5.3.1 Geometric Considerations

Geometric requirements for metered ramps depend upon several factors, including:

- **Peak hour volume** which affects the storage length and width of the ramp.
- **Design speed** of the mainline for the ramp under consideration, which affects the acceleration distance after the stop bar (acceleration distances per AASHTO A Policy on Geometric Design of Highways and Streets, latest edition).
- **Right-of-way availability**, which will factor into the length and width of the ramp.
- **Construction funding**, which may influence the extent to which the ramp can be modified, affecting ramp width, length, and acceleration lanes.

These considerations will indicate whether a ramp meter is retrofitted to existing conditions, rehabilitated while maintaining the current alignment, or completely reconstructed. Table 5.3-1 provides recommended and minimum widths for ramp meters based on configuration type. Refer to 11-30-1 for basic entrance ramp design.

<table>
<thead>
<tr>
<th>Ramp Meter Configuration</th>
<th>Ramp With Shoulders</th>
<th>With Curb and Gutter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Traveled Way</td>
<td>Shoulder</td>
</tr>
<tr>
<td></td>
<td>Inside</td>
<td>Outside</td>
</tr>
<tr>
<td>SOV</td>
<td>12 ft</td>
<td>4 ft 8 ft</td>
</tr>
<tr>
<td>2 SOV</td>
<td>24 ft</td>
<td>4 ft 8 ft</td>
</tr>
<tr>
<td>SOV / HOV</td>
<td>24 ft</td>
<td>4 ft 8 ft</td>
</tr>
<tr>
<td>HOV LANE</td>
<td>12 ft</td>
<td>n/a n/a</td>
</tr>
<tr>
<td>2 SOV / HOV</td>
<td>36 ft</td>
<td>2 ft 2 ft</td>
</tr>
<tr>
<td>3 SOV</td>
<td>36 ft</td>
<td>2 ft 2 ft</td>
</tr>
</tbody>
</table>

*Table 5.3-1: Ramp Meter Width Requirements*

**Single-Lane (SOV) Ramps**

Requirements for entrance ramps with one metered lane are shown in Fig. 5.3-1 & 5.3-2. For longer ramps, it may be desirable to add an intermediate queue detector to limit the delay per vehicle proceeding through the ramp meter. The stop bar signals should be placed to allow adequate visibility when traveling down the ramp. Refer to 11-10-5 for sight distance requirements.

**Metered Two-Lane (SOV/HOV, 2 SOV) Ramps**

Requirements for entrance ramps with two metered lanes are shown in Fig. 5.3-3 & 5.3-4.

**Metered Three-Lane (2 SOV/HOV, 3 SOV) Ramps**

A three-lane ramp may be designed when two single occupant vehicle (SOV) and an HOV lane or three SOV lanes are required. Requirements for entrance ramps with three metered lanes are shown in Fig. 5.3-5. A three-lane loop ramp is not recommended due to safety considerations.
Metered Four-Lane Ramps
In certain situations, two ramps come together for a four-lane ramp meter or for two separate ramp meters that are next to each other. This occurs in very rare instances. Contact the State Traffic Operations Center for assistance in this type of ramp meter design.

System to System Ramps
Due to higher rates of speed, system to system ramps require additional safety and advance warning considerations than found under single or dual lane metering. Close coordination with the State Traffic Operations Center is critical to decide if a system to system ramp meter is really needed, and if so, what geometric constraints exist.
Figure 5.3-1: Ramp Meter Design Guidelines, 1-Lane Diamond Leg Ramp

GENERAL NOTES

1. See FTMS Detail Design Drawing "stopbars.dgn" for complete stop bar layout.


3. Total storage to be determined by demand analysis using current ramp volumes, 15-minute periods minimum.

4. Loops are necessary for demand and passage detection.

5. All other detection can use loops or microwave detection. Detection zones are shown.
GENERAL NOTES

1. See FTMS Detail Design Drawing 'stopbars.dgn' for complete stop bar layout.


3. Total storage to be determined by demand analysis using current ramp volumes, 15-minute periods minimum.

4. Loops are necessary for demand and passage detection.

5. All other detection can use loops or microwave detection. Detection zones are shown.

Figure 5.3-2: Ramp Meter Design Guidelines, 1-Lane Loop Ramp
GENERAL NOTES

1. See FTMS Detail Design Drawing ‘stopbars.dgn’ for complete stop bar layout.


3. Total storage to be determined by demand analysis using current ramp volumes, 15-minute periods minimum.

4. HOV lane preferred placement on left-side.

5. Loops are necessary for demand and passage detection.

6. All other detection can use loops or microwave detection. Detection zones are shown.

Figure 5.3-3: Ramp Meter Design Guidelines, 2-Lane Diamond Leg Ramp
Figure 5.3-4: Ramp Meter Design Guidelines, 2-Lane Loop Ramp
Figure 5.3-5: Ramp Meter Design Guidelines, 3-Lane Diamond Leg Ramp (Non-Separated HOV)
5.3.2  Ramp Meter Stop Bar/Signal Placement

