SECTION 12

TRAFFIC SIGNAL DESIGN

12-01 GENERAL

This section of the manual is intended for use as a guide in the planning and design of the electrical portion of a traffic signal installation that conforms to Department policy. It will provide a means of developing uniformity in the design and plan preparation of traffic signals. The term "traffic signals" can include many types of control signals: pedestrian signals, lane-use control signals, hazard identification beacons, school sign flashing beacons, moveable bridge signals, priority control signals, and railroad pre-emption. However, certain general design criteria can be applied to all traffic signals.

Complying with all of the design criteria is sometimes difficult. It will require some judgment on the part of the designer to draw the necessary balance. However, it is necessary that the criteria be followed as closely as possible in order to achieve uniformity of traffic signal design. It is recognized that situations will occur where good engineering judgment dictates deviation from this Department policy. Any such deviation shall be detailed in writing and submitted for approval to the Manager in the Office of Traffic Signal and Safety Engineering.

It is not the intent of this section to reproduce all the information that is adequately covered by textbooks and other publications that are readily available to the designer. This section, when used in conjunction with engineering knowledge of traffic signal design and good judgment, should enable the designer to perform their job more efficiently.

The terminology used in this section, unless stated otherwise, is as defined in the current addition of National Electrical Manufacturers Association (NEMA) Standard Publication No. TS-1, Part 1, entitled, "Traffic Control Systems".

12-02 REFERENCE PUBLICATIONS

- FHWA *Manual on Uniform Traffic Control Devices* (MUTCD)
- ITE *Transportation and Traffic Engineering Handbook*
- FHWA *Traffic Control Device Handbook*
- ITE *Manual of Traffic Engineering Studies*
- ITE *Manual of Traffic Signal Design*
- SPECIFICATIONS:
  - NJDOT *Standard Specifications for Road and Bridge Construction*
  - NJDOT *Supplemental Specifications*

- NJDOT *Special Provisions*

- NJDOT *Standard Electrical Details*
- NJDOT *Electrical Material Specifications*
- NFPA *National Electrical Code* (NEC)
- AASHTO *Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals*
- NJDOT *Procedures Manual*
- NJDOT *Sample Plans*
- NJDOT *CADD Manual*
- OSHA *Code of Federal Regulations Title 29, Part 1926*

All publications shall be the latest edition.

12-03 GENERAL DESIGN CRITERIA

12-03.1 Warrants for Traffic Signals

All traffic signal installations must be warranted in accordance with the MUTCD. The Traffic Signal and Safety Engineering Unit is responsible for review and approval of the traffic signal warranting analysis. The designer shall have the Office of Traffic Signal and Safety Engineering's approval for the design prior to starting the actual electrical design of the traffic signal.

12-03.2 Traffic Signal Controller

The current Department standard is an eight phase fully actuated traffic signal controller. The controller is a microprocessor based digital unit with dual ring quad left or sequential operation, as specified in the current NJDOT Specification Nos. EB-TSC-ITB-8 and EB-TSC-8CL.

The designer shall review the timing sequence to insure that an eight phase traffic signal controller can perform it. The controller shall not require external timers or timing relays to perform the timing sequence. The designer shall, in all cases, consider and utilize the overlapping pedestrian movement or concurrent traffic movements. The timing schedule shall be on a separate plan sheet.

The controller is the most important component of the traffic signal; therefore, the designer must use extreme care in choosing a location for the controller at the intersection. As a minimum, the following criteria shall be adhered to:

1. The controller shall be offset as far as possible from the traveled roadway within the right-of-way, allowing adequate work area for maintenance.

2. The controller location shall provide the maintainer the best possible visibility of the signal indications when working on the cabinet.

3. The controller location shall be the least vulnerable to vehicular accidents and shall not restrict sidewalk areas.

12-03.3 Traffic Signal Standards

Types, designs and certain typical installation details for traffic signal standards and their foundations are included in the NJDOT *Standard Electrical Details*.

Traffic signal standards and transformer bases shall be of aluminum alloy to support traffic signal mast arms with a length of 25 feet or less. When the mast arm exceeds 25 feet, the traffic signal standard shall be steel. They shall be mounted on foundations as follows:

Traffic Signal Standard	Foundation
Type "C"	Type "SFT"
Type "K"	Type "SFK"
Type "S"	Type "STF"
Type "T"	Type "SFT"
Type "SC"	Type "STF"

Foundation Type "SFX" shall be installed in center barriers only and shall be used in special cases only. The designer must justify its use and obtain approval in writing. In conjunction with the installation, a small transformer base, Part No. NJTB-30 as shown on NJDOT *Standard Electrical Details* No. L-1501, shall be used. The Traffic Signal Standard Type "C" shall also be used when 12" signal face(s) of three sections or more are suspended at the end of the mast arm to obtain the minimum roadway overhead clearance.

