MCH 2473 Ramp Metering Calibration Guidelines

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# Ramp Metering

## Calibration Guidelines

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## GLOSSARY OF TERMS

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<th>Term</th>
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<td>ALINEA</td>
<td>Asservissement lineaire d’entree autoroutière (Main Carriageway Algorithm)</td>
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<td>CCTV</td>
<td>Closed Circuit Television</td>
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<td>HA</td>
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<td>H&amp;S</td>
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<td>MAC</td>
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<td>MIDAS</td>
<td>Motorway Incident Detection &amp; Automatic Signalling</td>
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<td>MTV</td>
<td>Motorway Traffic Viewer</td>
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<td>PPE</td>
<td>Personal Protection Equipment</td>
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<td>SAT</td>
<td>Site Acceptance Test</td>
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<tr>
<td>TCD</td>
<td>Traffic Count Data</td>
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<td>TSC</td>
<td>Traffic Signal Controller</td>
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Executive Summary

This document is one of a suite of ramp metering guidelines which explain the design, installation, maintenance and operation of a ramp metering system.

This document provides the reader with the necessary information to calibrate a ramp metering system. It provides the background and theory of ramp metering and discusses the practical considerations of calibrating the system.

The document is intended to be used as supporting material for ramp metering calibration and training. As calibration is a specialised task, the individual undertaking calibration should have attended an approved calibration training course.

The calibration of a ramp metering system is a highly subjective task. There is no single right or wrong way of deriving optimal settings due to the transient nature of traffic flows. This document provides the reader with the knowledge and tools to make reasoned judgements about the system settings. The document does not dictate a preferred method of systematically calibrating a system but does embrace best practice where appropriate. The best practice takes the form of recommendations and processes by which calibration of a site can be efficiently achieved, however, it is noted that more suitable processes may be developed in future.

This document complements the ‘Ramp Metering Technical Specification MCH1965’. MCH1965 is to be read in conjunction with this document.
1. **Introduction**

1.1 **Ramp Metering Background and Concept**

Ramp metering is a traffic management technique which regulates the manner in which vehicles join a motorway at peak periods. The purpose of the system is to prevent or delay the onset of flow breakdown on the main carriageway by a combination of:

- Restricting the flow onto the motorway of additional traffic that, if unrestricted would trigger flow breakdown; and,
- Managing the flow on the entry slip road to avoid large platoons of vehicles entering the main carriageway and causing flow breakdown.
- By preventing or delaying flow breakdown the system provides the following benefits:
  - Less congestion and improved traffic flows;
  - Greater throughput during peak periods;
  - Smoother and more reliable journey times;
  - Reduced risk of accidents; and,
  - Environmental improvements as a result of noise reduction and improved fuel consumption.

The ramp metering system uses part time signals on the slip road which come into operation when traffic sensors on the main carriageway indicate heavy traffic. Figure 1.1 below provides an overview of how the ramp metering system operates. The full operation is described in ‘MCH1965 – Ramp Metering System Requirements Specification’.

Generally, the traffic data is monitored by the main carriageway data filtering and ramp data filtering algorithms. The traffic data is used in the ramp metering control algorithms to determine the best traffic flow for the system to operate efficiently. This traffic flow is converted into a period of signal sequences to the motorists, in order to dissipate the intended traffic flows onto the main carriageway. The principle control algorithms used are as follows:

- Switch on-off algorithm - to turn the system on and off;
- Queue override algorithm – to counter the overload of slip road queue and avoid congestion in the local trunk road network;
- Queue management algorithm using proportional occupancy – to manage the queue on the slip road; and,
- Main carriageway algorithm using ALINEA – to maintain the main carriageway occupancy.
1.2 Ramp Metering Deployment

The Highways Agency undertook a project to deliver 30 ramp metering systems by the end of March 2007. The ramp metering systems are located in the West Midlands and the North of England. They have been installed in the following HA Managing Agent Contractor (HA MAC) Areas:

- Area 9: 10 sites.
- Area 10: 12 sites.
- Area 11: 1 site.
- Area 12: 7 sites.

1.3 Ramp Metering Scheme Overview

A typical ramp metering scheme can be split into sections as detailed in Figure 1.2. Each section can be defined individually but aspects from each will overlap and impact on the next. The calibration team should be aware of the ramp metering scheme life cycle and the impact of the different areas on the final site operation. Figure 1.2, on the following page, shows a brief description of each of the sections. A more detailed description can be found in additional ramp metering documentation.
1.3.1 Site Selection

This is primarily based on the traffic flows in and around each junction, with considerations being made to junction layout and topography. This can be initiated by a HA Area team looking for a solution to a particular congestion problem or a major ramp metering implementation scheme. The site selection will produce an output specifying any junction(s) which may be suitable for ramp metering.
1.3.2 Design

The underlying principle behind any design is the operational strategy. This is an agreed course of action that the ramp metering project team pursue in order to tackle a specific traffic congestion problem in a pre-determined way.

The designer has responsibility for developing the design intent and ensuring that the system components can be built and operated in a safe, efficient and cost effective manner.

It is essential to the success of the ramp metering project that the calibration team take due cognisance of the operational strategy and design intent.

1.3.3 Installation

The installation of the infrastructure is carried out by a designated contractor. This element includes installing all signs and signal poles, anti-skid surfacing, cabinet sites, ducting and cabling and slip road loops.

1.3.4 System Commissioning

The commissioning phase is completed once all infrastructure elements are completed. A default configuration file is loaded on to the system and a series of tests are undertaken to ensure that each system (hardware and software) has the intended functionality.

1.3.5 Calibration

During this phase the system is finely tuned to give maximum benefits. This process is a careful balance between the slip road and main carriageway activity. From the operational strategy generated during the design phase, values for the numerous parameters are derived to give an initial setup. This initial setup is then finely tuned whilst the system is live and metering traffic. At the end of this phase the system will be fully operational.

Unsuitable calibration parameters can easily cause unnecessary delays to the mainline and/or the slip road and local road network.

1.3.6 Operation and Maintenance

As the ramp metering system is designed as a stand alone system the operational impacts are negligible. The ramp metering system will adapt to normal changes in traffic flows during summer and winter and will operate automatically only when the mainline conditions require it.
1.3.7 Evaluation

The detailed setup at each site should be evaluated to ensure it is giving the optimum benefits available. Continuous evaluation and re-calibration may be required if the traffic flows around the area of a particular junction change. This could be due to a HA scheme in the vicinity of the junction or increased traffic on the slip road due to changes in the local area or road network.

1.4 Calibration Process Overview

The calibration process is a complex activity. It is an indispensable process of optimising the performance of the ramp metering system, such that the system will operate at its optimum performance. The calibration process involves a series of activities which includes but is not limited to the following:

- Health and safety considerations;
- Pre-calibration data collection;
- Pre-calibration data analysis;
- Calculation of the most appropriate initial system settings prior calibration;
- Pre-calibration surveys;
- Switch on-off algorithm calibration;
- Release levels and signal timings calculations;
- Queue management algorithm calibration;
- Queue override algorithm calibration;
- Ramp metering algorithm calibration;
- System monitoring during the system settling in period; and,
- System evaluation and re-calibration.

The likely timescale to complete the entire calibration process takes eight to twelve weeks depending on the availability of sufficient quality data. Once calibrated, the system is deemed to function effectively but the evaluation of the efficiency of its operation is a separate exercise following initial calibration.

1.5 Scope of Document

This document aims to give an insight to how the calibration process takes place and offers guidelines to the calibration team. It is the objective of this guide to deliver the necessary understandings and skill sets to the calibration team, in order to carry out the system calibration correctly.

1.6 Structure of Document

The document comprises the following sections:

- Section 1 is the basic introduction to the document;
- Section 2 provides an overview of the ramp metering system and its operation;
Section 3 explains the ramp metering theory and the available calibration tools;

Section 4 details the calibration process, its sequence of events and the operational strategy. It also explains the documentation, reporting and H&S considerations for the calibration process;

Section 5 explains the individual system settings and their initial configurations; and,

Section 6 illustrates the process of fine tuning the live ramp metering system and reviewing the effectiveness of the system after calibration.

1.7 Related Documents

It is advised the calibration team is familiar with the other aspects of the ramp metering scheme delivery including:

- IAN 103/08: Advice Regarding the Assessment of Sites for Ramp Metering.
- Ramp Metering Configuration Set-up and Management MCH 2472.

1.8 Document Limitations

This document is aimed as a guideline for the ramp metering calibration process and does not detail all of the algorithms available in MCH1965.

This document supplements the technical ramp metering specification MCH1965 and assumes that the reader has a detailed knowledge of the specification. This document only relates to the current system design and does not take any further enhancements into account. Due to the nature of the ramp metering system and its aims, ramp metering calibration engineers should have a thorough understanding of how the ramp metering system operates. Full training on the system calibration is required before any system calibration is carried out.

The calibration of a ramp metering system is a highly subjective task. There is no single right or wrong way of deriving optimal settings due to the transient nature of traffic flows. This document provides the reader with the knowledge and tools to make reasoned judgements about the system settings. The document does not dictate a preferred method of systematically calibrating a system but does embrace best practice where appropriate.

This document does not provide any guidance on the evaluation of a ramp metering site. Evaluation is an involved task which needs to be conducted over a period of time before and after the ramp metering system is switched on.
2. **Ramp Metering Overview**

2.1 **Introduction**

Before starting the calibration process it is essential to have a thorough understanding of the congestion problem and what ramp metering can achieve. The congestion problem should have already been identified prior to design, through the operational strategy stage. Calibration engineers should understand the design considerations and have a thorough knowledge of the characteristics of congestion.

2.2 **Ramp Metering Aims**

The aim of ramp metering is to regulate flow from the slip road on to the main carriageway at a level that maximises throughput on the main carriageway. A detailed explanation of ramp metering theory is provided in Section 3.

Most ramp metering sites use the ALINEA algorithm to maintain a steady occupancy on the main carriageway. The occupancy is a value which represents the amount of time a loop is covered by a vehicle. Occupancy is expressed as a percentage.

When traffic conditions on the main carriageway are busy the main carriageway loop occupancy is high.

A high occupancy directly equates to smaller distances between vehicles or short headways. In such conditions the road’s capacity is close to being reached and small changes in the nature of the traffic flow will cause the flow to become unstable and susceptible to flow breakdown.

The introduction of traffic from the slip road can cause vehicles to change lanes or brake which gives rise to higher occupancy and lower headways. These shorter headways can be unsustainable at the speed of the main carriageway. For comfort and safety, drivers will adjust their speed to account for the short stopping distances available. This adjustment of headway can occur over a distance of up to 2km after the on slip.

Often this adjustment of headway will cause following vehicles to brake, propagating a ‘wave’ of braking vehicles in the traffic stream. Traffic concentration in the wave will be even higher. To compound the problem, more vehicles will be entering the main carriageway boosting concentration even higher. If vehicles continue to join, ultimately the main carriageway speed will drop to a point where flow breakdown occurs. In this situation vehicles are stopping at the back of a queue and then driving off the front of the queue. This stationary traffic is typically seen between the merge area and approximately 2km downstream.

As a result of standing traffic, sometimes called a ‘phantom jam’, the road effectively has its lowest throughput when the demand is at its highest.

Weather conditions, daylight, vehicle mix and gradients amongst other things can all affect the maximum throughput of any section of motorway.
To address this problem, ramp metering aims to maximise throughput on the main carriageway without disrupting the local road network. It does this by controlling the discharge of traffic from the slip road to reduce the interference of merging traffic on the main line flow thereby maintaining flows at a higher level. Maintaining higher flows will postpone the onset and duration of flow breakdown on the main carriageway. The ramp metering system relies on the measurement of traffic conditions on the main carriageway and attempts to maintain this at ‘target occupancy’ by restricting the flow from the on slip road.

2.3 Site Selection Information Summary

Typical information that the calibration engineer should understand from the evaluation of the traffic statistics, which influence the operational strategy stage include the following:

- Determination of the exact point, or points of flow breakdown;
- Determination of the principal causes of flow breakdown;
- How long the ramp metering site needs to be on for, and how long the congestion lasts;
- The road layout immediately (2km) down stream of the merge point;
- The most suitable locations for MIDAS loops;
- Whether occupancy and flow breakdown are affected by bends/hills/visibility issues;
- Slip road flow should be considered in design, in respect of length of slip road; and,
- The main carriageway speed which the system can safely operate and the times when the ramp metering system should be active.

2.4 Ramp Metering Limitations

There are some congestion problems where ramp metering systems will not provide effective benefits. These are congestion problems caused by bottlenecks downstream of a slip road and the flow from the slip road is too low. In this situation the slip road flow, whether restricted or not, is unlikely to have a significant impact on the traffic flowing through the bottleneck.

Situations such as this are particularly relevant when:

- Flow from the slip road is low compared to main carriageway flow.
- The bottleneck problem causes a large congestion problem, where capacity of the road is greatly exceeded. Large bottleneck problems would typically include a large change in capacity on a road for example:
  - Capacity of road reduction due to lane loss;
  - Traffic backing up from an off slip and blocking a lane of the main carriageway;
  - Diverging tailbacks at motorway intersections; and,
  - Roadwork traffic management/ accident causing lane loss.
3. Ramp Metering Theory

3.1 Motorway Traffic Behaviour

There are a number of ways to examine the traffic behaviour on the motorway. To understand ramp metering theory, motorway traffic behaviour can be assessed using three main traffic parameters, namely main carriageway speed, traffic flow and motorway occupancy. The relationships between these traffic parameters are shown in the Figure 3.1 to 3.3 below:

Figure 3.1 - Speed-Occupancy Curve (Basic Linear Characteristic)

Figure 3.2 - Speed-Flow Curve (Complex Non-Linear Characteristic)
3.2 Congestion Characteristics

Commonly, the congestion, and therefore flow breakdown, at motorway junctions is caused by the following:

- Weaving;
- Large vehicle platoons / signalised roundabout;
- High slip road flow / poor or sub standard slip roads or merges; or,
- Shockwaves.

3.2.1 Weaving

This type of congestion occurs at sites where a significant amount of vehicles are weaving across the path of merging traffic to take the following exit.

A typical example weaving site is:

- A site at which there is an off slip directly after an on-slip; or,
- A site at which there is a motorway diverge occurring shortly after an on-slip/

Weaving sites exhibit the following traffic/driver behaviour:

- Vehicles wishing to use the following exit move into the left hand lane prior to the merge;
- Vehicles using the on-slip therefore have to join a highly occupied left hand lane to get into the main carriageway. This causes an initial merging problem; or,
- There is significant lane swapping by further vehicles trying to access the left hand lane to exit at the following junction at the same time as those vehicles which have just joined the main carriageway wish to move towards lanes two and three.
3.2.2 Large Vehicle Platoons / Signalised Roundabout

At many motorway interchanges, traffic signals are employed to maximise the traffic flow through the junction. An efficient traffic signalled junction will maximise its throughput by ‘bunching’ a large number of vehicles into a single movement. This can result in large platoons of traffic entering the slip road and attempting to merge at once.

3.2.3 High Slip Road Flow / Poor or Sub-Standard Slip Roads or Merges

Some junctions have very high slip road flow during the peak hours. Alternatively some junctions have constraints on the slip road or merge layout. This can cause congestion at the merge area on the main carriageway as too many vehicles try to merge onto the main carriageway.

3.2.4 Shockwaves

A busy and congested junction may cause a long traffic queue on the main carriageway. Moreover, the queue may back up to the preceding junctions. This is the phenomenon referred to as ‘shockwaves’ on the main carriageway. Shockwaves usually occur rapidly once the occupancy of the main carriageway has increased dramatically. As such, this will cause congestions to the preceding junctions.

3.3 Negative Control Feedback Loops

The ramp metering process is controlled by negative feedback control loops. The ramp metering control mechanism is illustrated in Figure 3.4 below. Under the negative feedback regime, the control algorithms will strive to maintain maximum throughput on the main carriageway without disrupting the local network roads.