Ramp meter stop bar placement revolves around the following fundamental issues:

- Ramp acceleration required
- Ramp storage required
- Stop bar signal sight distances

Once the acceleration and storage distance requirements have been established (from the initial data collection and determination of ramp meter type), the placement of the stop bar can be determined. If the ramp is being widened or lengthened, the stop bar placement must also be determined side-by-side with the geometric design of the ramp. For sight distance, the most desirable location for a stop bar is at the end of a tangent section of the ramp. For loop ramps, the stop bar placement typically should be near the freeway gore, provided adequate acceleration distance is present parallel to the mainline.

Under any circumstance, the placement of the stop bar for ramp meters must be reviewed by the State Traffic Operations Center prior to proceeding with final design and layout of the ramp.

When the use of an overhead sign support (mast-arm) becomes necessary, such as a non-separated 2 SOV / HOV ramp meter, placement of the overhead signals should be over the two single occupant vehicle lanes, with the side-mounted Type 2 signal assembly placed at the HOV lane. Only under the most restrictive geometric constraints should the overhead signals be placed over one SOV lane and the HOV lane.

5.3.3  Controller Cabinet Placement

Once the ramp meter type, geometric layout, and stop bar placement of the ramp has been determined, the placement of the controller cabinet can be established. This placement involves many factors, including:

- Visibility of the stop bar signals from the controller cabinet
- Distance between the controller cabinet and the loop detectors
- Distance between the controller cabinet and the signals on the ramp
- Grades
- Drainage
- Maintenance Accessibility (parking availability for maintenance vehicles)

For maintenance considerations, it is very important that the stop bar signals be visible from the controller cabinet. The distance between the cabinet and stop bar is dependent on the loop detector inductance ratio.

The slope of the terrain for cabinet placement must be no steeper than 4:1. Placement of the cabinet on 3:1 slopes or steeper requires grading provisions to provide a level area around the cabinet.

5.3.4  Advance Warning Sign Placement

Placement of a traditional advanced warning sign (e.g., “Ramp Metered When Flashing”) depends upon the functional intent of the warning signs.

- **Post-Entrance Notification** - The functional intent of the sign in this scenario is to warn road users that a freeway entrance ramp is metered and that road users will encounter a ramp control signal. A RAMP METERED WHEN FLASHING sign shall be installed on the ramp that metering is being implemented. The placement of advance warning signs under this scenario should provide adequate site distance upon entering the ramp, yet allowing sufficient distance between the sign and estimated back of queue.

- **Pre-Entrance Notification** - The functional intent of the sign in this scenario is to warn road users upon entering the ramp that metering is currently being implemented. A RAMP METERED WHEN FLASHING sign may be installed in advance of the ramp entrance on the arterial approaching the metered ramp. Criteria for installation of this sign may include long queue lengths or heavy turn movements on to the ramp. If used, the placement of advance warning signs under this scenario should provide adequate sight distance along the cross street, allowing the motorist ample time to decide whether to enter the freeway system at that location, or bypass the ramp meter and travel along alternate routes.

A minimum distance of 100-ft must be maintained between the advance warning sign and any existing signs.
For system connector ramps, or high-speed urban interchange ramps, overhead advance warning signs must be designed to provide additional warning of ramp meters. Overhead advance warning signs are “blank-out” signs that read RAMP METERED, and contain 2 yellow signal beacons above which flash alternately. Upon metering start-up, the RAMP METERED is displayed and the yellow beacons flash. In non-metering conditions, the display is blank. These advance-warning signs are typically installed above a freeway guide-sign, and mounted to a full-span or cantilever sign structure. Design issues with overhead advance warning signs include:

- **Placement** - The back of the design year queue must be calculated for the ramp meter. The overhead warning sign is placed to ensure that motorists have **adequate sight distance for the sign** based on roadway alignment, and **adequate perception and reaction time** based from the point of viewing the sign to the end of the ramp meter queue, in coordination with the vehicle’s approach speed.

