffic (with short or no queue) is not considered in relation to occupancy values in the queue management part of the control algorithm.

6.4.10.3. Ramp Entrance Detectors

Detectors are provided at the ramp entrance for queue length estimates and queue management in the ramp signal control algorithm. Generally, they are also used to determine when ramp queues may overflow onto the arterial road.

The ramp entrance detectors are positioned to suit the layout of the ramp entrance. The layouts are treated differently within the control algorithm.

Type 1

The left turn slip lane intersects the ramp and traffic gives way to the right turn traffic. A balanced queue is formed for vehicle detection and queue management.
Type 2

The left turn slip lane and the section of the ramp for the right turn traffic form separate queues at the ramp entrance. Although lane changing may occur within the ramp, vehicle detection is in separate lanes for queue management.

For a ramp that is longer than the desirable storage from the stop line as outlined in Section 6.3, the ‘ramp entrance’ detectors are placed at the 4 minute queue distance. Other queue overflow detectors as outlined in Section 6.4.10.4 may also be provided for queue management.

6.4.10.4. Queue Overflow Detectors

Whenever possible the freeway ramp storage should be designed to accommodate the estimated storage requirements as outlined in Section 6.3.4 to avoid queues overflowing into the arterial road. When this cannot be achieved, consideration may need to be given to installing separate queue overflow detectors.

The ramp signal control algorithm is generally set up to use the ramp entrance detectors in a dual role. This enables them to function as ramp entrance as well as queue overflow detectors. Where separate queue overflow detectors are provided, the ramp entrance and the queue overflow detectors both need to be occupied to activate the queue override facility in the algorithm.

Where the ramp is very short relative to the desirable storage, queue detectors may need to be provided on the arterial road at the start of the right and/or left turn lanes leading to the ramp.

For a long ramp, i.e., longer than the desirable 4 minute queue storage distance, the queue overflow detectors may be installed at the ramp entrance.

Note:

An interface with the SCATS system is available to obtain information from the signal detector loops on the arterial road. The interface also enables transfer of information from the ramp detectors to the SCATS traffic signal system to enable control of the adjacent arterial road intersection signals according to predetermined control strategies.

6.4.11. Poles for Wireless Detector Receivers

Access points (APs) receive the wireless data transmissions from the wireless vehicle detectors and repeater points (RPs). APs require cabling back to the field processor and are generally mounted on an appropriately located JUMA, JUP or gantry near the field processor and signal controller. The AP is installed near the top of the pole at a height of 8 metres (minimum 6 metres).

Repeater points (RPs) are wireless devices that receive transmissions from the vehicle detectors and then transmit the data to the AP. Generally RPs are installed at a height of 8 metres (minimum 6 metres) and may be installed on an appropriately located JUMA, JUP or on a separate pole as appropriate.

Subject to roadside safety design considerations, poles in the clear zone should be frangible or shielded with a safety barrier. The use of slip base lighting poles in vulnerable locations is generally avoided due to potential delays replacing poles after an accident.

6.4.12. Ramp Control Signs and Real Time Information Signs

Freeway ramp signals are part-time traffic control devices and drivers need to be advised when the signals are operating. Traveller information is also important to advise drivers of travel conditions on the freeway. Electronic ramp control signs (RC1), warning signs (RC2) and real time information signs (RC3) operate as part of the ramp signal, traveller information and incident management systems to provide the following information:
### 6.4.12.1. RC1 Warning and Regulatory Sign

The RC1 signs display warning and regulatory messages and are provided on the approaches to the arterial road/entry ramp intersection to face traffic turning into the ramp. ‘RAMP SIGNALS ON’ as shown in Figure 6.13 is displayed when the ramp signals are operating. The signs have a dual role and can also be activated for operation as part of freeway incident management to display ‘FREEWAY CLOSED’ and a symbolic No Right/No Left Turn, No Entry or other specified message, as appropriate.

<table>
<thead>
<tr>
<th>RC1</th>
<th>RC2</th>
<th>RC3</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Warning message when the ramp signals are operating</td>
<td>• Warning messages when the ramp signals are operating.</td>
<td>• Traveller information relating to:</td>
</tr>
<tr>
<td>• Regulatory and advice messages when the freeway ramp is closed.</td>
<td></td>
<td>– Travel time (default)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>– Freeway condition, i.e., level of congestion</td>
</tr>
<tr>
<td></td>
<td></td>
<td>– Incidents and events.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Freeway closure information.</td>
</tr>
</tbody>
</table>

**Note:** TOLLWAY CLOSED or FREEWAY CLOSED display is used as appropriate.

*Figure 6.13: RC1 Sign Messages*

### 6.4.12.2. RC2 Warning Sign

RC2 warning signs are used on an entry ramp for situations where there is restricted sight distance to the ramp signals. The sign arrangement indicates signals ahead (static symbolic sign W3-3B sign) and electronic ‘PREPARE TO STOP’ alternating with ‘RAMP SIGNALS ON’ signs as shown in Figure 6.14.

*Figure 6.14: Entry Ramp Warning Signs with Alternating Messages*
6.4.12.3. RC3 Sign - Real Time Information Sign

Real time information signs are multi-colour full matrix variable message signs which provide up to 3 lines of text and/or graphics within a display matrix of 1536mm x 480mm. The signs display travel time information on the freeway, including ramp delay, and contribute to the freeway management during periods of congestion or incidents. Examples of RC3 signs are shown in Figure 6.15 and Figure 7.4. Further information is included in the traveller information and incident management guidelines.