![Figure 3.4 - Negative Feedback Control Loops of Ramp Metering Process](image-url)
3.4 **Available Control Algorithms**

Generally, there are 7 algorithms available for ramp metering operations. They are listed as follows:

♦ Release algorithm;
♦ Arbitration algorithm;
♦ Switch On-Off algorithm;
♦ Ramp Metering algorithm;
♦ Queue Override algorithm;
♦ Queue Management algorithm; and,
♦ Data filtering algorithm(s).

3.4.1 **Release Algorithm**

The release algorithm sets the traffic signals appropriately to provide the required traffic flow released from the slip road. As a secondary function, the release algorithm also monitors the actual release rate.

There are ten different sets of signal times; each provides a distinct level and pattern of traffic flow from the stop line onto the main carriageway. The release algorithm also manages the transition from signals off to signals on, and vice versa, via a steady green state of a pre-defined minimum duration.

Figure 3.5 below shows the release algorithm schematic.


**3.4.2 Arbitration algorithm**

The arbitration algorithm monitors the required slip road flow from the ramp metering, queue management, queue override and switch on-off algorithms and determines the correct slip road release flow to pass on to the release algorithm.

The outputs of the ramp metering, queue management, queue override and switch on-off algorithms provide the input to the arbitration algorithm. Each of these outputs is re-calculated at different intervals. As such, the arbitration algorithm constantly monitors all of the desired flow rates and re-calculates the correct release flow output to the release algorithm in real time.

Figure 3.6 below shows the arbitration algorithm schematic. The arbitration algorithm always selects the highest desired release flow from the input algorithms and passes that value to the release algorithm.

![Arbitration Algorithm Schematic](image)

**Figure 3.6 - Arbitration Algorithm Schematic**

**3.4.3 Switch On-Off Algorithm**

The switch on-off algorithm switches the ramp metering system on or off. It switches off the ramp metering system by setting its desired release level to the pre-defined highest value flow rate. Likewise, it switches on the system by reducing its desired flow rate until the desired flow rate drops below the outputs from the other algorithms.

It switches on or off by monitoring the traffic conditions, when minimum operational levels of occupancy or flow and occupancy are exceeded during the period of operation. At the same time, it also takes into account the main carriageway speed as one of its switch on-off criteria. It initiates the switch off sequence or delays switch on if the main carriageway speed is at or above the pre-determined safe operational speed.

In order to avoid releasing a full slip road of queuing vehicles into the mainline, the switch on-off algorithm also monitors the occupancy of the two queue presence loops. If the occupancy of either queue presence loop is above the preset queue presence
threshold value, it holds the switch off sequence at the maximum release rate until the queue at the stop line has dissipated to allow the switch off sequence to continue.

Figure 3.7 below shows the switch on-off algorithm schematic. There are five operational modes in switch on-off algorithm, namely:

- **Manual on** – operational when the upstream mainline speed is low enough;
- **Manual off** – overwrite mode to turn the system off manually;
- **Timed** – operational when the day and time of day and maximum speed criteria are met;
- **Timed occupancy** – operational when the day and time of day, minimum occupancy and maximum speed criteria are met;
- **Timed flow and occupancy** – operational when the day and time of day, minimum flow and minimum occupancy criteria are met.

![Figure 3.7 - Switch On-Off Algorithm Schematic](image)

### 3.4.4 Queue Override Algorithm

The queue override algorithm reduces the queue of traffic waiting to join the main carriageway to prevent the queue from adversely affecting the local roads. It detects the presence of an excessive queue length and reduces the queue length immediately by releasing the traffic from the slip road to generate a sufficient space within the slip road to prevent disruption to the local road network. Operation of the queue override algorithm is at the expense of the main carriageway. Figure 3.8 below shows the queue override algorithm schematic.
3.4.5 Queue Management Algorithm

The queue management algorithm controls the queue length to acceptable limits to maximise the period of effective ramp metering operation whilst minimising the operation of the queue override function. Figure 3.9 below shows the queue management algorithm schematic.

There is a switch to enable the selection of 2 different queue management algorithms. These 2 algorithms are as follows:

1. Proportional occupancy queue management.

   The proportional occupancy queue management algorithm monitors the occupancy at each set of queue detection loops to obtain the average occupancy of the slip road, in which an estimate of the queue length is determined. Based on the estimated queue length, the proportional occupancy queue management algorithm sets the desired release rate to maintain the queue length at the pre-defined desired value. Figure 3.10 below shows the proportional occupancy queue management algorithm.
2. Weighted occupancy queue management.

Weighted occupancy queue management has not been applied in practice. It is not therefore discussed further here. Details of the algorithm can be found in MCH1965.

### 3.4.6 Ramp Metering Algorithm

The ramp metering algorithm determines the optimum traffic flow from the slip road to control the flow of traffic on to the main carriageway. Figure 3.11 below shows the ramp metering algorithm schematic.

![Figure 3.11 - Ramp Metering Algorithm Schematic](image-url)
There is a switch to enable the selection of two different ramp metering algorithms. These two algorithms are as follows:

1. **ALINEA algorithm**

   The ALINEA algorithm outputs the required slip road flow value in proportion to the difference between the measured downstream occupancy and the desired downstream occupancy. If the downstream occupancy is greater than the desired value, ALINEA reduces the slip road flow. However, if the downstream occupancy is less than the desired value, it increases the slip road flow. Hence, the subsequent measured downstream occupancy is maintained as close as possible to the desired value. Figure 3.12 below shows the ALINEA algorithm schematic.

   ![ALINEA Algorithm Schematic](image)

   **Figure 3.12 - ALINEA Algorithm Schematic**

2. **Demand capacity algorithm**

   The demand capacity algorithm has not been successfully applied in practice. It is not therefore discussed further here. Details of the algorithm can be found in MCH1965.

3.4.7 **Data Filtering Algorithms**

   Data filtering algorithms calculate smoothed values for flow, speed and occupancy from the raw vehicle data collected by the detectors. The smoothed values are used by the other algorithms outlined in this section.

   There are 2 data filters as follows:

   1. **Main Carriageway Data Filtering (MCDF) algorithm.**
The MCDF algorithm calculates the smoothed flow, speed and occupancy data from the raw vehicle from the MIDAS loops. It calculates the smoothed flow, speed and occupancy for every loop pair at every loop site.

2. Ramp Data Filtering (RDF) algorithm.

The RDF algorithm calculates the smoothed flow and occupancy values for the slip road activity. The RDF algorithm also calculates the number of vehicles passing each slip road loop to be used in the queue estimation and control algorithms.
4. Pre-Site Calibration

4.1 Sequence of Events

The calibration process involves a number of stages as detailed in the following table. The table defines the order in which the calibration events should be carried out in order to ensure a smooth process.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Obtaining the default settings from the pre-installed configuration file on the RMC. The default settings are described in Section 4.3.</td>
</tr>
<tr>
<td>2</td>
<td>Developing the operational strategy for the individual site. This is described in Section 4.4.</td>
</tr>
<tr>
<td>3</td>
<td>Determine the initial settings based on the operational strategy. This is explained in details in Section 5.</td>
</tr>
<tr>
<td>4</td>
<td>On-site calibration. This is explained in detail in Section 6.</td>
</tr>
<tr>
<td>5</td>
<td>Reporting, as described in Section 4.5.</td>
</tr>
</tbody>
</table>

Table 4.1 - An Overview of the Calibration Process

4.2 System Configuration Set-up

As part of the design process the designer will have set up the initial configuration file for the individual site. The configuration file contains all the site specific settings to allow the system to operate at that junction. Details such as MIDAS selected sites, ramp loops, passwords and access levels are setup during this phase. Calibration could not be carried out if the configuration set-up is not completed. The configuration set-up process is detailed in the report: Ramp Metering Configuration Set-up and Management - MCH 2472.

4.3 Default Settings

The default settings are installed on each site prior to a Site Acceptance Test (SAT). The default setting parameter values allow the system functionality for both the hardware and software to be suitably tested in a live environment. The default parameter settings will not be suitable for an operational site. Therefore, they need to be updated to initial settings before switch-on to give effective operation at start of on-site calibration attempt.
4.4 Operational Strategy

It is necessary to carry out pre-calibration preparation. The preparation enables planning of the optimum operational strategy to calibrate the individual site based on its congestion problem. Moreover, the operational strategy is closely related to the ramp metering system design process. It is advised that prior to submission of a design, discussions between the ramp metering system designers and calibration teams are engaged. The design and calibration team should carry out the following:

♦ Site visit.

The calibration process may involve working on live carriageway. A ramp metering calibration H&S risk assessment must be carried out before any site activity takes place.

A site visit is essential for the pre-calibration preparation. A visit to the ramp metering site allows the team to perform a site drive-through and to familiarise themselves with the site’s geographical configuration from a safety point of view. The ideal standing ground for the team to carry out the calibration can be identified. More importantly, the point where the traffic merges from the slip road, distance from stop line to merge point, length of the slip road, and the typical length of queues on the slip road can also be identified. These characteristics, particularly the length of existing queues, should be recorded to ensure that the introduction of ramp metering does not make slip road queuing significantly worse.

It is also worthwhile to check if there is sufficient HA CCTV coverage. Calibration could be carried out from the Regional Control Centre (RCC) if there is adequate CCTV coverage and remote communications to the Ramp Metering Controller (RMC) are in place.

♦ Obtain and review MTV plots.

The cause of traffic flow breakdown, whether it is shockwaves from downstream congestion or heavy traffic at junction, can be determined by studying the Motorway Traffic Viewer (MTV) plots. Based on the nature of the traffic flow problem, the appropriate control strategy for the ramp metering can be devised. MTV plots are used during the site selection process but the most recent MTV plots should be used in the pre-calibration preparation as the traffic pattern may have changed since the site was selected.

Analysis of the MTV plots will identify the most appropriate MIDAS Out Station (MOS) to use for the downstream detection point. Once the ideal MOS has been selected they can be configured. They could be set under Component Configuration - MIDAS Selected Sites on the Ramp Metering Controller (RMC) supervisory interface. The following Figure 4.1 shows the configuration page.
4.4.1 Examples of MTV plots

MTV data is checked to identify bottlenecks in the region. MTV plots show speed information with respect to time and can identify the MOS sites where the flow breakdown first occurs.

Figure 4.2 below shows the MTV plot of the M1 between Junction 39 and 41 Northbound generated on 6/12/2006. This example illustrates merging traffic from upstream junctions which leads to three merge bottlenecks. This is identified by a series of white colour blocks across the horizontal time line at three different junctions. They are generally known as the ‘head of the queue’ on the motorway. The white colour blocks also exhibit a diagonal shaped propagation trend across the horizontal time line. This trend indicates the downstream junctions are affected by the shockwaves of traffic queuing at the merge bottlenecks.

Figure 4.3 below shows the MTV plot for the same section of carriageway generated on 4/12/2006 where shockwaves extend throughout the whole region from the head of the queue. The graphs allow the identification of the optimal downstream loop site for use with the mainline algorithm. This is the loop site closest to the head of the queue, but not beyond it. Any downstream MOS selected which is beyond the bottleneck will not allow the ALINEA algorithm to function properly.
Figure 4.2 - Example of Active Merge Bottlenecks at M1 Northbound J39-41 on 06/12/06
Figure 4.3 - Example of Shockwaves Propagation at M1 Northbound on 04/12/06
4.5 Safety and Risk Assessments, Documentation and Reporting

This document does not overwrite the specific Health & Safety (H&S) requirements of any organisations that may refer to this document. Ramp metering calibration may involve working on live carriageways. The calibration process should be planned carefully and working close to a live carriageway must be avoided whenever possible. If it is not possible to calibrate without access to the live carriageway, the manager and the calibration team are to ensure that specific H&S risk assessments are carried out prior start of calibration process.

4.5.1 Ramp Metering Calibration Risk Assessments

A risk assessment specifically designed to carry out the ramp metering calibration should be completed. If a calibration team is on site and the working conditions change, re-assessment needs to be carried out to ensure all conditions are covered. Should there be any safety concerns not covered by the risk assessment, the calibration process should be terminated immediately. Re-assessment is required to continue the calibration process. Personnel carrying out calibration activities must be competent to do so from both the point of view of working on site and being suitably trained and experience in the calibration of a ramp metering system. Allowing non competent personnel to change system settings may put drivers at unnecessary additional risk. (See Appendix A)

4.5.2 Access to Site

All personnel accessing site should be declared competent to do so and should have the necessary authorisation from their organisation. When working in different areas in the Highway Agency’s network, it is required that the calibration team has received the relevant Area induction. The calibration team should not be on site if the Area induction has not been completed.

4.5.3 Documentation

The calibration team must save and record the system settings before starting any calibration. This will ensure the backup settings are up to date and available for the system settings recovery process should anything go wrong. The team should also record all changes made to the system settings including the reason why those changes are made. This will ensure that all changes are auditable for future reference. Appendix B shows an example of the record of change of settings form.

Finally, video evidence of traffic conditions should be recorded both before and during the calibration process. Such video evidence can be used as a reference to understand how the system affects the traffic on the motorway and the local roads.

4.5.4 Reporting

The progress of the calibration process needs to be recorded and reported to the Highways Agency. Appendix C shows an example of the calibration report template to be used.
5. **Initial Settings**

Once a site has completed a successful SAT, the RMC will retain the installed default parameter settings. These settings will need to be re-configured so that they are suitable for the individual site. The re-configured system settings are referred to as the ‘Initial Settings’ of the ramp metering system. There are 10 main algorithms requiring calibration as detailed in the following table:

<table>
<thead>
<tr>
<th>No.</th>
<th>Algorithm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ALINEA</td>
</tr>
<tr>
<td>2</td>
<td>Common</td>
</tr>
<tr>
<td>3</td>
<td>Demand capacity</td>
</tr>
<tr>
<td>4</td>
<td>Main Carriageway Data Filtering (MCDF).</td>
</tr>
<tr>
<td>5</td>
<td>Proportional occupancy queue management</td>
</tr>
<tr>
<td>6</td>
<td>Queue override</td>
</tr>
<tr>
<td>7</td>
<td>Ramp Data Filtering (RDF)</td>
</tr>
<tr>
<td>8</td>
<td>Release</td>
</tr>
<tr>
<td>9</td>
<td>Switch on-off</td>
</tr>
<tr>
<td>10</td>
<td>Weighted occupancy</td>
</tr>
</tbody>
</table>

**Table 5.1 - List of Ramp Metering Algorithms**

The order of the algorithms in this section is arranged in accordance to the order of the algorithms being set in the Ramp Metering Supervisory interface. It does not indicate the order to determine the initial settings.

5.1 **ALinea**

ALINEA is the algorithm used to maintain the occupancy on the main carriageway. It will strive to operate the mainline downstream at a pre-defined desired occupancy, \(o_{Des}\) where a maximum flow throughput can be delivered. The ALINEA algorithm accounts for traffic flow on the slip road as well as the main carriageway traffic. If slip road flow is low, the ALINEA output may appear to be artificially low. The ALINEA algorithm calculates the desired ramp flow using the following formula:

\[
r_{al}(k_{al}) = r_{al}(k_{al} - 1) + K_{al}[o_{des} - o_{out}(k_{al} - 1)]
\]

\(K_{al}\) not being used in the current Ramp Metering operation. Hence this is not discussed in this document.
There are 4 parameters to configure in ALINEA as follows:

1. \( t_{Al} \)
2. \( o_{Des} \)
3. \( k_{Al} \)
4. \( \delta \)

### 5.1.1 \( t_{Al} \)

**Description:** Time period for each iteration of the ALINEA algorithm.

**Default value:** 20 seconds.

**Initial value:** 20 seconds per number of downstream MOS selected.

**Range:** 0-120 seconds.

**Resolution:** Multiple of \( t_{Agg} \) of filter algorithm.

**Function:** This is the time required for most vehicles to get from stop line to the downstream MIDAS loop.

**Impact:** Setting \( t_{Al} \) incorrectly will cause ALINEA to become unstable or insensitive to the traffic pattern.

### 5.1.2 \( o_{Des} \)

**Description:** Desired occupancy at the critical position downstream of the merge point.

**Default value:** \(<o_{Cr}>\%\)

**Initial value:** \( o_{Cr} – 0.5\% \)

**Range:** 0-100\%

**Resolution:** 0.1 \%

**Function:** This is the desired main carriageway occupancy for ALINEA to set the optimum released rate.

**Impact:** If \( o_{Des} \) is set too high, the system will try to flush more vehicles on to the main carriageway. As such, there is a possibility of causing unnecessary congestion. Like wise, if \( o_{Des} \) is set too low, ALINEA will not function effectively.
5.1.3 kAl

**Description:** Constant gain factor for ALINEA algorithm.

**Default value:** 70 vph/%

**Initial value:** \( \frac{2}{3} \times \text{release levels step size} \)

**Range:** 0-200 vph/%

**Resolution:** 0.01 vph/%

**Function:** This is the gain factor which determines the responsiveness of the ALINEA algorithm.

**Impact:** Setting kAl incorrectly will cause ALINEA to request inappropriate required release level for the encountered traffic pattern. If kAl is set to low, ALINEA will become insensitive to the traffic pattern. If set too high, ALINEA will become unstable.