- **New Type I Guide Signs** - If a new freeway guide-sign and advance warning sign is installed, sign spacing becomes a concern, and must be coordinated with the Region traffic/signing engineer. Typically, 800-ft minimum spacing is required between WisDOT Type I signs.

- **Installation on Existing Sign Structures** - If the advance warning signs are to be placed on an existing structure, a thorough structural review **must** be conducted to determine the load capabilities of the existing structure, and whether that structure is capable of supporting the overhead advance warning sign.

![Figure 5.3-7: Typical Advanced Flasher Assembly Placement](image)
• **Demand Loops** - A 6 x 20-ft loop is placed just upstream of the stop bar in each metered lane. The distance between the leading edge of the loop and the stop bar pavement marking line is 25 feet, leaving a five-foot space between the lagging edge of the demand loop to the stop bar.

• **Passage Loops** - In each metered lane, a 6 x 6-ft loop is placed just downstream of the stop bar. The distance between the leading edge of the loop and the stop bar pavement marking line is 10 feet.

• **Queue Loops** – Each queue loop should be 6 feet long (along the ramp) and sized to fit the width of each lane or ramp. Each queue detector placement is unique in its placement upstream of the stop bar. This involves a trade-off between maximizing ramp storage without having vehicles detected, while at the same time anticipating additional vehicles entering from the side street (i.e., platoons of vehicles entering as a result of a traffic signal). The designer must consult the State Traffic Operations Center to obtain guidance in placement of queue detectors.

• **Entrance Ramp Reporting Loops** - A reporting loop detector (for traffic counts) should be placed on multi-lane entrance ramps downstream of the stop bar where the ramp narrows to a single lane prior to entering the freeway. Reporting loops also must be placed on any non-metered entrance ramps within the interchange of the ramp meter. Entrance ramp loops should be sized to fit the ramp such that vehicles cannot avoid passing over the loop.

• **Exit Ramp Reporting Loops** - Reporting loops also must be placed on any exit ramps within the interchange of the ramp meter. Exit ramp reporting loops should be sized to fit the ramp such that vehicles cannot avoid passing over the loop.

• **Turning Count Reporting Loops** - Reporting loops at the entrance of a ramp meter counting entering traffic by direction is preferred, but optional. These loops are typically installed on a ramp that has a traffic island at the entrance separating the directional movements.

• **Mainline Loops** - Loops should be placed upstream of the entrance ramp gore. These loops are used when the ramp meter is operated locally in response to traffic conditions along the mainline. Placement of mainline loops should also be coordinated with the spacing considerations as documented in Chapter 10, System Detector Stations.

• **Non-Intrusive Detectors**
  - **Microwave Detection** – Can be used instead of any of the above mentioned loops, except for demand and passage detection, since it doesn’t do well at point detection. Microwave detection can be placed on a detector camera pole or lighting pole. It has the ability to detect volume and speed in up to three to four lanes.
  - **Video Detection** – Used for mainline as well as ramp meter detection. It may be used for demand and passage detection, though it is not the preferred option.

Loop detectors are typically illustrated at precise locations in the plan. A loop detector chart provides additional information in the plan, such as the loop description (type), location (station), size (in feet), and the number of turns of wire contained within the loop. Mainline loops do not require a station, since most ITS plan sets do not require the contractor to establish stationing along the mainline. In this instance, since each lane contains primary and secondary loops (for speed data), the location is the lane number. The farthest left-hand (inside) lane on a freeway direction is always Lane 1, with lane number progressions increasing from left to right.

Table 5.3-2 illustrates a typical loop detector chart and information provided on the design location sheets.
Table 5.3-2: Loop Detector Detail Chart