Advising the public in real time of travel time, incidents and roadworks can influence motorists into using alternate routes by providing the opportunity for drivers to make informed travel choices. This not only reduces individual inconvenience experienced by waiting in slow moving traffic, but has the potential to reduce the demand on mainline flow and improve safety associated with advance warning of freeway conditions after a motorist enters the freeway, e.g., left lane closed. Being able to manage the freeway during events also facilitates faster recovery of the freeway after an incident.

Figure 6.15: Examples of RC3 Real Time Information Sign Messages

RC3 signs are located on the arterial road according to the following principles:

- Separate signs are provided for all metered ramps in advance of the left and right turn lanes at the interchange
- When the interchange is close to a downstream freeway fork, i.e., one or two interchanges prior to the freeway dividing into two downstream routes creating a route choice, two RC3 signs are provided at each approach to enable separate displays of travel time and incident information for each downstream route
- Where an RC3 sign is not justified on an approach, e.g., due to a low traffic movement turning onto the freeway or where downstream travel time data is not available, an advanced RC1 would generally be provided on the approach to supplement the RC1 sign at the intersection.

RC3 signs are generally installed on an RC3 pole (refer VicRoads Standard Drawings). A joint use signal pole (JUP) may also be used if appropriate. Where a median or footway is of insufficient width to provide the minimum of 500mm lateral clearance from the sign to the kerbline, the RC3 may be installed on a mastarm (generally with 2.5m outreach) so that the sign is cantilevered over the roadway (minimum clearance 5.4m or 5.9m on an over dimensional route).

Note:

An Instinct and Reason report prepared for Austroads (2008) relating to research on road user information needs with an emphasis on variable message signs, indicates that 80% of participants would find travel time in minutes useful and that 79% would find the colour coding of traffic flow useful. A Sinclair Knight Merz report (2005) based on focus group discussions relating to the Drive Time System it was indicated that “The ‘minutes’ information was considered most valuable to regular road users whereas the ‘colours’ based information was thought to be most useful to infrequent users.”
6.4.13. Other Signs
Static signs shown on the drawings as forming part of the ramp signals installation include:

- **Stop Here on Red Signal (R6-6A)**
  These regulatory signs are required at the stop line as it is remote from the traffic signals.

- **One Vehicle Per Green and Each Lane (G9-V198)**
  These signs are located on the signal pedestal near each lantern.

- **Form One lane (G9-15B)**
  These signs are located 20 metres downstream of the stop line.

- **Speed limit sign (R4-1B) or variable speed limit sign.**
  These signs are located 20m prior to the ramp nose to indicate the speed limit on the carriageway being entered.

- **T2 / Truck lane signs (special sign) to designate the use of the left lane if a priority access lane is provided. The use and positioning of these signs is consistent with Rule 329 of Road Safety Road Rules 2009. The signs are supplemented with a ‘Left Lane’ or ‘Signals do not apply’ sign as appropriate.**

Other signs which may be required in association with a freeway entry ramp, e.g. Merging Traffic warning sign, Emergency Stopping Lane sign etc. shall be provided in accordance with the Traffic Engineering Manual Vol. 2, Chapter 12: Freeway Signs and Markings.

6.4.14. Pavement Markings
The pavement markings and RRPMs associated with the ramp signal designs as shown on the Standard Drawings are provided according to the Traffic Engineering Manual Vol. 2 and the following principles:

- Longitudinal line marking includes a 30 metre single continuous lane line on the approach to the stop line
- Edge lines are provided on both sides of the ramp. Downstream of the stop line the left edgeline provides guidance for the merging traffic
- The two to one lane merging downstream of the stop line is a ‘zip’ merge, i.e., no continuity line
- The merging from the entry ramp into the main carriageway of the freeway is a lane changing movement, i.e., provide a continuity line
- The stop line is located 10 metres upstream of the traffic signal pedestal.
6.4.15. CCTV Cameras
The provision of a CCTV camera with pan, tilt, zoom capability is included in the ramp signal design to ensure appropriate operator observation during fine tuning of algorithm parameters and operation as well as monitoring queues, driver behaviour and identification of operational problems. Desirable visibility of traffic includes:

- Along the full length of the ramp
- The arterial road approaches, i.e., the left and right turn lanes in case of queue overflow, and
- At the freeway merge.

A camera at the interchange near the ramp entrance generally provides the best coverage of these areas for ramp metering. Alternatively, a camera may be included in the design for installation on the JUMA, JUP or gantry pole extension as appropriate. While this camera location provides a solution at relatively low cost, it would generally not provide a view of the arterial road approaches.

6.4.16. Power Supply and Communications
The power supply connection to the ramp signal controller is provided from an Electricity Supply Authority point of supply. Power is then distributed to other devices. A separate local power supply may be provided to RC3 signs where wireless communications are provided to the sign.

Electrical conduits (E100mm orange) and communications conduits (C100mm white) generally connect devices to the controller. Separate pits are provided for the communications and power. Pits are provided at all changes of direction and at a maximum spacing of 250m on straight lengths.

The preferred arrangement for system control is the use of fibre optic communications in mainline trunk conduits. In some situations a wireless communication network may be necessary.

6.4.17. Lighting
Generally, street lighting is not specifically required as part of the installation of freeway ramp signals. The need for lighting of the entry ramp may need to be considered in accordance with VicRoads freeway lighting policy and guidelines.