5.1.4 delta

**Description:** Constant ramp flow offset factor.

**Default value:** 400

**Initial value:** 1000

**Range:** 200-1000

**Resolution:** 1

**Function:** Delta is the constant offset value required by the ALINEA algorithm to limit the maximum slip road flow.

**Impact:** Setting delta to sufficient high value ensures ALINEA to be able to maintain the occupancy as close as possible to the desired value, but it will allow ALINEA to set unrealistic flow rates.

5.2 Common

There are 17 common parameters that are shared by all control algorithms as follows:

- rMin;
- rMax;
- rFf;
5.2.1 rMin

**Description:** The minimum practical metered traffic flow that can be achieved with full signal sequences.

**Default value:** 300 vph

**Initial value:** rLev1

**Range:** 0-4000 vph

**Resolution:** 1 vph

**Function:** It defines the minimum traffic flow for the control algorithms.

**Impact:** Setting rMin incorrectly will result in high levels of non-compliance and inaccurate required release levels being calculated in the control algorithms.

5.2.2 rMax

**Description:** The maximum practical metered traffic flow that can be achieved with full signal sequences.

**Default value:** 2400 vph

**Initial value:** rLev10

**Range:** 0-4000 vph

**Resolution:** 1 vph

**Function:** It defines the maximum traffic flow for the control algorithms.

**Impact:** Setting rMax incorrectly will result in inaccurate required release level being calculated in the control algorithms.
5.2.3 rFf

Description: The practical free flow traffic when only the green aspect is displayed.

Default value: 2700 vph

Initial value: \( r_{Max} + (2 \times \text{release levels step size}) \)

Range: 0-5000 vph

Resolution: 1 vph

Function: It defines the free flow traffic for the control algorithms.

Impact: Setting \( r_{Ff} \) incorrectly will result in inaccurate required release level being calculated in the control algorithms.

5.2.4 rOff

Description: The maximum theoretical traffic flow of the slip road with no ramp metering signals.

Default value: 3000 vph

Initial value: \( r_{Ff} + (3 \times \text{release levels step size}) \)

Range: 0-6000 vph

Resolution: 1 vph

Function: It defines the theoretical traffic flow when ramp metering is not in operation for the control algorithms.

Impact: Setting \( r_{Off} \) incorrectly will result in incorrect operation of the switch on-off algorithms.
5.2.5 oCr

**Description:** Occupancy at the critical position downstream of the merge point when the maximum traffic flow is maintained and flow breakdown is avoided.

**Default value:** User defined, %.

**Initial value:** The critical occupancy can be identified from the occupancy-flow curves. This is the occupancy at the apex point of the curve which represents the optimum operating point delivering maximum flow.

Figure 5.1- shows an example of the flow-occupancy curve of M6 J10 Northbound on 26/06/2007.
Range: 0-100 %
Resolution: 0.1 %
Function: It defines the critical occupancy at the critical position downstream of the merge point. It can be used to determine \( o_{Des} \)
Impact: If \( o_{Cr} \) is set too high, the system will react slowly to the traffic breakdown and may not work efficiently. On the contrary, if \( o_{Cr} \) is set too low the system will restrict traffic flow from slip road to the main carriageway while there is still capacity available.

### 5.2.6 \( q_{Des} \)

**Description:** Desired downstream main carriageway flow rate.

**Default value:** 5000 vph

**Initial value:** 1750 x number of downstream lanes.

**Range:** 0-10000 vph

**Resolution:** 1 vph

**Function:** This is the desired downstream main carriageway flow for demand capacity algorithm to set the required release level.

**Impact:** If \( q_{Des} \) is set too high, the system will try to flush more vehicles on to the main carriageway. As such, there is a possibility of causing unnecessary congestion. On the other hand, if \( o_{Des} \) is set too low, demand capacity algorithm will not be able to function effectively. The system may constantly remain in Queue Management mode and affects the efficiency of the main carriageway utilisation.

\( q_{Des} \) is not discussed in detail in this document as Demand capacity algorithm is not used in current Ramp Metering operation.
5.2.7 tAgg

Description: Length of aggregation period.

Default value: 5 seconds

Initial value: 10 seconds

Range: 5-30 seconds

Resolution: 1 second

Function: This is the time over which calculations of smoothed traffic flow; smoothed speed and smoothed occupancy are carried out.

Impact: Setting tAgg incorrectly will affect the calculations of traffic data from the data filtering algorithms. Subsequently, the calculations from all the control algorithms will be affected as all their time constants must be multiples of tAgg.

5.2.8 rLev1-rLev10

Description: Release level traffic flow from 1 to 10

Default value: 300 to 2100 vph with step size of 200.

Initial value: Slip road data provides traffic flow onto the main carriageway from the slip road. The slip road flow profile indicates the required range of release levels for the ramp metering operation. The derived release level flow rate can then be used to calculate the ideal signal timings.

Figure 5.2 gives an example of the slip road flow curve for M1 Junction 40 Northbound. This junction is controlled by a set of traffic lights on the roundabout at the entrance of the slip road. Therefore, the traffic demand on the slip road shows a more stable predictable traffic demand, shown for the peak period (06:00am – 09:00am) in the following graph.
Figure 5.2 - Slip Road Traffic Flow for M1 J40 NB on 13/02/2007

Figure 5.3 shows an example of the slip road flows of a non signalised junction, M62 Junction 25 Eastbound. It can be seen that the flow shows higher peaks in a shorter duration due to the random arrival rates of traffic.

Figure 5.3 - Slip Road Flows at M62 J25 EB on 30/11/2006
Range: \( r_{min} - r_{max} \)

Resolution: 1 vph

Function: The 10 release levels define the range of slip road traffic flow to be used by the control algorithms.

Impact: Setting the release levels incorrectly will result in inaccurate required traffic flow being demanded by the system.

5.3 Main Carriageway Data Filtering

The Main Carriageway Data Filtering (MCDF) algorithm calculates the smoothed traffic data, including flow, speed and occupancy on the main carriageway. There are 3 parameters to configure in MCDF as follows:

- \( aQ \);
- \( aV \);
- \( aO \).

5.3.1 \( aQ \)

Description: Smoothing factor for main carriageway traffic flow measurements.

Default value: 0.25

Initial value: 1 (no smoothing)

Range: 0-1

Resolution: 0.1

Function: This is the ratio over which current traffic flow is taken account in the flow measurement calculation. For example: \( aQ = 0.1 \) means 10% of current traffic flow and 90% of previous traffic flow are taken into account in the calculation.

Impact: Setting \( aQ \) incorrectly will affect the calculations of traffic data from the data filtering algorithms. The smoothed traffic flow will fluctuate too much if \( aQ \) is set too high, and too little if it is too low.

\(^3\) \( aQ \) is not discussed in detail as it is not used in the current system settings.
5.3.2 \( aV \)

**Description:** Smoothing factor for main carriageway speed measurements.

**Default value:** 0.25

**Initial value:** 0.7

**Range:** 0-1

**Resolution:** 0.1

**Function:** This is the ratio over which current speed is taken account in the speed measurements calculation. For example: \( aV = 0.1 \) means 10% of current speed and 90% of previous speed are taken into account in the calculation.

**Impact:** Figure 5.4 shows the difference between unsmoothed speed and smoothed speed curves respectively. A low value of \( aV \) will heavily linearise the speed curve.

![Speed vs Time](image)

**Figure 5.4 - Example of Smoothed Speed with \( aV = 0.3 \) and \( aV = 0.7 \) Respectively**

**Impact:** Setting \( aV \) incorrectly will affect the calculations of traffic data from the data filtering algorithms. The smoothed speed will fluctuate too much if \( aV \) is set too high, and vice versa.
5.3.3 \( aO \)

**Description:** Smoothing factor for main carriageway occupancy measurements.

**Default value:** 0.25

**Initial value:** 0.6

**Range:** 0-1

**Resolution:** 0.1

**Function:** This is the ratio over which current occupancy is taken account in the occupancy measurements calculation. For example: \( aO = 0.1 \) means 10% of current occupancy and 90% of previous occupancy are taken into account in the calculation.

**Impact:** Figure 5.5 shows the difference between unsmoothed speed and smoothed speed curves respectively. A low value of \( aO \) will heavily linearise the occupancy curve.

![Occupancy vs Time](image)

**Figure 5.5 - Example of Smoothed Occupancy with \( aO = 0.3 \) and \( aO = 0.7 \) Respectively**

**Impact:** Setting \( aO \) incorrectly will affect the calculations of traffic data from the data filtering algorithms. The smoothed occupancy will fluctuate too much if \( aO \) is set too high, and too little if it is too low.
5.4 Proportional Occupancy Queue Management

The proportional occupancy queue management algorithm monitors the occupancy on the slip road and sets the desired release level to maintain the queue length at the desired value. It calculates the desired ramp flow using the following formula:

$$r_{poqm} = r_{rm} + K_{poqm} [o_{eq} - o_{descp}]$$

There are three parameters to configure in proportional occupancy queue management as follows:

1. $t_{Poqm}$;
2. $k_{Poqm}$;
3. $o_{DesCq}$.

5.4.1 $t_{Poqm}$

Description: Time period for each iteration of proportional occupancy queue management.

Default value: 20 seconds

Initial value: $t_{Agg}$

Range: 0-120 seconds

Resolution: Multiple of $t_{Agg}$ of filter algorithm.

Function: This is the time period for each iteration of proportional occupancy queue management.

Impact: Setting $t_{Poqm}$ incorrectly will cause proportional occupancy queue management to become insensitive to the traffic pattern on the slip road.
5.4.2 kPoqm

**Description:** Constant gain factor for proportional occupancy queue management.

**Default value:** 20 vph/%

**Initial value:**
\[
\frac{(rlev10 - rlev1)}{oCqmax - oDesCq}
\]

Where oCqmax is the maximum observable occupancy value when the traffic is just about to hit the queue override loop.

**Range:** 0-200 vph/%

**Resolution:** 0.01 vph/%

**Function:** This is the gain factor to convert occupancy to number of vehicles per hour in the proportional occupancy queue management algorithm.

**Impact:** Setting \( kPoqm \) incorrectly will cause proportional occupancy queue management to request inappropriate required release level for the encountered traffic pattern. If \( kPoqm \) is set too low, proportional occupancy queue management will be insensitive to the traffic pattern. If set too high, proportional occupancy queue management will become unstable.
5.4.3 oDesCq

**Description:** Desired combined occupancy for slip road.

**Default value:** 30 %

**Initial value:** 20 %

**Range:** 0-100%

**Resolution:** 0.1 %

**Function:** This is the desired combined slip road occupancy for proportional occupancy queue management to set the required released rate.

**Impact:** If \( o_{DesCq} \) is set too high, the system will restrain traffic from flowing on to the main carriageway. As such, there is a possibility of building up too much traffic on the slip road, subsequently triggering the queue override mode too frequently. On the contrary, if \( o_{DesCq} \) is set too low, queue management will not be able to build an optimum queue on the slip road, preventing ramp metering from functioning effectively.

5.5 Queue Override

The queue override algorithm detects the presence of an excessive queue length and reduces the queue length immediately by releasing the traffic from the slip road to generate sufficient space within the slip road. The queue override algorithm triggers when the following conditions are met:

\[
 r_{qo} = \begin{cases} 
 r_{\min} & \text{if } o_{qo1} \leq o_{qo1t} \text{ or } o_{qo2} \leq o_{qo2t} \\
 r_{qo}\ max \ (for \ t_{qo}) + r_{\min} \ (for \ t_{qo}) & \text{if } o_{qo1} > o_{qo1t} \text{ or } o_{qo2} > o_{qo2t} 
\end{cases}
\]

There are six parameters to configure as follows:

1. tQot;
2. oQo1t;
3. oQo2t;
4. tQoc;
5. tQor;
6. rQoMax.
5.5.1  tQot

**Description:** Time period for each iteration of queue override algorithm to trigger the queue override operation.

**Default value:** 5 seconds

**Initial value:** tAgg

**Range:** 0-120 seconds

**Resolution:** Multiple of tAgg of filter algorithm.

**Function:** This is the time period for each iteration of queue override. It should take into account the time for HGVs to cross the override loops, such that queue override is not triggered falsely.

**Impact:** If tQot is set too low, queue override may trigger too frequently when slow moving vehicles are crossing the override loops. On the contrary, if tQot is set too high, queue override will become insensitive to the traffic overflow on the slip road and may cause disruption to the local roads.

5.5.2  oQo1t and oQo2t

**Description:** Threshold value for lane one and two occupancy of slip road at the detector on the slip road at the maximum permitted queue length.

**Default value:** 45 %

**Initial value:** 50 %

**Range:** 0-100 %

**Resolution:** 0.1 %

**Function:** This is the percentage occupancy on the lane 1 override loop, in order to justify when queue override should trigger when the override loops are occupied over a certain defined period.

**Impact:** Setting oQo1t and oQo2t incorrectly will cause queue override to become too sensitive or insensitive to queue overflow.
5.5.3 \textit{tQoc}

\textbf{Description:} Time period for operation of maximum queue override desired slip road flow to clear the queue overflow.

\textbf{Default value:} 30 seconds

\textbf{Initial value:} \(2.5 \times rLev10\) entire cycle time (i.e. \(s tA10+gT10+spA10+rT10\))

\textbf{Range:} 0-120 seconds

\textbf{Resolution:} 1 second

\textbf{Function:} This is the time period required for operation of maximum queue override desired slip road flow to clear the queue overflow. The value of \textit{tQoc} depends on the length of the slip road and typical type of vehicles travelling through it.

\textbf{Impact:} Setting \textit{tQoc} incorrectly will prevent queue override from clearing the queue overflow in the allowed clearance time or causes too much flow into the main carriageway.

5.5.4 \textit{tQor}

\textbf{Description:} Time period required before queue override is reset following a queue override trigger and operation at the maximum desired queue override slip road flow.

\textbf{Default value:} 15 seconds

\textbf{Initial value:} \(1.5 \times rLev10\) entire cycle time (i.e. \(s tA10+gT10+spA10+rT10\))

\textbf{Range:} 0-120 seconds

\textbf{Resolution:} 1 second

\textbf{Function:} This is the time period for which the queue override is prohibited from being triggered again. The value of \textit{tQor} depends on the slip road flow level, in which a lower value is required for a slip road which has constant heavy flow and frequent queue override triggers.