<table>
<thead>
<tr>
<th>NO.</th>
<th>DESCRIPTION</th>
<th>LOCATION</th>
<th>SIZE</th>
<th>NO. OF TURNS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>QUEUE A</td>
<td>48B+60</td>
<td>6' x 6'</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>DEMAND A</td>
<td>58B+30</td>
<td>6' x 20'</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>DEMAND B</td>
<td>58B+30</td>
<td>6' x 20'</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>DEMAND C</td>
<td>58B+30</td>
<td>6' x 20'</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>PASSAGE A</td>
<td>58B+65</td>
<td>6' x 6'</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>PASSAGE B</td>
<td>58B+65</td>
<td>6' x 6'</td>
<td>4</td>
</tr>
<tr>
<td>7</td>
<td>PASSAGE C</td>
<td>58B+65</td>
<td>6' x 6'</td>
<td>3</td>
</tr>
<tr>
<td>8</td>
<td>NORTHBOUND PRIMARY LANE 1</td>
<td>6' x 6'</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>NORTHBOUND PRIMARY LANE 2</td>
<td>6' x 6'</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>NORTHBOUND PRIMARY LANE 3</td>
<td>6' x 6'</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>NORTHBOUND SECONDARY LANE 1</td>
<td>6' x 6'</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>NORTHBOUND SECONDARY LANE 2</td>
<td>6' x 6'</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>NORTHBOUND SECONDARY LANE 3</td>
<td>6' x 6'</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>REPORTING - EB MAIN STREET ENTRANCE</td>
<td>45B+80</td>
<td>6' x 12'</td>
<td>3</td>
</tr>
<tr>
<td>15</td>
<td>REPORTING - WB MAIN STREET ENTRANCE</td>
<td>SEE PLAN</td>
<td>6' x 20'</td>
<td>3</td>
</tr>
<tr>
<td>16</td>
<td>REPORTING - HOV LANE</td>
<td>52B+70</td>
<td>6' x 6'</td>
<td>3</td>
</tr>
<tr>
<td>17</td>
<td>REPORTING - NB ENTRANCE RAMP</td>
<td>61B+75</td>
<td>6' x 15'</td>
<td>5</td>
</tr>
<tr>
<td>18</td>
<td>REPORTING - NB EXIT RAMP</td>
<td>SEE PLAN</td>
<td>6' x 10'</td>
<td>3</td>
</tr>
</tbody>
</table>

NOTES:
1. DEMAND / PASSAGE LOOPS STATIONED ASSUMING STOPBAR STATION 58B+55
2. ALL LOOPS ARE STATIONED TO THE LEADING EDGE

5.3.6 Underground Infrastructure

When the controller cabinet, electrical service, loops, stop bar, and advance flasher assemblies have been placed, the underground conduit infrastructure can be designed. HDPE ducts are the recommended conduit installation for ramp meter raceways and all ITS deployments for WisDOT. Issues to keep in mind when designing the ramp meter conduit infrastructure include:

- **Conduit Size** - 3-Inch conduit is typically used for ramp meter raceways. Conduit entering electrical service pedestals must be sized per pedestal requirements.

- **Conduit Fill** - The size and number of conduits along a run is dependent on percentage of fill as established by the National Electric Code (NEC). Although it may not violate the NEC fill code, no more than 13 loop detector lead-in cables should be designed for installation in a single 4-inch conduit. Installation of more than 13 lead-in cables becomes difficult due to the quantity and weight of the cables.

- **Pull Box Spacing** - Pull boxes should be spaced no greater than 250 - 350 feet within a ramp meter.

- **Terrain** - Conduit infrastructure should be designed on relatively flat (4:1 slope or flatter) terrain. For steeper sloped terrain (3:1 or greater), conduit may be run perpendicular to (i.e., up or down) the slope to locations where the terrain is more suitable for conduit installation.

5.3.7 Cable Routing

General

Cable routing for ramp meters involves the connection of all equipment to the controller cabinet, including loop detectors, signal assemblies, advance flashers, and the electrical service electrical service. Other devices such as cameras (see Chapter 15) and blank-out signs (see Chapter 20) may be added to a ramp meter site and require cable routing as described in their respective chapters. When routing cables for a ramp meter, issues to consider include:

- **Grouping of cables** - It is desirable to “group” cables within individual conduits throughout the system based on destination. For example, given a three-lane ramp meter with mainline detection and exit ramp loop(s), cables can be grouped such that the stop bar cables (conductor and loop lead-in cables) occupy the same conduit. The mainline and exit ramp lead-in cables can be grouped in a separate conduit, while the equipment cables near the entrance ramp (5-conductor for advance flashers and queue/reporting loop lead-in cables) grouped in yet another conduit. By grouping cables, the ramp meter cabling system is easier to maintain.