\textbf{Impact:} Setting \textit{tQor} incorrectly may cause ‘double’ queue override operation.
5.5.5 rQoMax

**Description:** The desired flow rate to reduce the queue length to acceptable levels within the required time frame.

**Default value:** \( rLev10 \)

**Initial value:** \( rLev10 \)

**Range:** \( rMin-rFf \)

**Resolution:** 1 vph

**Function:** This is the traffic flow required for queue override to clear the overflow.

**Impact:** Setting \( rQoMax \) incorrectly may cause queue override to unable to clear the traffic overflow.

5.6 Ramp Data Filtering

The Ramp Data Filtering (RDF) algorithm calculates the smoothed traffic data, including flow, speed and occupancy on the slip road. There are two parameters to configure in RDF as follows:

1. \( aRQ \).
2. \( aRO \).

5.6.1 \( aRQ \)

**Description:** Smoothing factor for slip road traffic flow measurements.

**Default value:** 0.5

**Initial value:** 1 (no smoothing)

**Range:** 0-1

**Resolution:** 0.01

**Function:** This is the ratio over which current traffic flow is taken account in the flow measurement calculation. For example: \( aRQ=0.1 \) means 10% of current traffic flow and 90% of previous traffic flow are taken into account in the calculation.

---

\( aRQ \) is not discussed in detail as it is not used in the current system settings.
Impact: Setting $aRQ$ incorrectly will affect the calculations of traffic data from the data filtering algorithms. The smoothed traffic flow will fluctuate too much if $aRQ$ is set too high, and too little if set too low.

5.6.2 aRO

Description: Smoothing factor for slip road occupancy measurements.

Default value: 0.5

Initial value: 0.9

Range: 0-1

Resolution: 0.01

Function: This is the ratio over which current occupancy is taken account in the occupancy measurements calculation. For example: $aRO=0.1$ means 10% of current occupancy and 90% of previous occupancy are taken into account in the calculation.

Previous Figure 5.5 shows the difference between unsmoothed speed and smoothed speed curves respectively. A low value of $aRO$ will heavily linearise the occupancy curve. A low $aRO$ value is required if there is a low number of occupancy loops on the slip road.

Impact: Setting $aRO$ incorrectly will affect the calculations of traffic data from the data filtering algorithms. The smoothed traffic flow will fluctuate too much if $aRO$ is set too high, and too little if set too low.
5.7 Release

The release algorithm sets the traffic signals appropriately to provide the required traffic flow released from the slip road. It also monitors the actual release rate. In order to provide ten distinct traffic release levels, there are ten sets of signal times to configure. In addition, there are another ten parameters to configure. They are as follows:

♦ gT1-gT10;
♦ spA1-spA10;
♦ rT1-rT10;
♦ stA1-stA10;
♦ gTMin;
♦ gTMax;
♦ gTOnMin;
♦ gTOffMin;
♦ spAMin;
♦ spAMax;
♦ rTMin;
♦ rTMax;
♦ stAMin;
♦ stAMax;

Ten sets of signal timings, representing ten release levels
5.7.1 Signal Timings

**Description:** 10 sets of signal times for release levels 1-10.
gT1-gT10 are the 10 green signal times.
spA1-spA10 are the 10 stopping amber signal times.
stA1-stA10 are the 10 starting amber signal times.
rT1-rT10 are the 10 red signal times.

**Default value:**
- gT1-gT10: 2, 5 and 7 seconds accordingly
- spA1-spA10: 3 seconds for all
- stA1-stA10: 2 seconds for all
- rT1-rT10: Between 2.75-25 seconds

**Initial value:** Initial green time settings are based on a predicted number of vehicles leaving the stop line per green period. The two, five and seven green times are based on assumed vehicle platoon size of five, seven and nine respectively.

The initial values can be calculated quickly on a spreadsheet. Figure 5.6 shows the calculation of 10 level release rates of 500-1400 with a step size of 100, where:

- Release level = 10 release levels;
- Starting amber = stA1-stA10;
- Green = gT1-gT10;
- Stopping amber = spA1-spA10;
- Red = rT1-rT10;
- Total cycle time = amber + green + amber + red times;
- Released / cycle = Assumed platoon size;
- Cycles / hour = 3600 ÷ Total cycle time;
- Vehicles / hour = (release / cycle) x (cycles / hour);
- Ideal release flow = 10 release level flow defined; and,
- Error = vehicles / hour – Ideal release flow.
### Calibration Guidelines

#### Figure 5.6: Example of Excel Spreadsheet Showing Signal Timing Calculations

<table>
<thead>
<tr>
<th>Release Level</th>
<th>Starting amber</th>
<th>Green</th>
<th>Stopping amber</th>
<th>Red</th>
<th>Total cycle time</th>
<th>Released / cycle</th>
<th>Cycles / hour</th>
<th>Vehicles / hour</th>
<th>Ideal release flow</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>25</td>
<td>32</td>
<td>112.5</td>
<td>500</td>
<td>600</td>
<td>162.5</td>
<td>0.5</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>23</td>
<td>30</td>
<td>120.0</td>
<td>600</td>
<td>700</td>
<td>218.2</td>
<td>18.2</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>19</td>
<td>25</td>
<td>138.5</td>
<td>600</td>
<td>700</td>
<td>218.2</td>
<td>18.2</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>15</td>
<td>22</td>
<td>163.6</td>
<td>600</td>
<td>800</td>
<td>218.2</td>
<td>18.2</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>13</td>
<td>20</td>
<td>180.0</td>
<td>600</td>
<td>800</td>
<td>218.2</td>
<td>18.2</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>11</td>
<td>19</td>
<td>200.0</td>
<td>800</td>
<td>1000</td>
<td>218.2</td>
<td>18.2</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>9</td>
<td>19</td>
<td>225.0</td>
<td>1100</td>
<td>1200</td>
<td>218.2</td>
<td>18.2</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>11</td>
<td>21</td>
<td>250.0</td>
<td>1200</td>
<td>1200</td>
<td>218.2</td>
<td>18.2</td>
</tr>
<tr>
<td>9</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>13</td>
<td>25</td>
<td>275.0</td>
<td>1200</td>
<td>1300</td>
<td>218.2</td>
<td>18.2</td>
</tr>
<tr>
<td>10</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>11</td>
<td>23</td>
<td>300.0</td>
<td>1400</td>
<td>1400</td>
<td>218.2</td>
<td>18.2</td>
</tr>
</tbody>
</table>

**Range:** $g_{TMin}$-$g_{TMax}$, $sp_{Amin}$-$sa_{Amax}$, $r_{TMin}$-$r_{TMax}$ and $st_{Amin}$-$st_{Amax}$

**Resolution:** 0.25 seconds

**Function:** The signal timings correspond to their respective flow release level.

**Impact:** Setting signal times incorrectly will result in different release level size. This will cause the ramp metering system to release inappropriate traffic flow on to the motorway. As such, ramp metering will not operate effectively.

#### 5.7.2 $g_{TMin}$

**Description:** Minimum operational green time.

**Default value:** 2 seconds

**Initial value:** 2 seconds

**Range:** 1-30 seconds

**Resolution:** 0.25 seconds

**Function:** This is the minimum allowable operational green time that can be set.

**Impact:** Setting $g_{TMin}$ incorrectly prohibits the green time of value less than $g_{TMin}$ from being keyed in.
5.7.3  gTMax

Description: Maximum operational green time.

Default value: 60 seconds

Initial value: 60 seconds

Range: 1-120 seconds

Resolution: 0.25 seconds

Function: This is the maximum allowable operational green time that can be set.

Impact: Setting \( gTMax \) incorrectly may allow an inappropriate long green time value to be set.

5.7.4  gTOnMin

Description: Minimum green time for first steady green aspect following switch-on.

Default value: 20 seconds

Initial value: 20-30 seconds

Range: 1-120 seconds

Resolution: 0.25 seconds

Function: \( gTOnMin \) is the value of the journey time on the slip road. This is the green time shown to the motorists before ramp metering switch on and goes into operational state

Impact: Setting \( gTOnMin \) incorrectly may result in ramp metering showing red lights during initial switch-on.

5.7.5  gTOffMin

Description: Minimum green time for last steady green aspect before switch-off.

Default value: 60 seconds

Initial value: 60 seconds
RAMP METERING

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<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Default Value</th>
<th>Initial Value</th>
<th>Range</th>
<th>Resolution</th>
<th>Function</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>gTOffMin</td>
<td></td>
<td></td>
<td></td>
<td>1-120 seconds</td>
<td>0.25 seconds</td>
<td>This is the green time shown to the motorists before ramp metering switch-off.</td>
<td>Setting $gTOffMin$ incorrectly may result in ramp metering showing red lights before switch-off.</td>
</tr>
<tr>
<td>spAMin</td>
<td>Minimum stopping amber time.</td>
<td>3 seconds</td>
<td>3 seconds</td>
<td>1-5 seconds</td>
<td>0.25 seconds</td>
<td>This is the minimum allowable stopping amber time that can be set.</td>
<td>Currently the DfT have only approved stopping amber times of three seconds. Therefore $spAMax$ must be set to three seconds.</td>
</tr>
<tr>
<td>spAMax</td>
<td>Maximum stopping amber time.</td>
<td>3 seconds</td>
<td>3 seconds</td>
<td>1-5 seconds</td>
<td>0.25 seconds</td>
<td>This is the maximum allowable stopping amber time that can be set.</td>
<td>Currently the DfT have only approved stopping amber times of three seconds. Therefore $spAMax$ must be set to three seconds.</td>
</tr>
</tbody>
</table>
5.7.8 rTMin

Description: Minimum red time.

Default value: 3 seconds

Initial value: 3 seconds

Range: 1-120 seconds

Resolution: 0.25 seconds

Function: This is the minimum allowable red time that can be set.

Impact: Setting rTMin incorrectly prohibits the red time of value less than rTMin from being keyed in.

5.7.9 rTMax

Description: Maximum red time.

Default value: 25 seconds

Initial value: 25 seconds

Range: 1-120 seconds

Resolution: 0.25 seconds

Function: This is the maximum allowable red time that can be set.

Impact: Setting rTMax incorrectly may allow inappropriate long red time value to be set.
5.7.10 stAMin

Description: Minimum starting amber time.
Default value: 2 seconds
Initial value: 2 seconds
Range: 1-120 seconds
Resolution: 0.25 seconds
Function: This is the minimum allowable starting amber time that can be set.
Impact: Setting stAMin incorrectly may allow stopping amber time other than two seconds to be set.

5.7.11 stAMax

Description: Maximum starting amber time.
Default value: 2 seconds
Initial value: 2 seconds
Range: 1-120 seconds
Resolution: 0.25 seconds
Function: This is the maximum allowable starting amber time that can be set.
Impact: Setting stAMax incorrectly may allow stopping amber time other than two seconds to be set.

5.8 Switch On-Off

The switch on-off algorithm switches the ramp metering system on or off. There are several parameters to configure as follows:

♦ activationMode;
♦ tOo;
♦ kOn;
♦ kOff;
♦ vMax;
♦ oMin;
5.8.1 activationMode

Description: The operational modes of the ramp metering system.

Default value: manualOff

Initial value: manualOff

Range: 5 modes: manualOn, manualOff, timed, timedOccupancy and timedFlowOccupancy

Resolution: N/A

Function: The ramp metering system will switch on and off with different criteria depending on which mode is being set.

Impact: If the operational mode is set incorrectly, the system will not work effectively.

5.8.2 tOo

Description: Time period for each iteration of switch on-off algorithm

Default value: 30 seconds

Initial value: tAgg

Range: 0-120 seconds

Resolution: Multiple of tAgg of filter algorithm.

Function: This is the time period for each iteration of switch on-off algorithm, in which the system starts counting down / up using the defined step sizes.

Impact: If tOo is set too low, switch on-off tends to turn on the system quicker. On the contrary, if tOo is set too high, switch on-off will become too slow to react when the switch on/off criteria are met.
5.8.3 kOn

**Description:** Defined step change in release level at each iteration of the on-off algorithm.

**Default value:** 800 vph

**Initial value:** 5 x release levels step size.

**Range:** 100-3000 vph

**Resolution:** 1 vph

**Function:** The current release level will step down according to the kOn value set when the switch-on criteria are met.

**Impact:** If kOn is set too high, the system will switch on too quickly, and vice versa.

5.8.4 kOff

**Description:** Defined step change in release level at each iteration of the on-off algorithm.

**Default value:** 300 vph

**Initial value:** 3 x release levels step size

**Range:** 100-3000 vph

**Resolution:** 1 vph

**Function:** The current release level will step up (i.e. switch off) according to the kOff value set when the switch-on criteria are met.

**Impact:** If kOff is set too high, the system will switch off too quickly, and vice versa.
5.8.5 \( v_{\text{Max}} \)

**Description:** Maximum operational speed of lane 1 of main carriageway, upstream of merge area.

**Default value:** 85 kph

**Initial value:** Design safe speed, depending on operational strategy (low value for first time the system is switched on).

**Range:** 0-250 kph

**Resolution:** 1 kph

**Function:** The system will switch on when the upstream speed on the lane 1 of main carriageway is less than \( v_{\text{Max}} \).

**Impact:** If \( v_{\text{Max}} \) is set too high, the system will switch on when it is not safe. The merging traffic may have difficulty to pick up the speed required to merge safely. On the contrary, if \( v_{\text{Max}} \) is set too low, the system may switch on too late to be able to function effectively.

5.8.6 \( o_{\text{Min}} \)

**Description:** Minimum operational occupancy of main carriageway, at the critical location downstream of merge area.

**Default value:** 5 %

**Initial value:** Site specific. Figure 5.7 shows an example of the downstream occupancy curve of M6 J10 Northbound on 26/06/2007. The occupancy curve shows the averaged occupancy on the motorway over the time period. The minimum switch on occupancy of the ramp metering can be estimated from the graph.
Figure 5.7 - Example of Occupancy Curve with Respect to Time

Range: 0-100 %
Resolution: 1 %
Function: The system will switch on when the averaged downstream occupancy is more than $o_{Min}$
Impact: If $o_{Min}$ is set too high, the system will not switch on when the traffic is about to breakdown. On the contrary, if $o_{Min}$ is set too low, the system may switch on too quickly.
5.8.7 qMin

Description:  Minimum operational flow of main carriageway, at the critical location downstream of merge area.

Default value:  1000 vph

Initial value:  1000 x Number of downstream lanes.

Range:  0-10000 vph

Resolution:  1 vph

Function:  The system will switch on when the averaged downstream occupancy is more than qMin.

Impact:  If qMin is set too high, the system will not switch on when the traffic is about to breakdown. On the contrary, if qMin is set too low, the system may switch on too quickly.

5.8.8 oQpt

Description:  Occupancy threshold to determine queue presence at the stop line.

Default value:  35 %

Initial value:  35 %

Range:  0-100 %

Resolution:  0.1 %

Function:  This is the percentage occupancy of the presence loops, in order to determine the presence of a queue at the stop line.

Impact:  If oQpt is set too high, the system will become insensitive to the presence of vehicles on the presence loops, and vice versa.

---

qMin is not discussed in detail as it is not used in the current system settings.
6. On-Site Calibration

6.1 Calibration Plan

The traffic pattern for a particular site or traffic problem is generally dynamic and subject to change at anytime. It is important to carry out calibration during worst case traffic condition at the junction in order to ensure that the calibration effort is efficient.

By calibrating the ramp metering system, the behaviour of the merging traffic from the slip road will change accordingly to the parameter settings. There is risk of causing severe traffic congestion either on the main carriageway or on the local road network if the calibration is not carried out correctly.

The information contained in this section has been preened from best practice of calibrating the first 30 ramp metering sites in England. This is a series of suggested processes which are considered appropriate for the task. They should not however be considered as the only method. Methods must be developed to be appropriate for the particular task at hand taking due cognisance of the operational strategy.

The suggested minimum calibration time, to allow for weekly tidal variations of traffic, is five days. Table 6.1 below shows the recommended generic calibration plan.

<table>
<thead>
<tr>
<th>Day</th>
<th>Calibration Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Switch On-Off algorithm and signal timings.</td>
</tr>
<tr>
<td>2</td>
<td>Queue management algorithm using proportional occupancy and slip road smoothing factor.</td>
</tr>
<tr>
<td>3</td>
<td>Queue Override algorithm.</td>
</tr>
<tr>
<td>4</td>
<td>Main carriageway metering algorithm using ALINEA and main carriageway smoothing factor.</td>
</tr>
<tr>
<td>5</td>
<td>Performance review of all previous settings. Calibration change during this period is likely.</td>
</tr>
</tbody>
</table>

Table 6.1 - An Overview of the Calibration Plan Recommended

6.2 Before System Switch-On

The calibration team should log into the RMC supervisory interface using an account with write access administrative rights. This is shown in Figure 6.1 below. Once in the supervisory interface, access the Site Monitor. The Shared Memory Data
function located on the Site Monitor can be used to access the inputs, variables and outputs for the system algorithms.

Figure 6.1 - Screenshot Showing Ramp Metering System Log in Interface

6.2.1 Switch On-Off Algorithm

The switch on-off algorithm turns the ramp metering system on or off based on the following five criteria:

- System off regardless of mainline conditions – **manual Off**;
- Upstream mainline speed (Vmax) only – **manual On**;
- Upstream mainline speed (Vmax) and by time of day (tOn & tOff) – **timed**;
- Upstream mainline speed (Vmax) and by time of day (tOn & tOff) and minimum downstream occupancy (oMin) – **timed occupancy**; and,
- Upstream mainline speed (Vmax) and by time of day (tOn & tOff) and minimum downstream occupancy (oMin) and minimum mainline flow (qMin) – **timed flow and occupancy**.

The system will switch on and off depending on real time conditions and which mode the system is set to operate in. The calibration team should arrive on site before the peak period. There may be two peak periods (A.M. and P.M.) in a single day for some sites and therefore two visits are necessary. Prior to arrival on site the
calibration team should ensure that all system settings are correct and check that the system is set to \textit{manualOff} from \textit{SwitchOnOff} configuration menu. This is illustrated in Figure 6.2 below. It is vital to download a copy of the system configuration settings before uploading any new configurations.

![Figure 6.2 - Screenshot Showing the SwitchOnOff Parameters Configuration Page](image)

The signal head isolation switch needs to be turned on prior to the first session of calibration. This could only be carried out on the site. It is important to check that the signal heads do not light up in \textit{manualOff} mode.

### 6.2.2 Suggested Process

To calibrate switch on-off algorithm, the following may be performed:

1. The first parameter to calibrate during initial start up is the switch on speed, \(v_{\text{Max}}\). This is to ensure that the traffic from the ramp metering stop line merges into the main carriageway in a comfortable manner.

2. The calibration team should wait until the breakdown occurs then set the system to \textit{timedOccupancy}. Since flow breakdown has already occurred vehicles will be travelling at speeds low enough for ramp metering to be safely switched on for the first time.
3. Make sure that the system starts up swiftly. If the system starts up too slowly, adjust the values of time period for each iteration of the switch on-off algorithm, $t_{Oo}$, and/or defined step change in release level at each iteration of the on-off algorithm, $k_{On}$ in SwitchOnOff menu as shown in Figure 6.2 above and vice versa.

4. Observe how the traffic merges with the main carriageway. If the vehicles are merging safely increase the value of $v_{Max}$. If the vehicles seemed to merge difficultly and braking lights are seen frequently at the merging point, reduce the value $v_{Max}$ immediately. Keep observing and change $v_{Max}$ value to get the best merge speed. This allows a safe switch-on speed ($v_{Max}$) to be selected.

5. Once the peak flows start to reduce and main carriageway speed increases above $v_{Max}$, check that the system begins to turn off. This could be monitored under Arbitration Input, in which the ramp flow value required by the switch on-off algorithm, $r_{0Ok}$ should increase gradually and finally reaching $r_{Off}$. If the $r_{0Ok}$ value steps up pretty slow, $k_{Off}$ may need to be increased. At this stage the system will turn off. Observe the traffic volume passing over the presence loop just upstream of the stopline. If the system does not turn off quickly enough after $r_{Max}$ is reached, check the value of the presence loop threshold, $o_{Qpt}$ and adjust if necessary.
Once the signal heads are off, set the system to manualOff. The switch on off algorithm is subject to constant review in the remaining sessions throughout the calibration process.

6.3 Verifying Signal Timings

This process can be done in conjunction with switch on-off calibration. Initial signal timing settings \((gT1-10, rT1-10, stA1-10, spA1-10)\) are based on a predicted number of vehicles leaving the stop line per green period. The actual number of vehicles released based on the initial signal timing settings needs to be verified.

6.3.1 Suggested Process

To verify the signal timings, the following may be performed:

1. Set each of the ten release levels in the Common algorithm.

2. For each release level, count samples of the number of vehicles leaving the stop line for every green period. Calculate the average number of vehicles released per cycle. On the site monitor interface, clicking on the signal heads will display the current release level.

3. For each release level, input the average number of vehicles released per cycle in a spreadsheet as described in Section 5.7.1, as shown below in Figure 6.4.

<table>
<thead>
<tr>
<th>Release Level</th>
<th>Starting Green</th>
<th>Stopping Green</th>
<th>Red</th>
<th>Total Cycle Time</th>
<th>Released / Cycle</th>
<th>Cycles / Hour</th>
<th>Vehicles / Hour</th>
<th>Ideal Release Flow</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>25</td>
<td>32</td>
<td>112.5</td>
<td>500</td>
<td>62.5</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>25</td>
<td>30</td>
<td>120.0</td>
<td>600</td>
<td>60.0</td>
<td>0.0</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>19</td>
<td>26</td>
<td>198.5</td>
<td>580</td>
<td>58.0</td>
<td>-7.7</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>15</td>
<td>22</td>
<td>183.6</td>
<td>510</td>
<td>51.0</td>
<td>0.0</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>15</td>
<td>22</td>
<td>183.6</td>
<td>510</td>
<td>51.0</td>
<td>0.0</td>
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<tr>
<td>6</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>11</td>
<td>19</td>
<td>153.0</td>
<td>410</td>
<td>41.0</td>
<td>0.0</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>9</td>
<td>16</td>
<td>126.0</td>
<td>330</td>
<td>33.0</td>
<td>0.0</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>11</td>
<td>21</td>
<td>171.4</td>
<td>570</td>
<td>57.0</td>
<td>0.0</td>
</tr>
<tr>
<td>9</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>13</td>
<td>25</td>
<td>144.0</td>
<td>450</td>
<td>45.0</td>
<td>-4.0</td>
</tr>
<tr>
<td>10</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>11</td>
<td>23</td>
<td>156.5</td>
<td>480</td>
<td>48.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

4. For each release level, recalculate the green and red times to obtain the correct vehicles released per hour.

5. The initial signal timings need to be modified to reflect the changes. This is shown in the Release configuration page in Figure 6.5 below.
6. The initial released levels under the **Common** configuration page, as shown in Figure 6.6 below may also need to be changed to reflect the calculated values.

7. Allow drivers to become familiar with the signal settings and repeat process to ensure release flows achieved are as required.
6.4 Queue Management using Proportional Occupancy

Excessive queuing on the slip poses a possibility of traffic backing up to the local network. Managing this slip road queue is achieved by monitoring the slip road loops and determining a queue profile by detecting vehicles, via inductive loops located between the beginning of the slip road and the stop line, and taking corrective action.

The number of loops utilised is related to the length of the slip road. The queue management strategy is such that when the queue is very small, the queue management algorithm will request a low flow to access the main carriageway through relatively long red and short green aspects shown to the motorist. When the queue develops towards the top of the slip road, the queue management algorithm will request a high release rate by showing very short red and longer green aspects to the motorists. The queue management algorithm should always request release level ten before the queue reaches back to the queue override loops.

Figure 6.7 below shows the proportional occupancy queue management configuration page.
The calibration process determines the optimum value of the following parameters:

- Desired slip road occupancy, $o_{DesCq}$; and,
- Constant gain factor, $k_{Poqm}$.

The data to observe in this calibration process is the combined occupancy of the slip road, $oCq$. It can be found in the Proportional Occupancy Variables pop-up under Share Memory Data menu as shown in Figure 6.8 below.

When the ramp metering system is operational and subject to slip road flows, a queue will form at the stop line. The ideal queue length should occupy between 1/2 and 2/3 (site dependant) of the slip road length from the stop line. A queue this size should leave enough space such that arriving vehicles do not block the local network.
6.4.1 Suggested Process

To calibrate queue management algorithm, the following may be performed:

1. Observe $o\text{DesCq}$ when the queue reaches the desired length. The queue management algorithm should not request a release level higher than $r\text{Lev1}$ until the queue extends beyond the desired queue length.

   Changing the $o\text{DesCq}$ value will change the cumulated length of queue on the slip road and its release rate into the main carriageway. It is important to set the appropriate value such that the queue does not reach the queue override loop on the top of the slip and trigger queue override operation too frequently.

2. The constant gain factor, $k\text{Pqm}$ needs to be adjusted every time the value of $o\text{DesCq}$ is changed. To calibrate $k\text{Pqm}$, observe the two following $o\text{Cq}$ values:

   a) When traffic is free flowing down the slip road – $o\text{CqMin}$.  
   
   b) When traffic is just about to hit the Queue Override loop or maximum observable value wherever possible – $o\text{CqMax}$. 

Figure 6.8 - Screenshot Showing the ProportionalOccupancy Variables
**RAMP METERING**

**Calibration Guidelines**

\( k_{Poqm} \) is obtained using the following formula:

\[ K_{poqm} = \frac{r_{Levl0} - r_{Levl}}{o_{Cq\text{ max}} - o_{DesCq}} \]

Any changes in \( o_{DesCq} \) will require a recalculation of \( K_{poqm} \). Queue management will not function effectively when \( o_{DesCq} \) is set without an appropriate associated \( K_{poqm} \) value.

3. Observe the queue with respect to the release levels requested by the queue management. A small queue should request a low release level whilst a large queue should request a high release level.

A well calibrated queue management should request release level ten just before triggering the queue override operation.

6.5 **Ramp Data Filtering**

The queue management algorithms use the smoothed traffic data calculated from the ramp data filtering algorithm. There are two parameters to calibrate in ramp data filtering as follows:

1. \( a_{RQ} \).
2. \( a_{RO} \).

6.5.1 **Suggested Process**

To calibrate \( a_{RO} \), the following may be performed. If there are fewer slip road loops due to a short slip road, consider increasing the smoothing.

1. Monitor \( o_{Cq} \) as shown in previous Figure 6.8.
2. If the \( o_{Cq} \) value fluctuates too much, lower \( a_{RO} \) value to further smooth the occupancy, and vice versa.

6.6 **Queue Override**

When a queue override loop on the slip road is occupied for a certain defined period, queue override operation will be triggered. In this calibration process, it is aimed to ‘clear’ the excessive queue to a satisfactory length before it exceeds the motorway boundary. This is to ensure that the ramp metering operation does not affect the local network traffic.

If the slip road queue reaches the slip road entrance, the queue override function must be triggered to disperse the queue. The loops closest to the entrance of the slip road are used as queue override detection loops.

\[ a_{Q} \] is not discussed in detail as it is not used in current system settings.
The queue override calibration process defines a time period for which the loop must be occupied in order to trigger the queue override algorithm. There are four main parameters to set up queue override correctly.

The first two parameters related to the detection of queue override conditions by defining the occupancy threshold required to trigger the queue override operation for both slip road lanes.

The third parameter is the time for which the queue override remains active. This should be enough time for the queue to dissipate to approximately half way whilst not causing flow breakdown on the mainline.

The fourth parameter to calibrate is the time for which the queue override is prohibited from activating following completion of the queue override action. This function will stop the queue override from activating too frequently. There is a possibility that the slip road flow is low and queue override may not trigger during the operational period. If this is the case, this process cannot be completed. In this case it is possible to change the system settings and artificially generate a queue but that decision needs to be made by the individual calibrating the system.

This process can be done after the queue management calibration. It is best to be carried out whilst the main carriageway is congested because queue override calibration requires development of a queue.

The following parameters need to be calibrated:

- The time period for the queue override algorithm to have a threshold occupancy on the override loops $t_{Qot}$;
- The percentage occupancy on the queue override loops for lane 1, $o_{Qo1t}$ and lane 2, $o_{Qo2t}$ respectively;
- The time period for queue override to clear the excessive queue, $t_{Qoc}$;
- The time period for which the queue override is prohibited from being triggered again, $t_{Qor}$.

$o_{Qo1t}/2t$ and $t_{Qoc}$ need to be sufficiently high such that slow moving HGVs approaching the back of a queue half-way down the slip road do not trigger queue override.

Furthermore, the values also need to be sufficiently low such that the queue does not reach the local network before the override is triggered, particularly taking into consideration the arrival rate once the queue override is activated and the dissipation rate of the queue from the stop line.

It is ideal to find a ‘balance point’ and regard it as the optimum settings, so that queue override will try to reduce the queue to a reasonable level and allow queue management to ‘take over’.

Figure 6.9 below shows the queue override configuration page.
6.6.1 Suggested Process

Queue override can be configured using the following instructions:

1. Generate a queue by setting the desired occupancy, \( o_{\text{DesCq}} \) in Queue Management menu to a high value (maybe 70%). This step can be skipped if there is sufficient traffic to trigger queue override.

2. Set \( o_{Q_{1t}} \) and \( o_{Q_{2t}} \) to about 50% and observe the queue override operation. If queue override is triggered too frequently, increase the values. Otherwise, reduce the values so that queue override triggers at the critical period to avoid traffic building up at the local roads.

3. At the same time, count the time in seconds for the back of the queue to dissipate to the ‘ideal-length’ queue. Use that time to set \( t_{Qoc} \). Beware that the time period may be so long that it actually causes flow breakdown on the main carriageway. This should be avoided and \( t_{Qoc} \) value needs to be as low enough to guard against this situation.
4. Make sure queue management is in operation immediately after queue override. If the queue override triggers twice in a row and it is clear on street that it is premature, increase the $t_{Qor}$ value to ensure this is avoided.

Ideally the control of the junction should see-saw between the queue management and ALINEA algorithms. $t_{Qor}$ should be used to maintain this control and should be set at a value high enough to stop queue override being the dominant operational algorithm.

6.7 ALINEA

ALINEA is the algorithm used to maintain the occupancy on the main carriageway. This calibration process should enable the main carriageway to operate at a pre-defined desired occupancy, $o_{Des}$ where a maximum flow throughput is delivered. The ALINEA algorithm accounts for traffic flow on the slip road as well as the main carriageway traffic. If slip road flow is low, its output may be restricted. Figure 6.10 below shows the ALINEA configuration page.

![Figure 6.10 - Screenshot Showing the ALINEA Parameters Configuration Page](Figure 6.10 - Screenshot Showing the ALINEA Parameters Configuration Page)
In this calibration process the optimum values for the following parameters are determined:

- The time period for each ALINEA iteration, $t_{AI}$;
- The desired occupancy of the mainline operation, $o_{Des}$; and,
- The constant gain factor for the ALINEA algorithm, $k_{AL}$.

### 6.7.1 Suggested Process

ALINEA can be configured using the following instructions:

1. $t_{AI}$ should be the time taken for traffic released from the stop line to reach the downstream MIDAS loops. It is found that ALINEA works well with $t_{AI} = 20s$, provided that the first downstream MOS site is used. If ALINEA is not sensitive to the traffic pattern, $t_{AI}$ may need to be reduced, and if ALINEA is unstable $t_{AI}$ may need to be increased.

2. Monitor $o_{Out}$ as shown in previous Figure 6.3. $o_{Out}$ indicates the occupancy at the downstream MOS. Review the main carriageway conditions and change $o_{Des}$ as necessary to make sure that the system is not trying to overload the main carriageway. If this is the case, $o_{Des}$ needs to be reduced. On the contrary, if $o_{Des}$ is set too low the system may constantly remain in queue management mode where $r_{Qmk} > r_{Rmk}$, adversely affects the efficiency of the main carriageway utilisation. In this case, $o_{Des}$ value needs to be increased.