- **Separation of Power and Communication** - The power distribution traffic signal cables, or any cabling for AC power, running between the controller cabinet, signal heads, and advance flasher assemblies, must be in separate conduits from copper communications cable, yet may be installed through the same pull boxes. The communications cable performance will be degraded by close proximity to AC power conductors. It is strongly recommended that the traffic signal cables be installed in separate conduits from fiber optic communications cables as well, but if necessary, they may be run in the same duct, since the AC power conductors do not affect the performance of the fiber optic communication cable.
- **Power Service Cabling** – The power distribution wires used between the power source (examples include a meter breaker pedestal at the utility connection or an adjacent lighting distribution cabinet with a circuit dedicated for ITS use) and the cabinet or step-down transformer must be installed in an entirely separate conduit and pull box system. The conduit may be installed in the same trench as other ducts, but must be connected to a different set of pull boxes. The pull boxes for the power distribution system must all be grounded independently. The conduit for this installation should be 2-inch HDPE duct(s).

**Stop Bar Signal Cables**

The number of conductors required for the stop bar signals is dependent on the number of lanes being metered, and the number of signals wired independently. For a five-section ramp meter signal assembly (R-Y-G upper signals, R-G lower signals), a minimum of three conductors is required to power the assembly. The upper and lower red indications are wired in series, as well as the upper and lower green indications. In addition to the conductors assigned to the individual signal heads, the White conductor in the traffic signal cable must be used as the neutral return conductor.

<table>
<thead>
<tr>
<th>Ramp Meter Type</th>
<th>Wiring Configuration</th>
<th># of Conductors Required</th>
<th>Indications Wired</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Lane Metering</td>
<td>Jumpered</td>
<td>Three Total Conductor</td>
<td>Red1, Yellow1, Green1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 to first signal</td>
<td>Red2, Yellow2, Green2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 jumpered to second signal</td>
<td></td>
</tr>
<tr>
<td>2 Lane Metering</td>
<td>Independent</td>
<td>Six Total Conductor</td>
<td>Red1, Yellow1, Green1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 to first signal</td>
<td>Red2, Yellow2, Green2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 to second signal</td>
<td></td>
</tr>
<tr>
<td>3 Lane Metering</td>
<td>Independent</td>
<td>Nine Total Conductor</td>
<td>Red1, Yellow1, Green1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 to side-mount signal</td>
<td>Red2, Yellow2, Green2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6 to overhead signal</td>
<td>Red3, Yellow3, Green3</td>
</tr>
<tr>
<td>4 Lane Metering</td>
<td>Independent</td>
<td>Twelve Total Conductor</td>
<td>Red1, Yellow1, Green1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 to first signal</td>
<td>Red2, Yellow2, Green2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 to second signal</td>
<td>Red3, Yellow3, Green3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 to third signal</td>
<td>Red4, Yellow4, Green4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 to fourth signal</td>
<td></td>
</tr>
</tbody>
</table>

Table 5.3-3: Ramp Meter Signal Conductors

If a ramp meter has two advance flasher assemblies, and a single 5-conductor is wired between the controller cabinet and the first advance flasher assembly, and another 5-conductor cable is wired between that advance flasher and the second flasher, the 2 advance flasher assemblies are considered to be **jumpered**. If, however, 2 separate 5-conductor cables are run from the controller cabinet, one to each advance flasher assembly, the flasher assemblies are considered to be wired **independently**. The same can be said for ramp meter stop bar signals. Typically, only single lane ramp meter stop bar signals are **jumpered**.

Common practice is to use 7-conductor, 12-conductor, and 19-conductor traffic signal cables for ramp meter stop bar signalization.

The cabling is installed in the following sequence:

**1 Lane Metering:**
- Cabinet to first signal base – 1/7C Cable
- First signal base to second signal base – 1/7C cable (Jumpered)

**2 Lane Metering:**
- Cabinet to first signal base – 1/12C Cable
- First signal base to second signal base – 1/12C cable (Independent)

**3 Lane Metering:**
- Cabinet to first signal base – 1/19C cable
- First signal base to second base – 1/12C cable (Independent)
- Second signal base to third signal base – 1/7C cable (Independent)
4 Lane Metering:
With the large number of potential variations on 4-lane metering layout, it is not practical to define all possibilities here. The conductor assignment should be done in a manner consistent with the 3 lane metering conductor assignment with the use of the Black, White/Black, and Blue conductors for Red, Yellow, and Green signals respectively for Heads 7 and 8 on the 4th signal base.