3. Experience shows that the $k_{AI}$ value is related to the release level step size. Suggested $k_{AI} = 2/3 \times$ step size. This value needs to be changed every time a set of release levels with new step size is configured for the ramp metering system.

### 6.8 Main Carriageway Data Filtering

ALINEA algorithm uses the smoothed traffic data calculated from the main carriageway data filtering algorithm. There are three parameters to calibrate in ramp data filtering as follows:

- $aQ^7$;
- $aV$;
- $aO$;

#### 6.8.1 Process

To calibrate $aO$ and $aV$, follow the instructions below:

1. Monitor $o_{Out}$ and $V_{In}$ as shown in previous Figure 6.3.

---

$^7$ $aQ$ is not discussed in detail as it is not used in current MAM settings.
2. If the $oOut$ value fluctuates too much, lower $aO$ value to smooth the occupancy, and vice versa.

3. If the $VIn$ value fluctuates too much, lower $aV$ value to smooth the speed, and vice versa.

6.9 Performance Review

Evaluating the effectiveness of a calibrated ramp metering site is an involved process which requires a great deal of data to be analysed. Evaluation does not form part of the calibration process in the first instance, however if a site is deemed to be performing badly post evaluation then clearly there is a need to understand the reasons and recalibrate if necessary.

That said, it is important to the calibration team to understand whether the system is operating correctly before leaving the system in $\text{timedOccupancy}$ mode. The calibration team will not however know how effective the system is until evaluation has been completed.

It is recommended that the calibration teams use some method of satisfying themselves that the settings they have made are safe and that they are not adding to the traffic problems.

If a competent calibration team follows the processes recommended in Sections 5 and 6 then the system should be safe to leave in $\text{timedOccupancy}$. Once the system settings are decided on, it is recommended that the data logs are analysed for a period of time following (and during) calibration.

The suitability of the settings can be subjectively reviewed by making some of the following checks:

♦ Does the system switch on quickly enough to delay flow breakdown?
♦ How often is ALINEA operational?
♦ How often is queue management operational?
♦ How often is queue override activated?
♦ How does the requested traffic release rate compare to the actual release rate?
♦ How does the actual main carriageway occupancy compare to the desired main carriageway occupancy?
♦ Does the traffic queuing profile of the slip road match with the queue management settings?
♦ Does the system switch off quickly enough when the flow breakdown has recovered?
♦ Getting reasonable answers to these questions will give the calibration team reassurance that the evaluation is likely to be positive.
Appendix A: Competency Checklist
Staff Competency Checklist (Example Only)

This document records the competency of individuals who are permitted to change the calibration settings of an operational ramp metering system.

There are 5 levels of competency which individuals will be categorised by.

**Recognised Experts**

These individuals are not necessarily part of the immediate calibration project team but do have extensive knowledge of the system and traffic behaviour. They should be consulted by the rest of the project team when unusual or new challenges are faced.

**System Administrator**

Responsible for setting up the configuration of the system. This person may also make changes to the calibration settings with the agreement of the Calibration Manager. For the purposes of this document the system configuration is considered to be all the settings which are specific to the physical characteristics of the system. Such settings would be loop numbers, access passwords and site data for the MOS.

**Calibration Manager**

Ultimately responsible for the final calibration settings of the system. The calibration manager will sign off the calibration certificate after a successful system calibration.

The Calibration Manager is also responsible for ensuring that individuals are competent to do the work expected. It is the calibration manager’s responsibility to ensure that the people on this list are only utilised to the extent to which they are deemed competent. This includes all H&S responsibilities.

The calibration manager, may or may not, have a detailed understanding of the ramp metering algorithms.

**Team Leader**

The team leader is responsible for making the calibration settings on the system. They must communicate their actions to the client to the satisfaction of the calibration manager.

The team leader will be fully conversant with all aspects of the ramp metering system and the effects that each setting can have. They will be adequately trained in the operation of the system.

They will have completed not less than ten calibration sessions calibrating two complete systems as a calibration assistant.

The team leader must take due cognisance to the extent of their capabilities and knowledge. They must know when to seek assistance from other team leaders and recognised experts.
Calibration Assistant

The calibration assistant will support the team leader in selecting the optimal system settings during calibration. The calibration assistant must have been adequately trained.

Although calibration may take place solely in an office environment it must be anticipated that site visits will be required. All personnel must have the necessary health and safety authorisations to attend site by a live carriageway.
## Calibration Guidelines

<table>
<thead>
<tr>
<th>Name</th>
<th>Sector Scheme</th>
<th>HA Pass</th>
<th>Live Carriageways Competency Checklist</th>
<th>Atkins Calibration Training Course</th>
<th>10 Calibration Sessions</th>
<th>Position (s) held</th>
<th>Signature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roger Higginson</td>
<td>N/A</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>Recognised Expert</td>
<td></td>
</tr>
<tr>
<td>Keith McCabe</td>
<td>N/A</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>Recognised Expert</td>
<td></td>
</tr>
<tr>
<td>Alan Hindley</td>
<td>N/A</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td>System Administrator</td>
<td></td>
</tr>
<tr>
<td>Rob Porter</td>
<td>N/A</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>Calibration Manager</td>
<td>Team Leader</td>
</tr>
<tr>
<td>Pete Kirby</td>
<td>N/A</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>Calibration Manager</td>
<td>Team Leader</td>
</tr>
<tr>
<td>Mike McMahon</td>
<td>N/A</td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
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<td>Team Leader</td>
</tr>
<tr>
<td>Keith Lee</td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
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<td></td>
</tr>
<tr>
<td>Yousef Majeed</td>
<td>N/A</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td>Calibration Assistant</td>
<td></td>
</tr>
<tr>
<td>Harry Starling</td>
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<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td>Calibration Assistant</td>
<td></td>
</tr>
</tbody>
</table>

I agree that the above is true and consider these individuals to be competent to perform the tasks commensurate with the position held.

Project Manager Name: ..................................................................................

Project Manager Signature .........................................................................
Appendix B: Record of Change of Settings
Junction Name:

<table>
<thead>
<tr>
<th>DATE &amp; TIME</th>
<th>ACTION or OBSERVATION</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
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</tr>
</tbody>
</table>
Appendix C: Calibration Report
### Calibration Guidelines

**Team Leader:** ……  
**Junction:** M… J.. ..../B  
**Date:** ………….  

<table>
<thead>
<tr>
<th>Issue</th>
<th>Time / Value etc</th>
<th>Comments / Reasoning</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Time system switched from manual off to timed occupancy.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Time signal switched on /off.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Typical queue length (average) and typical delay.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Max observed queue length and JT for vehicles on slip road.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Frequency of queue override operation.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Did operation impact upon local network.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Compliance with signals.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Algorithms being run.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Faults on system.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Is system still being tuned at the site.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Time system switched from timed occupancy to manual off.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. Other observation notable of comment.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Note:** Highlight each section using colour codes - RED (Problem) / Amber (Needs Attention) / Green (OK)
Appendix D: List of Parameters
### Calibration Guidelines

#### Algorithm and Parameters

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>MCH1965 label</th>
<th>Parameters</th>
<th>Description</th>
<th>Unit</th>
<th>Min</th>
<th>Max</th>
<th>Resolution</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carriageway Data Filter</td>
<td>( a_0 )</td>
<td>( aO )</td>
<td>Smoothing factor for occupancy measurements</td>
<td>VPH</td>
<td>0</td>
<td>1</td>
<td>0.01</td>
<td>0.25</td>
</tr>
<tr>
<td>Carriageway Data Filter</td>
<td>( a_q )</td>
<td>( aQ )</td>
<td>Smoothing factor for flow measurements</td>
<td></td>
<td>0</td>
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<td>0.01</td>
<td>0.25</td>
</tr>
<tr>
<td>Ramp Data Filter</td>
<td>( a_{Ro} )</td>
<td>( aRO )</td>
<td>Smoothing factor for occupancy measurements</td>
<td></td>
<td>0</td>
<td>1</td>
<td>0.001</td>
<td>0.5</td>
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<td>Ramp Data Filter</td>
<td>( a_{Rq} )</td>
<td>( aRQ )</td>
<td>Smoothing factor for flow measurements</td>
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<td>1</td>
<td>0.001</td>
<td>0.5</td>
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<tr>
<td>Carriageway Data Filter</td>
<td>( a_v )</td>
<td>( aV )</td>
<td>Smoothing factor for speed measurements</td>
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<td>1</td>
<td>0.01</td>
<td>0.25</td>
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<tr>
<td>ALINEA</td>
<td>D</td>
<td>delta</td>
<td>Constant ramp flow offset factor.</td>
<td>VPH</td>
<td>200</td>
<td>1000</td>
<td>1</td>
<td>400</td>
</tr>
<tr>
<td></td>
<td>f(m)</td>
<td></td>
<td>Vehicle count in aggregation period for each loop pair</td>
<td></td>
<td>0</td>
<td>100</td>
<td>1</td>
<td>0</td>
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<tr>
<td></td>
<td>( f_{\text{loop}}(k) )</td>
<td></td>
<td>Number of vehicle passing each loop in the aggregation period</td>
<td></td>
<td>0</td>
<td>100</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Release</td>
<td>( g_{\text{loffmin}} )</td>
<td>( gT_{\text{offmin}} )</td>
<td>Minimum green time for last steady green aspect before switch-off.</td>
<td>Seconds</td>
<td>1</td>
<td>120</td>
<td>0.25</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>( g_{\text{onmin}} )</td>
<td>( gT_{\text{onmin}} )</td>
<td>Minimum green time for first steady green aspect following switch-on.</td>
<td>Seconds</td>
<td>1</td>
<td>120</td>
<td>0.25</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>( g_{1-10} )</td>
<td>( gT_{1-10} )</td>
<td>Ten green signal times (release levels 1-10);</td>
<td>Seconds</td>
<td>( g_{\text{tmin}} )</td>
<td>( g_{\text{tmax}} )</td>
<td>0.25</td>
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#### Algorithm Settings

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<tr>
<td>Release</td>
<td>gT&lt;sub&gt;max&lt;/sub&gt;</td>
<td>gTMax</td>
<td>Maximum green time (Note: this does not apply to the free flow / steady green operational state)</td>
<td>Seconds</td>
<td>1</td>
<td>120</td>
<td>0.25</td>
<td>60</td>
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<td>Release</td>
<td>gT&lt;sub&gt;min&lt;/sub&gt;</td>
<td>gTMin</td>
<td>Minimum operational green time</td>
<td>Seconds</td>
<td>1</td>
<td>30</td>
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<td>ALINEA</td>
<td>K&lt;sub&gt;kal&lt;/sub&gt;</td>
<td>kAI</td>
<td>Constant gain factor for ALINEA Algorithm</td>
<td>VPH/%</td>
<td>0</td>
<td>200</td>
<td>0.01</td>
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<td>Switch On/Off</td>
<td>K&lt;sub&gt;off&lt;/sub&gt;</td>
<td>kOff</td>
<td>Defined step change in release level at each iteration of the on-off algorithm</td>
<td>VPH</td>
<td>100</td>
<td>3000</td>
<td>1</td>
<td>300</td>
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<tr>
<td>Switch On/Off</td>
<td>K&lt;sub&gt;on&lt;/sub&gt;</td>
<td>kOn</td>
<td>Defined step change in release level at each iteration of the on-off algorithm</td>
<td>VPH</td>
<td>100</td>
<td>3000</td>
<td>1</td>
<td>800</td>
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<td>Proportional Occupancy</td>
<td>K&lt;sub&gt;pqm&lt;/sub&gt;</td>
<td>kPqm</td>
<td>Constant gain factor for Proportional Occupancy Queue Management Algorithm</td>
<td>VPH/%</td>
<td>0</td>
<td>200</td>
<td>0.01</td>
<td>20</td>
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<tr>
<td>Carriageway Data Filter</td>
<td>L&lt;sub&gt;loop&lt;/sub&gt;</td>
<td>LLoop</td>
<td>Length of each loop in direction of travel</td>
<td>M</td>
<td>0</td>
<td>6</td>
<td>0.1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>L&lt;sub&gt;q1&lt;/sub&gt; – L&lt;sub&gt;q2&lt;/sub&gt;</td>
<td></td>
<td>Software switches to enable or disable queue detection loops in the algorithm (Max 20)</td>
<td></td>
<td>0</td>
<td>1</td>
<td>N/A</td>
<td>1</td>
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<td>Carriageway Data Filter</td>
<td>L&lt;sub&gt;veh&lt;/sub&gt;</td>
<td></td>
<td>Vehicle length</td>
<td>M</td>
<td>0</td>
<td>25.5</td>
<td>0.1</td>
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<td></td>
<td>N&lt;sub&gt;loops&lt;/sub&gt;</td>
<td>nLoops</td>
<td>Number of loop pairs at the site</td>
<td></td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>site specific</td>
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<tr>
<td>Proportional Occupancy</td>
<td>nPoqm</td>
<td>nPoqm</td>
<td>Number of queue detection loops used in the Proportional Occupancy Queue Detection algorithm</td>
<td></td>
<td>2</td>
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<td>16</td>
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<td>Ramp Data Filter</td>
<td>NLoops</td>
<td>nRLoops</td>
<td>Number of lanes</td>
<td></td>
<td>1</td>
<td>2</td>
<td>1</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Ocq</td>
<td>Combined occupancy averaged over all slip road loops</td>
<td>%</td>
<td>0%</td>
<td>100%</td>
<td>0.10%</td>
<td>N/A</td>
</tr>
<tr>
<td>Common</td>
<td>oCr</td>
<td>Ocr</td>
<td>Critical Occupancy at the critical position downstream of the merge point when the maximum traffic flow is maintained and flow breakdown is avoided.</td>
<td>%</td>
<td>0%</td>
<td>100%</td>
<td>0.10%</td>
<td>Defined</td>
</tr>
<tr>
<td>ALINEA</td>
<td>oDes</td>
<td>Odes</td>
<td>Desired Occupancy at the critical position downstream of the merge point.</td>
<td>%</td>
<td>0%</td>
<td>100%</td>
<td>0.10%</td>
<td>&lt; Ocr</td>
</tr>
<tr>
<td></td>
<td>oDesq</td>
<td>Odesq</td>
<td>Desired combined occupancy for slip road</td>
<td>%</td>
<td>0%</td>
<td>100%</td>
<td>0.10%</td>
<td>50%</td>
</tr>
<tr>
<td></td>
<td>oloop(k)</td>
<td>oloop(k)</td>
<td>Mean occupancy of the loop pair (calculated for each loop pair)</td>
<td>%</td>
<td>0%</td>
<td>100%</td>
<td>0.01</td>
<td>n/a</td>
</tr>
<tr>
<td></td>
<td>oloop1 to oloop2</td>
<td>oloop1 to oloop2</td>
<td>Occupancy level for each queue detector.</td>
<td>Integers</td>
<td>0</td>
<td>3</td>
<td>1</td>
<td>N/A</td>
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<tr>
<td>Switch On/Off</td>
<td>omin</td>
<td>oMin</td>
<td>Minimum operational occupancy of main carriageway, at the critical location downstream of merge area.</td>
<td>%</td>
<td>0%</td>
<td>100%</td>
<td>0.10%</td>
<td>5%</td>
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## Algorithm Parameters

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>O&lt;sub&gt;out&lt;/sub&gt;(k&lt;sub&gt;ar&lt;/sub&gt;-1)</td>
<td></td>
<td>O&lt;sub&gt;out&lt;/sub&gt;(k&lt;sub&gt;ar&lt;/sub&gt;-1)</td>
<td>Occupancy of the main carriageway, at the critical position downstream of the merge as measured on the previous iteration of the ALINEA Algorithm averaged over the time period for the operation of the ALINEA algorithm</td>
<td>%</td>
<td>0%</td>
<td>100%</td>
<td>0.10%</td>
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<tr>
<td>O&lt;sub&gt;out&lt;/sub&gt;(k&lt;sub&gt;dc&lt;/sub&gt;-1)</td>
<td></td>
<td>O&lt;sub&gt;out&lt;/sub&gt;(k&lt;sub&gt;dc&lt;/sub&gt;-1)</td>
<td>Occupancy of the main carriageway, downstream of the merge at the critical position measured and averaged over the last (finishing) period (k&lt;sub&gt;dc&lt;/sub&gt;-1)</td>
<td>%</td>
<td>0%</td>
<td>100%</td>
<td>0.10%</td>
<td>0</td>
</tr>
<tr>
<td>O&lt;sub&gt;out&lt;/sub&gt;(k&lt;sub&gt;co&lt;/sub&gt;)</td>
<td></td>
<td>O&lt;sub&gt;out&lt;/sub&gt;(k&lt;sub&gt;co&lt;/sub&gt;)</td>
<td>Occupancy of main carriageway at the critical position downstream of the merge area averaged over the switch on off aggregation period.</td>
<td>%</td>
<td>0%</td>
<td>100%</td>
<td>0.10%</td>
<td>0</td>
</tr>
<tr>
<td>O&lt;sub&gt;qo1&lt;/sub&gt;(k&lt;sub&gt;pooqm&lt;/sub&gt;) to O&lt;sub&gt;qo2&lt;/sub&gt;(k&lt;sub&gt;pooqm&lt;/sub&gt;)</td>
<td></td>
<td>O&lt;sub&gt;qo1&lt;/sub&gt;(k&lt;sub&gt;pooqm&lt;/sub&gt;) to O&lt;sub&gt;qo2&lt;/sub&gt;(k&lt;sub&gt;pooqm&lt;/sub&gt;)</td>
<td>Occupancy of each slip road queue detector. (Maximum 20 for a 2 lane slip road) averaged over time period for alternative queue management algorithm.</td>
<td>%</td>
<td>0%</td>
<td>100%</td>
<td>0.10%</td>
<td>0</td>
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<tr>
<td>Algorithm</td>
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<td>Description</td>
<td>Unit</td>
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<td>Max</td>
<td>Resolution</td>
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<td>------</td>
<td>-----</td>
<td>-----</td>
<td>------------</td>
<td>---------</td>
</tr>
<tr>
<td>$O_{qo1}(k_{qo})$</td>
<td></td>
<td></td>
<td>Lane 1 Occupancy of slip road at the first detector on the ramp which should be at the maximum permitted queue length, averaged over the Queue Override trigger time ($k_{qo}$).</td>
<td>%</td>
<td>0%</td>
<td>100%</td>
<td>0.10%</td>
<td>0</td>
</tr>
<tr>
<td>$O_{qo1}(k_{wqm})$ to $O_{qo2}(k_{wqm})$</td>
<td></td>
<td></td>
<td>Occupancy of each slip road queue detector. (Maximum 16 for a 2 lane slip road) averaged over time period for weighted occupancy queue management algorithm.</td>
<td>%</td>
<td>0%</td>
<td>100%</td>
<td>0.10%</td>
<td>0</td>
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<tr>
<td>$O_{qo1B1}$ to $O_{qo1B2}$</td>
<td></td>
<td></td>
<td>Separate threshold values for occupancy level 1 for each queue detector.</td>
<td>%</td>
<td>0%</td>
<td>100%</td>
<td>0.10%</td>
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<td>$O_{qo2B1}$ to $O_{qo2B2}$</td>
<td></td>
<td></td>
<td>Separate threshold values for occupancy level 2 or each queue detector.</td>
<td>%</td>
<td>0%</td>
<td>100%</td>
<td>0.10%</td>
<td>30%</td>
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<tr>
<td>$O_{qo2B1}$ to $O_{qo2B3}$</td>
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<td>Separate threshold values for occupancy level 3 for each queue detector.</td>
<td>%</td>
<td>0%</td>
<td>100%</td>
<td>0.10%</td>
<td>45%</td>
</tr>
<tr>
<td>Queue Override</td>
<td>$O_{qo1}$</td>
<td>oQo1t</td>
<td>Threshold value for lane 1 occupancy of slip road at the detector on the slip road at the maximum permitted queue length.</td>
<td>%</td>
<td>0%</td>
<td>100%</td>
<td>0.10%</td>
<td>45%</td>
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<tr>
<td><strong>Queue Override</strong></td>
<td>O_{qo2t}</td>
<td>oQo2t</td>
<td>Threshold value for lane 2 occupancy of slip road at the detector on the slip road at the maximum permitted queue length.</td>
<td>%</td>
<td>0%</td>
<td>100%</td>
<td>0.10%</td>
<td>45%</td>
</tr>
<tr>
<td><strong>Switch On/Off</strong></td>
<td>O_{qpt}</td>
<td>oQpt</td>
<td>Occupancy threshold for the queue presence loops to determine the presence of a queue at the stop line.</td>
<td>%</td>
<td>0%</td>
<td>100%</td>
<td>0.10%</td>
<td>35%</td>
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<tr>
<td><strong>Unsmoothed occupancy (%)</strong></td>
<td>o_{Rloop}(k)</td>
<td></td>
<td>Unsmoothed occupancy (%)</td>
<td>%</td>
<td>0</td>
<td>100</td>
<td>0.01</td>
<td>0</td>
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<tr>
<td><strong>Mean occupancy of the loop site</strong></td>
<td>o_{site}(k)</td>
<td></td>
<td>Mean occupancy of the loop site (calculated for each loop site)</td>
<td>%</td>
<td>0</td>
<td>100</td>
<td>0.01</td>
<td>n/a</td>
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<td><strong>Presence signal from each loop</strong></td>
<td>p_{Rloop}</td>
<td></td>
<td>Presence signal from each loop</td>
<td></td>
<td></td>
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<tr>
<td><strong>Common</strong></td>
<td>q_{des}</td>
<td>qDes</td>
<td>Desired downstream main carriageway flow rate</td>
<td>VPH</td>
<td>0</td>
<td>10000</td>
<td>1</td>
<td>5000</td>
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<tr>
<td><strong>Main carriageway flow into the merge area averaged over the last (finishing) period (k_{dc-1})</strong></td>
<td>q_{in} (k_{dc-1})</td>
<td></td>
<td>Main carriageway flow into the merge area averaged over the last (finishing) period (k_{dc-1}).</td>
<td>VPH</td>
<td>0</td>
<td>10000</td>
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<tr>
<td>$q_{\text{loop}}(k)$</td>
<td></td>
<td></td>
<td>total flow across the loop pair (calculated for each loop pair)</td>
<td>VPH</td>
<td>0</td>
<td>20000</td>
<td>0.1</td>
<td>n/a</td>
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<tr>
<td>Switch On/Off</td>
<td>$Q_{\text{min}}$</td>
<td>qMin</td>
<td>Minimum operational flow of main carriageway, at the critical location downstream of merge area.</td>
<td>VPH</td>
<td>0</td>
<td>10000</td>
<td>1</td>
<td>1000</td>
</tr>
<tr>
<td>$Q_{\text{out}}(k_0)$</td>
<td></td>
<td></td>
<td>Flow of main carriageway at the critical position downstream of the merge area averaged over the switch on off aggregation period.</td>
<td>VPH</td>
<td>0</td>
<td>10000</td>
<td>1</td>
<td>0</td>
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<tr>
<td>$q_{\text{qr}}(k)$</td>
<td></td>
<td></td>
<td>Measured flow from queue release loops aggregated over the ramp data filtering aggregation period.</td>
<td>VPH</td>
<td>0</td>
<td>6000</td>
<td>1</td>
<td>N/A</td>
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<td>$q_{\text{qr}}(k_{al})$</td>
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<td>Measured flow from queue release loops averaged over the ALINEA aggregation period.</td>
<td>VPH</td>
<td>0</td>
<td>6000</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>$q_{\text{qr}1} - q_{\text{qr}10}$</td>
<td></td>
<td></td>
<td>Record of actual Release Rates for each release level 1 – 10, to aid manual calibration of signal timings.</td>
<td>VPH</td>
<td>0</td>
<td>4000</td>
<td>1</td>
<td>N/A</td>
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<td>$q_{\text{Rloop}}(k)$</td>
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<td></td>
<td>Unsmoothed flow</td>
<td>VPH</td>
<td>0</td>
<td>$r_{\text{max}}$</td>
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<td>N/A</td>
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<td>$q_{\text{site}}(k)$</td>
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<td></td>
<td>flow across the loop site (calculated for each loop site)</td>
<td>VPH</td>
<td>0</td>
<td>20000</td>
<td>0.1</td>
<td>n/a</td>
</tr>
<tr>
<td>$r$</td>
<td></td>
<td></td>
<td>The required release flow (from Arbitration algorithm)</td>
<td>VPH</td>
<td>$r_{\text{min}}$</td>
<td>$r_{\text{off}}$</td>
<td>1</td>
<td>N/A</td>
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![Highways Agency logo](image)

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<tr>
<td>r</td>
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<td></td>
<td>The required release flow (to Release Algorithm)</td>
<td>VPH</td>
<td>r&lt;sub&gt;min&lt;/sub&gt;</td>
<td>r&lt;sub&gt;off&lt;/sub&gt;</td>
<td>1</td>
<td>r&lt;sub&gt;off&lt;/sub&gt;</td>
</tr>
<tr>
<td>r&lt;sub&gt;al&lt;/sub&gt; (k&lt;sub&gt;al&lt;/sub&gt;)</td>
<td></td>
<td></td>
<td>Desired Release Rate from the ALINEA Algorithm for current iteration of the ALINEA Algorithm.</td>
<td>VPH</td>
<td>r&lt;sub&gt;min&lt;/sub&gt;</td>
<td>r&lt;sub&gt;max&lt;/sub&gt;</td>
<td>1</td>
<td>r&lt;sub&gt;max&lt;/sub&gt;</td>
</tr>
<tr>
<td>r&lt;sub&gt;al&lt;/sub&gt; (k&lt;sub&gt;al&lt;/sub&gt;-1)</td>
<td></td>
<td></td>
<td>The desired ramp flow calculated by the ALINEA Algorithm on the previous iteration of the ALINEA Algorithm (and truncated to lie within [r&lt;sub&gt;min&lt;/sub&gt; - r&lt;sub&gt;max&lt;/sub&gt;]</td>
<td>VPH</td>
<td>r&lt;sub&gt;min&lt;/sub&gt;</td>
<td>r&lt;sub&gt;max&lt;/sub&gt;</td>
<td>1</td>
<td>r&lt;sub&gt;max&lt;/sub&gt;</td>
</tr>
<tr>
<td>r&lt;sub&gt;dc&lt;/sub&gt; (k&lt;sub&gt;dc&lt;/sub&gt;)</td>
<td></td>
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<td>Desired Release Rate from the Demand Capacity Algorithm for current iteration of the Demand Capacity Algorithm.</td>
<td>VPH</td>
<td>r&lt;sub&gt;min&lt;/sub&gt;</td>
<td>q&lt;sub&gt;des&lt;/sub&gt;</td>
<td>1</td>
<td>q&lt;sub&gt;des&lt;/sub&gt;</td>
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<tr>
<td>Common</td>
<td>r&lt;sub&gt;ff&lt;/sub&gt;</td>
<td>rFf</td>
<td>The practical free flow traffic flow when only the green aspect is displayed</td>
<td>VPH</td>
<td>0</td>
<td>5000</td>
<td>1</td>
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<td>Common</td>
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<td>rLev1</td>
<td>Release level 1 traffic flow</td>
<td>VPH</td>
<td>r&lt;sub&gt;min&lt;/sub&gt;</td>
<td>r&lt;sub&gt;lev2&lt;/sub&gt;</td>
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<tr>
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<td>r&lt;sub&gt;lev10&lt;/sub&gt;</td>
<td>rLev10</td>
<td>Release level 10 traffic flow</td>
<td>VPH</td>
<td>r&lt;sub&gt;lev9&lt;/sub&gt;</td>
<td>r&lt;sub&gt;max&lt;/sub&gt;</td>
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<td>Release level 2 traffic flow</td>
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<td>r&lt;sub&gt;lev3&lt;/sub&gt;</td>
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<td>Release level 3 traffic flow</td>
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<td>r&lt;sub&gt;lev4&lt;/sub&gt;</td>
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<td>rLev4</td>
<td>Release level 4 traffic flow</td>
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<td>r&lt;sub&gt;lev5&lt;/sub&gt;</td>
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<td>r&lt;sub&gt;lev5&lt;/sub&gt;</td>
<td>rLev5</td>
<td>Release level 5 traffic flow</td>
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<td>Release level 6 traffic flow</td>
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<td>rLev7</td>
<td>Release level 7 traffic flow</td>
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<td>Common</td>
<td>r&lt;sub&gt;lev8&lt;/sub&gt;</td>
<td>rLev8</td>
<td>Release level 8 traffic flow</td>
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<td>r&lt;sub&gt;lev9&lt;/sub&gt;</td>
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March 2008  
D-87  
MCH 2473
### RAMP METERING

**Calibration Guidelines**

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<tr>
<th>Algorithm</th>
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<tr>
<td>Common</td>
<td>r_{lev9}</td>
<td>r_{Lev9}</td>
<td>Release level 9 traffic flow</td>
<td>VPH</td>
<td>r_{lev8}</td>
<td>r_{lev10}</td>
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<tr>
<td>Common</td>
<td>r_{max}</td>
<td>r_{Max}</td>
<td>The maximum practical metered traffic flow that can be achieved with full signal sequences</td>
<td>VPH</td>
<td>0</td>
<td>4000</td>
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<tr>
<td>Common</td>
<td>r_{min}</td>
<td>r_{Min}</td>
<td>The minimum practical metered traffic flow that can be achieved with full signal sequences</td>
<td>VPH</td>
<td>0</td>
<td>4000</td>
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<tr>
<td>Common</td>
<td>r_{off}</td>
<td>r_{Off}</td>
<td>The maximum theoretical traffic flow of the ramp with no ramp metering signals</td>
<td>VPH</td>
<td>0</td>
<td>6000</td>
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<td>r_{oo}(k)</td>
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<td>The release flow (for the current iteration of the ramp metering algorithm) required by the Switch On-Off Algorithm</td>
<td>VPH</td>
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<td>r_{off}</td>
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<td>r_{oo}(k_{oo})</td>
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<td>Desired Release Rate from the Switch On-Off algorithm</td>
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<td>r_{off}</td>
<td>1</td>
<td>r_{off}</td>
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<td>r_{poqm}(k_{poqm})</td>
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<td>Desired Release Rate from the Proportional Occupancy Queue Management algorithm, updated every iteration of the Proportional Occupancy Queue Management algorithm.</td>
<td>VPH</td>
<td>r_{min}</td>
<td>r_{max}</td>
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<td>r_{min}</td>
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<td>r_{qm}(k)</td>
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<td>r_{min}</td>
<td>r_{max}</td>
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## Ramp Metering Calibration Guidelines