As WisDOT uses low current draw LED traffic signal heads for ramp meters, it is unlikely that 14 AWG traffic signal cable will not be sufficient; however, it is up to the designer to verify that the voltage drop to the signal heads is less than 3%.

Advance Flasher Assembly Signal Cables
The conductor size required between the controller cabinet and advance flasher assembly signals is dependent upon the number of signals being wired onto the same conductor, and the distance to the cabinet. 5-conductor traffic signal cables are used for advance flasher assemblies.

As WisDOT uses low current draw LED traffic signal heads for ramp meters, it is unlikely that 14 AWG traffic signal cable will not be sufficient; however, it is up to the designer to verify that the voltage drop to the signal heads is less than 3%.

In addition to the conductor cable routing, a wire chart must be developed for individual ramp meters. Traffic signal cables used in Wisconsin conform to the requirements as established by the International Municipal Signal Association (IMSA). More specifically, as documented in section 655 of Wisconsin’s Standard Specifications, signal cables are required to conform to IMSA specification 20-1. IMSA 20-1 provides a 600 volt cable, solid copper conductors with polyethylene insulation, spirally wrapped with mylar tape and a polyethylene jacket. The individual conductors within the cable conform to a standard color code.

For each ramp meter, the cable routing must be illustrated under the “from”, “and”, “to” columns. The head number identifies the upper or lower heads on signal displays, or the left or right signal displays on a mast arm. For consistency in maintenance, the conductors used for individual stop bar indications are as follows:

- **Red Indications** - Red insulation color. Utilize conductor numbers 3, 8, and 13 except for 4 lane configurations, which will make use of the Black conductor for the fourth red signal.

- **Yellow Indications** - Orange insulation color, except when wiring the first signal in a three-lane ramp meter. Blue insulation color is used in this instance to make consistent use of the white striped conductors at the first signal. Utilize conductor numbers 5, 10, and 15 except for 4 lane configurations, which will make use of the White/Black conductor for the fourth yellow signal.

- **Green Indications** - Green insulation color. Utilize conductor numbers 4, 9, and 14 except for 4 lane configurations, which will make use of the Blue conductor for the fourth green signal.

Advance Flasher Assembly Cables
For advance flasher assembly cables, a single conductor is required to power the amber signal indications. A 5-conductor cable is typically used, and the orange conductor is used at all times. If a set of 2 advance flasher assemblies are wired independently, or are jumpered together, the orange conductor is still maintained throughout the cable(s), since the conductor is landed on the same output in the controller cabinet.

A 5-conductor cable is also used for overhead advance warning signs used in system connector ramp meter design. Since most of these signs are placed farther in advance of the ramp meter than with advance flasher assemblies, the cable gauge becomes crucial. If the distance between the controller cabinet and sign exceeds 1000-ft, additional electrical equipment (such as a relay assembly) may be required. Design of this equipment should be coordinated with and reviewed by the State Electrical Engineer.

Loop Detectors
Each loop detector reporting to the ramp meter controller cabinet requires a lead-in cable between the loop and the cabinet. A maximum of 48 detectors can be housed in a standard 2070 field cabinet.
Figure 5.3-8: Traffic Signal Wiring Diagram Example
Electrical service
The power distribution wires running between the electrical service and the controller cabinet consists of stranded copper single conductors, cross-linked polyethylene (XLP), USE rated. Section 655 of the standard specifications provides guidance on additional requirements. The bid items for Electrical Wire Traffic Signals (gauge #) AWG or Electrical Wire Lighting (gauge #) AWG will meet the requirements. The gauge of conductors must be calculated per the requirements of the National Electrical Code.

Consistent with the design practice recommended in the National Electric Code, the power distribution system should be designed for a maximum of a 3% voltage drop between the electrical service location, which may be a utility connection point or a dedicated circuit in an adjacent installation such as a lighting distribution cabinet, and the Ramp Meter or other field cabinet. When calculating the voltage drop, it is important that the ultimate potential power draw is considered. The sum of the size of the circuit breakers within the cabinet should be used as the potential draw. This will mean a 50-Amp power draw should be used as most ITS cabinets come with 2-25-Amp circuit breakers.

Depending on the availability and location of electrical service locations, these requirements may dictate the use of step-down voltage transformers adjacent to field cabinets. Refer to the SDD and specification for use of step-down voltage transformers.