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<tr>
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<tr>
<td>(r_{qp})</td>
<td>(r_{qp})</td>
<td>(r_{qo})</td>
<td>Desired Release Rate from the Queue Override algorithm</td>
<td>VPH</td>
<td>(r_{min})</td>
<td>(r_{max})</td>
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<td>(r_{lev10})</td>
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<td>(r_{qp}(k))</td>
<td>(r_{qp}(k))</td>
<td>(r_{qo}(k))</td>
<td>The release flow (for the current iteration of the Queue Override algorithm) required by the Queue Override Algorithm</td>
<td>VPH</td>
<td>(r_{min})</td>
<td>(r_{ff})</td>
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<td>N/A</td>
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<td>Queue Override</td>
<td>(r_{qomax})</td>
<td>(r_{QoMax})</td>
<td>The desired flow rate to reduce the queue length to acceptable levels within the required time frame.</td>
<td>VPH</td>
<td>(r_{min})</td>
<td>(r_{ff})</td>
<td>1</td>
<td>(r_{lev10})</td>
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<td>(r_{rm})</td>
<td>(r_{rm})</td>
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<td>(r_{max})</td>
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<td>(r_{max})</td>
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<td>(r_{rm}(k))</td>
<td>(r_{rm}(k))</td>
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<td>VPH</td>
<td>(r_{min})</td>
<td>(r_{max})</td>
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<td>Release</td>
<td>(r_{t1-10})</td>
<td>(r_{T1} - r_{T10})</td>
<td>Ten red signal times (release levels 1-10);</td>
<td>Seconds</td>
<td>(r_{t_{min}})</td>
<td>(r_{t_{max}})</td>
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<td>Release</td>
<td>(r_{t_{max}})</td>
<td>(r_{TMax})</td>
<td>Maximum red time</td>
<td>Seconds</td>
<td>1</td>
<td>120</td>
<td>0.25</td>
<td>60</td>
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<tr>
<td>Release</td>
<td>(r_{t_{min}})</td>
<td>(r_{TMin})</td>
<td>Minimum red time</td>
<td>Seconds</td>
<td>1</td>
<td>120</td>
<td>0.25</td>
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<td>(r_{woqm}(k_{woqm}))</td>
<td>(r_{woqm}(k_{woqm}))</td>
<td>(r_{woqm}(k_{woqm}))</td>
<td>Desired Release Rate from the weighted occupancy queue management algorithm, updated every iteration of the weighted occupancy queue</td>
<td>VPH</td>
<td>(r_{min})</td>
<td>(r_{max})</td>
<td>1</td>
<td>(r_{max})</td>
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<tr>
<td>Algorithm</td>
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<td>management algorithm.</td>
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<td>$r_{woqm1af1}$ &amp; $r_{woqm2af1}$</td>
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<td>Adjustment factors for weighted occupancy level 1 for each lane.</td>
<td>VPH</td>
<td>0</td>
<td>2400</td>
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<td>$r_{woqm1af10}$ &amp; $r_{woqm2af10}$</td>
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<td>Adjustment factors for weighted occupancy level 10 for each lane.</td>
<td>VPH</td>
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<td>$r_{woqm1af2}$ &amp; $r_{woqm2af2}$</td>
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<td>Adjustment factors for weighted occupancy level 2 for each lane.</td>
<td>VPH</td>
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<td>$r_{woqm1af3}$ &amp; $r_{woqm2af3}$</td>
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<td>Adjustment factors for weighted occupancy level 3 for each lane.</td>
<td>VPH</td>
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<td>$r_{woqm1af4}$ &amp; $r_{woqm2af4}$</td>
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<td>Adjustment factors for weighted occupancy level 4 for each lane.</td>
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<td>$r_{woqm1af5}$ &amp; $r_{woqm2af5}$</td>
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<td>Adjustment factors for weighted occupancy level 5 for each lane.</td>
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<td>$r_{woqm1af6}$ &amp; $r_{woqm2af6}$</td>
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<td>Adjustment factors for weighted occupancy level 6 for each lane.</td>
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<td>$r_{woqm1af7}$ &amp; $r_{woqm2af7}$</td>
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<td>Adjustment factors for weighted occupancy level 7 for each lane.</td>
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<td>Adjustment factors for weighted occupancy level 9 for each lane.</td>
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<td>spA1 - spA10</td>
<td>Ten stopping amber signal times (release levels 1-10);</td>
<td>Seconds</td>
<td>spa(_{min})</td>
<td>spa(_{max})</td>
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<td>Release</td>
<td>spa(_{max})</td>
<td>spAMax</td>
<td>Maximum stopping amber time</td>
<td>Seconds</td>
<td>1</td>
<td>5</td>
<td>0.25</td>
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<tr>
<td>Release</td>
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<td>sPAMin</td>
<td>Minimum stopping / (leaving) amber time</td>
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<td>5</td>
<td>0.25</td>
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<tr>
<td>Release</td>
<td>sta1-10</td>
<td>stA1 - stA10</td>
<td>Ten starting amber signal times (release levels 1-10);</td>
<td>Seconds</td>
<td>st(_{min})</td>
<td>st(_{max})</td>
<td>0.25</td>
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<tr>
<td>Release</td>
<td>sta(_{max})</td>
<td>stAMax</td>
<td>Maximum starting amber (red and amber) time</td>
<td>Seconds</td>
<td>1</td>
<td>5</td>
<td>0.25</td>
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<td>Release</td>
<td>sta(_{min})</td>
<td>stAMin</td>
<td>Minimum starting amber (red and amber) time</td>
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<td>The state of the algorithm</td>
<td>Switching On / Steady State / Switching Off</td>
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<td>T</td>
<td></td>
<td></td>
<td>Present Day and Time</td>
<td>Day:Hour:Minute:Second</td>
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<tr>
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<td>Length of aggregation period</td>
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<td>Demand Capacity</td>
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<tr>
<td>Switch On/Off</td>
<td>T_{off(Mon 1)} to T_{off(Sun 4)}</td>
<td>tOff</td>
<td>Times that the Switch On-Off algorithm switches off. Up to four different switch off times per day with different switch off times for different days of the week.</td>
<td>Hour: Min: Sec</td>
<td>0:00:00</td>
<td>23:59:59</td>
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<tr>
<td></td>
<td>T_{on(Mon 1)} to T_{on(Sun 4)}</td>
<td>tOn</td>
<td>Times that the Switch On-Off algorithm switches on. Up to four different switch on times per day with different switch on times for different days of the week.</td>
<td>Hour: Min: Sec</td>
<td>0:00:00</td>
<td>23:59:59</td>
<td>1 sec</td>
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<td>t_oo</td>
<td>tOo</td>
<td>Time period for each iteration of Switch On-Off algorithm.</td>
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<td>t_poqm</td>
<td>tPoqm</td>
<td>Time period for each iteration of Proportional Occupancy Queue Management Algorithm</td>
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<td>t_qoc</td>
<td>tQoc</td>
<td>Time period for operation of maximum Queue Override desired ramp flow to clear the queue overflow.</td>
<td>Seconds</td>
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<tbody>
<tr>
<td>Queue Override</td>
<td>t_qqr</td>
<td>t_Qor</td>
<td>Time period required before the Queue Override algorithm is reset following a Queue Override trigger and operation at the maximum desired Queue Override ramp flow.</td>
<td>Seconds</td>
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<td>120</td>
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<td>t_qot</td>
<td>t_Qot</td>
<td>Time period for each iteration of Queue Override Algorithm to trigger the Queue Override operation.</td>
<td>Seconds</td>
<td>0</td>
<td>120</td>
<td>Multiple of filter algorithm</td>
<td>5</td>
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<tr>
<td>Ramp Data Filter</td>
<td>T_Rloop</td>
<td>t_RLoop</td>
<td>Period of loop information</td>
<td>sec</td>
<td>0.01</td>
<td>0.1</td>
<td>0.001</td>
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<tr>
<td></td>
<td>t_total(m)</td>
<td></td>
<td>Summated time occupied in aggregation period for each loop pair</td>
<td>sec</td>
<td>0</td>
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<td>0.1</td>
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<td></td>
<td>two_1</td>
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<td>Total weighted occupancy for lane 1.</td>
<td>Integer</td>
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<td>24000</td>
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<tr>
<td></td>
<td>two_1t1 &amp; two_2t1</td>
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<td>Thresholds for total weighted occupancy level 1, corresponding to adjustment factor 1 for each lane.</td>
<td>Integers</td>
<td>0</td>
<td>24000</td>
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<td>100</td>
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<tr>
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<td>two_1t2 &amp; two_2t2</td>
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<td>Thresholds for total weighted occupancy level 2, corresponding to adjustment factor 2 for each lane.</td>
<td>Integers</td>
<td>0</td>
<td>24000</td>
<td>1</td>
<td>200</td>
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<tr>
<td></td>
<td>two_1t3 &amp; two_2t3</td>
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<td>Thresholds for total weighted occupancy level 3, corresponding to adjustment factor 3 for each lane.</td>
<td>Integers</td>
<td>0</td>
<td>24000</td>
<td>1</td>
<td>300</td>
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</table>
## Calibration Guidelines

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>MCH1965 label</th>
<th>Parameters</th>
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<th>Resolution</th>
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</tr>
</thead>
<tbody>
<tr>
<td>two14 &amp; two214</td>
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<td>Thresholds for total weighted occupancy level 4, corresponding to adjustment factor 4 for each lane.</td>
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<td>two15 &amp; two215</td>
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<td>Thresholds for total weighted occupancy level 5, corresponding to adjustment factor 5 for each lane.</td>
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<td>two16 &amp; two216</td>
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<td>Thresholds for total weighted occupancy level 6, corresponding to adjustment factor 6 for each lane.</td>
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<td>two17 &amp; two217</td>
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<td>Thresholds for total weighted occupancy level 7, corresponding to adjustment factor 7 for each lane.</td>
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<td>Thresholds for total weighted occupancy level 8, corresponding to adjustment factor 8 for each lane.</td>
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<td>two19 &amp; two219</td>
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<td>Thresholds for total weighted occupancy level 9, corresponding to adjustment factor 9 for each lane.</td>
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<td>Integer</td>
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### Weighted Occupancy

<table>
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<th>Parameters</th>
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<th>Min</th>
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<tr>
<td>twoqm</td>
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<td>tWoQm</td>
<td>Time period for each iteration of Weighted Average Queue management Algorithm</td>
<td>Seconds</td>
<td>0</td>
<td>120</td>
<td>Multiple of filter algorithm</td>
<td>5</td>
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# Calibration Guidelines

<table>
<thead>
<tr>
<th>Algorithm</th>
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<th>Max</th>
<th>Resolution</th>
<th>Default</th>
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<tbody>
<tr>
<td>$V_{in}(k_{oo})$</td>
<td></td>
<td></td>
<td>Speed of lane 1 of main carriageway, upstream of the merge area averaged over the switch on off aggregation period.</td>
<td>kph</td>
<td>0</td>
<td>250</td>
<td>1</td>
<td>250</td>
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<tr>
<td>$v_{loop}(k)$</td>
<td></td>
<td></td>
<td>mean speed across the loop pair (calculated for each loop pair)</td>
<td>Kph</td>
<td>0</td>
<td>200</td>
<td>0.01</td>
<td>n/a</td>
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<tr>
<td>Switch On/Off</td>
<td>$v_{max}$</td>
<td>vMax</td>
<td>Maximum operational speed of lane 1 of main carriageway, upstream of merge area.</td>
<td>kph</td>
<td>0</td>
<td>250</td>
<td>1</td>
<td>85</td>
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<td></td>
<td>$v_{site}(k)$</td>
<td></td>
<td>mean speed across the loop site (calculated for each loop site)</td>
<td>Kph</td>
<td>0</td>
<td>200</td>
<td>0.01</td>
<td>n/a</td>
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<tr>
<td></td>
<td>$v_{total}(m)$</td>
<td></td>
<td>Summated speed in aggregation period for each loop pair</td>
<td>Kph</td>
<td>0</td>
<td>300</td>
<td>0.1</td>
<td>0</td>
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<tr>
<td></td>
<td>$v_{veh}$</td>
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<td>Vehicle speed</td>
<td>Kph</td>
<td>0</td>
<td>255</td>
<td>1</td>
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<td></td>
<td>$w_{f_{q11}}$ to $w_{f_{q12}}$</td>
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<td>Weighting factor for next queue detector on slip road</td>
<td>Integers</td>
<td>0</td>
<td>1000</td>
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<td></td>
<td>$w_{f_{q21}}$ to $w_{f_{q22}}$</td>
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<td>Weighting factor for next queue detector on slip road</td>
<td>Integers</td>
<td>0</td>
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<td>100</td>
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<tr>
<td></td>
<td>$w_{f_{q31}}$ to $w_{f_{q32}}$</td>
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<td>Weighting factor for next queue detector on slip road</td>
<td>Integers</td>
<td>0</td>
<td>1000</td>
<td>1</td>
<td>70</td>
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</table>
## Calibration Guidelines

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>MCH1965 label</th>
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<th>Resolution</th>
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<tbody>
<tr>
<td>wf&lt;sub&gt;q41&lt;/sub&gt; to wf&lt;sub&gt;q42&lt;/sub&gt;</td>
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<td>Weighting factor for next queue detector on slip road</td>
<td>Integers</td>
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<td>60</td>
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<td>wf&lt;sub&gt;q51&lt;/sub&gt; to wf&lt;sub&gt;q52&lt;/sub&gt;</td>
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<td>Weighting factor for next queue detector on slip road</td>
<td>Integers</td>
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<td>wf&lt;sub&gt;q61&lt;/sub&gt; to wf&lt;sub&gt;q62&lt;/sub&gt;</td>
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<td>Weighting factor for next queue detector on slip road</td>
<td>Integers</td>
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<td>1000</td>
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<td>wf&lt;sub&gt;q71&lt;/sub&gt; to wf&lt;sub&gt;q72&lt;/sub&gt;</td>
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<td>Weighting factor for next queue detector on slip road closest to stop line</td>
<td>Integers</td>
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<td>1000</td>
<td>1</td>
<td>10</td>
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<tr>
<td>wf&lt;sub&gt;qo1&lt;/sub&gt; to wf&lt;sub&gt;qo2&lt;/sub&gt;</td>
<td></td>
<td></td>
<td>Weighting factor for first queue detector on slip road, (also used for Queue Override function)</td>
<td>Integers</td>
<td>0</td>
<td>1000</td>
<td>1</td>
<td>200</td>
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<tr>
<td>wo&lt;sub&gt;qo1&lt;/sub&gt; to wo&lt;sub&gt;qn2&lt;/sub&gt;</td>
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<td>Weighted occupancy level factor for each queue detector.</td>
<td>Integers</td>
<td>0</td>
<td>3000</td>
<td>1</td>
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\[
\begin{align*}
\hat{\tilde{o}} & \quad \text{Smoothed occupancy} \\
\hat{\tilde{o}}_{\text{loop}} (k) & \quad \text{smoothed occupancy of the loop pair (calculated for each loop pair)} \\
\hat{\tilde{o}}_{\text{site}} (k) & \quad \text{smoothed occupancy of the site (calculated for each site)} \\
\tilde{v} & \quad \text{Smoothed speed} \\
\tilde{v}_{\text{loop}} (k) & \quad \text{smoothed speed across the loop pair (calculated for each loop pair)} \\
\tilde{v}_{\text{site}} (k) & \quad \text{smoothed speed across the site (calculated for each site)} \\
\hat{q}_{\text{loop}} (k) & \quad \text{smoothed flow across the loop pair (calculated for each loop pair)}
\end{align*}
\]
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<table>
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<th>Resolution</th>
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<td>smoothed flow across the site (calculated for each site)</td>
<td>VPH</td>
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<tr>
<td>$\tilde{q}_{site}(k)$</td>
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<tr>
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<td></td>
<td>Smoothed flow (veh/hr)</td>
<td>VPH</td>
<td>0</td>
<td>$r_{\text{max}}$</td>
<td>0.1</td>
<td>0</td>
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<tr>
<td>$\tilde{\phi}_{\text{loop}}(k)$</td>
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<td>Smoothed flow (veh/hr)</td>
<td>VPH</td>
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<td>$r_{\text{max}}$</td>
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<td>Green signal</td>
<td>State</td>
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<td>N/A</td>
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<tr>
<td>Amber Signal (Stopping Amber) (time for the signal phases to change from green to red).</td>
<td>State</td>
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<td>Red Signal</td>
<td>State</td>
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<td>N/A</td>
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<tr>
<td>Red and Amber Signal (Starting Amber) (time for the signal phases to change from red to green).</td>
<td>State</td>
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<td>On</td>
<td>N/A</td>
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<td>Manual Override to switch the operational state as follows: On / Off / Timed / Timed Occupancy / Timed Flow and Occupancy</td>
<td>State</td>
<td>Off</td>
<td>On</td>
<td>N/A</td>
<td>Off</td>
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<tr>
<td>Fault signal from each loop</td>
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<td>On</td>
<td>N/A</td>
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