Electrical Wire Routing
The conduit system for ramp meters should be bonded together, because power cables are running within the system. Bonding all metallic components of the system together assures that there will be no difference in voltage potential across two points in that system. In addition, grounded conductor should be run with current-carrying cables (such as traffic signal conductors, power distribution wires, etc.), which returns the circuit’s current at zero voltage. The bonding/grounding wires in system typically use Electrical Wire Traffic Signals 10 AWG and should be placed according to State Standard Specifications for electrical wiring. The gauge of grounded conductors must be calculated per the requirements of the National Electric Code. A conservative method is to use the same size as associated power conductors. There is a distinct method required for the bonding system.

There is a distinct method required for the bonding/grounding system. For the bonding system, the wire should be run from free standing item to free standing item (i.e., poles, cabinets, electrical services, where the wire is attached to the item’s grounding electrode), and then from the freestanding item to its nearest pull box. The conduit between the cabinet and nearest pull box also needs a run of wire. At pull boxes, the bonding wire is fastened to the pull box via a grounding lug, thereby grounding each pull box. Once all freestanding items have been bonded together, a bonding wire should be installed to the last pull box in the system. Bond pull box per SDD 9B4-9.

Bond and ground all conduit systems, since equipment is frequently added to various locations in the future. For assistance in bonding and grounding of underground systems, consult the State Electrical Engineer.

The grounded conductor only should be run with current-carrying (ungrounded) cables. Therefore, the grounded conductor will follow the exact same routing as described under “Stop Bar Cables” and “Advance Flasher Assembly Cables” described previously. The grounded conductor may be sized by individual circuit, or as a combination thereof. The gauge of grounded conductor required is also dependent on load as documented in the NEC. A conservative method is to use the same size as associated power conductors.
5.3.8 Ramp Meter Signing

Signing required for ramp meters is again dependent on the type of ramp meter being designed. Examples of different types of ramp meter signs are shown in Figure 5.3-10. Usage of these signs is explained as follows:

- **R10-6 (L or R)** - These signs are placed at the stop bar. In one, two, and three lane (median separated) metering, where side-mounted signals are used, these signs are fastened to the signal assembly. Under three-lane (no median separation) metering, a mast-arm is used for 2 lanes of signals, and the R10-6 sign on the mast-arm side is placed on a wood post.

- **R3-11 (MOD 4 & 5)** - The R3-11 HOV signs are placed on the ramp, typically near the “entrance” of the HOV lane. If the HOV lane exceeds 400 feet in length, a second R3-11 sign may be placed along the ramp as reinforcement of the lane restriction.

- **R3-10 (MOD and MOD 2)** - The R3-10 HOV signs are optional for ramp meter design. They are typically placed along the cross street, visible in advance of entering the lane. These signs warn the motorist that the ramp ahead has a restrictive lane. The SE Region has determined that R3-10 signs are not required for ramp meter operation. However, the designer should consult the appropriate Region signing representative to determine whether these signs are appropriate for ramp meters containing HOV priority lanes.

- **R10-10 (L, C, or R) (MOD)** - These signs are also used in conjunction with two or three lane metering, where signal assignment by lane is needed for proper ramp meter operation. In many instances, the operation of a ramp meter “staggers” metering, with the left lane green while the right and/or center lane signals remain red, and vice versa.

- **SP-11** - This sign is placed on the advance warning sign assemblies, and is accompanied by two yellow flashing beacons.

- **W4-2 (L or R)** - These signs are used in conjunction with two or three lane metering, where the ramp tapers down to one lane after the stop bar. The direction of the lane drop (i.e., the use of W4-2L or W4-2R) must match the direction of the taper on the ramp. These signs are typically placed between 75 and 100 feet downstream of the stop bar, depending on existing signing, overhead sign supports, beginning of taper, etc.
- **W9-1 (L or R)** - In the case of double tapers (e.g., tapers from 3 lanes to 1 from both sides of the ramp), a W4-2 sign is used on one side of the ramp, with a “RIGHT (LEFT) LANE ENDS” sign, W9-1, placed on the opposite side. This configuration is used in place of both W4-2L and W4-2R, which would give the indication that 4 lanes are narrowing to two lanes. The W9-1 sign should be placed on the side of the ramp with the HOV lane.

These signs are only signs typically associated with ramp metering, and do not include signing such as R1-2 (yield), R5-57 (pedestrians prohibited), or other signing that may be required for a particular ramp. All signing must also adhere to the Manual on Uniform Traffic Control Devices (MUTCD). Central office sign plates must be used, and all signing must be reviewed by and coordinated with the District Signing Engineer. Bid items for signing can be found in the Standard Specifications.

---

**Figure 5.3-10: Ramp Meter Signing**
Figure 5.3-11: 1-Lane Ramp Meter Signing Placement

Figure 5.3-12: 2-Lane Ramp Meter Signing Placement
5.3.9 Ramp Meter Pavement Marking

Pavement marking for ramp meters is dependent upon the type of ramp meter. All ramp meters must contain 4-inch epoxy edge-lines (yellow and white).

- **Epoxy, 4-inch Lane-Line** - A white, epoxy, 4-inch lane-line is used in a 12 ½ -ft marking, 37 ½ -ft spaced pattern to separate multiple SOV lanes on a ramp meter. Typically, only three to four “skips” are required just upstream of the stop bar, rather than dividing the SOV lanes along the entire ramp. By doing this, motorists establish a dual-lane queue at the stop bar, and other motorists will move into these two queues upstream. During free-flow conditions, however, multiple lanes are not established on the ramp. Where significant ramp curvature exists, this lane line may need to be extended further upstream along the ramp for safety considerations.

- **Epoxy, 18-inch Stopbar** - At all ramp meter locations, a white, epoxy, 18-inch stop bar pavement marking is required across the ramp at the location of the ramp meter signals.

- **Epoxy, 8-inch Channelizing Line** - For ramp meters containing an HOV lane without physical (i.e., median) separation between the SOV lane, a white, epoxy, 8-inch channelizing line is required from a point just downstream of the ramp entrance to the stop bar. The location of the beginning of this channelizing line must allow ample sight distance to the HOV lane to allow motorists to make the appropriate lane change.

- **Wet Reflective Tape** – For entrance and exit ramps, place 8” wet reflective tape in the gore area. Refer to SDD 15C 8-f.

- **Epoxy, 8-inch Channelizing DOT Pattern** - At the “entrance” of the HOV lane, a white, epoxy, 8-inch “skip” line is used in a 5-ft marking, 5-ft spaced pattern. This marking is established from the beginning of the channelizing line, and angled upstream and across the ramp to the edge of pavement. When a high-occupant vehicle enters the HOV lane, it crosses the skip line. HOV skip lines typically run between 75-ft and 100-ft in length, dependent upon width of the HOV lane and ramp alignment.

- **Epoxy, HOV Symbols** - For the length of the HOV lane, white, epoxy, “diamond” symbols are spaced 100-ft apart. A symbol must be within 30-ft of the stop bar. The 100-ft spacing may be shortened between symbol nearest to the stop bar and the symbol immediately upstream to maintain this requirement. HOV symbols serve as a Regional reinforcement of usage of the lane.

The HOV symbol can be found in SDD 15C 7-a. The 8-inch channelizing lines require construction details.
Figure 5.3-14: Ramp Meter Pavement Marking Details

LEGEND
(1) PAVEMENT MARKING, EPOXY, 4-INCH WHITE
(2) PAVEMENT MARKING, EPOXY, 4-INCH YELLOW
(3) PAVEMENT MARKING, CHANNELIZING, EPOXY, 8-INCH
(4) PAVEMENT MARKING, CHANNELIZING, EPOXY, 8-INCH HOV SKIP LINE (5 FT-5 FT PATTERN)
(5) PAVEMENT MARKING, EPOXY, HOV SYMBOL
(6) PAVEMENT MARKING, EPOXY, 4-INCH LANE LINE (12.5 FT-37.5 FT PATTERN)
(7) PAVEMENT MARKING, STOPBAR, EPOXY, 18-INCH

Figure 5.3-15: 1-Lane Pavement Marking Requirements
Figure 5.3-16: 2-Lane Pavement Marking Requirements

Figure 5.3-17: 3-Lane Pavement Marking Requirements
5.3.10 Ramp Lighting

Ramp lighting is required for every ramp meter. The stop bar area must be lighted, and static signing and pavement markings must be visible under all lighting conditions. WisDOT roadway lighting guidelines can be found in Section 11-50-15 of the *Facilities Design Manual*. Ramp lighting must also be coordinated through the Region’s Highway Lighting Engineer. To avoid delays in design, notify the Highway Lighting Engineer early in the design process to complete the lighting design and establish review submission due dates.