When 12" signal face(s) of four sections or more are suspended at the end of the mast arm, the Traffic Signal Standard Type "T" shall not be used. The roadway overhead clearance of the signal head shall be examined and calculated when a traffic signal standard, particularly Type "T", is installed at the low side of a banked section of roadway.

When a single free swinging indication is to be installed at the end of a mast arm, an aluminum signal head shall be used.

Traffic Signal Standard Type "K" shall be used for 25 foot mast arms.

The designer is responsible for loading calculations necessary to verify that the standard and arm will support the signal indications and signs. When the loading of a traffic signal standard or traffic signal arm is approaching its limit, a warning note "consult Traffic Signal & Safety Engineering for additional load" shall be shown near the installation on the plan.

Mast arm signs shall be free swinging in accordance with the standard details.

Traffic signal standards shall be located as follows:

1. The minimum offset shall be 32" from face of curb or edge of pavement to center of the standard.

2. Steel traffic signal standards should be located as far off the roadway as possible. A minimum of 5 feet from the face of the curb to the center of the steel traffic signal standard should be maintained.

3. Traffic signal standards shall not be located in areas of handicap ramps nor shall they obstruct the crosswalks.

4. Traffic signal standards, where feasible, shall also be used to support pedestrian signals and push buttons.

5. Traffic signal standards shall not be located on the traffic side of (in front of) the guide rail or any natural or manmade deflecting barrier. The location should provide the distance necessary for rail deflection when struck and a reachable distance for pedestrians to push the pedestrian push button. Exceptions on a case by case basis may be made only with approval of the Electrical Engineer in the Office of Traffic Signal and Safety Engineering.

6. Traffic signal standards shall not be located near the curve of:

   A. A corner with a radius of less than 15 feet, or;

   B. A corner with a radius of less than 30 feet provided where trucks and buses turn right occasionally, or;

   C. A corner with a radius of less than 50 feet provided where large truck combinations and buses frequently turn right.

7. The designer is responsible for locating and identifying the horizontal and vertical clearances of the utility companies primary (750 volts or more) and secondary power lines and shall assure that the minimum clearances are in accordance with the NEW JERSEY ADMINSTRATIVE CODE CHAPTER 25 UTILITY ACCOMMODATION, Section 16:25-5.3 (c) and Section 10 of the NJDOT *Procedures Manual*. The designer shall coordinate the electrical design work with the present and future plans of the utility companies. All overhead and underground utilities must be shown on the plans. There shall be no conflicts with the lighting installation. See Figure 11-C.

12-03.4 Traffic Signal Indications

The location and type of indications shall be approved and/or determined by the Traffic Engineer in the Office of Traffic Signal and Safety Engineering. The Department currently maintains the following signal indications:

Type	Specification No.
Polycarbonate 8" Signal Head	EB-TS-1
Polycarbonate 12" Signal Head	EB-TS-1
Aluminum 8" Signal Head	EB-TS-1A
Aluminum 12" Signal Head	EB-TS-1A
12" Fiberoptic Bi-modal Arrows	EB-TS-3
Pedestrian Signal	EB-PS-1
Optically Programmed	EB-TS-2
8"/12" Red LED Module	EB-REDLED-TSM
8"/12" Green LED Module	EB-GRNLED-TSM
12" Bi-Modal LED Module	EB-LED-BTAM
12" GRN, AMBER,RED LED Arrows	EB-LED-GARTAM

12-03.5 Intersection Lighting

Intersection lighting shall be included as part of the traffic signal design at all signalized intersections and shall conform to Section 11-08, "Lighting At Intersections". The intersection lighting shall be installed on Traffic Signal Standards, Type "C", Type "SC", or Type "K" with a "KE" extension.

12-03.6 Conduits

Rigid metallic conduits, 3" in diameter, shall be used throughout for all traffic signal circuits. Conduits for loop detector cables shall be 1-1/2" in diameter. Conduits for overhead electrical services and telephone services shall be 2" in diameter or as required by the utility company. Consult the utility company for any special requirements. Typical details regarding conduit installations are included in the standard electrical details.

Rigid nonmetallic conduits (RNMC) may be used for interconnect conduits between intersections or for conduits to control "Red Signal Ahead" signs. A ground wire shall be installed.

Multiple runs of conduits shall be placed in a common trench. When they are installed in a common trench cut in an existing roadway, only one conduit shall be classified as type CUR. All others shall be classified as type CUG.

Conduits installed under existing concrete sidewalk or bituminous concrete shall be classified as type CUR.

When a conduit run is installed as a combination of type CUG and type CUR, both construction items shall be indicated on that run. The construction quantities of each item shall be calculated.

12-03.7 Cables and Wires

All cables and wires, including neutrals, to be used for traffic signal circuits and incoming secondary service shall conform to the SPECIFICATIONS and shall be fully color coded. The designer shall provide a block wiring diagram as shown on NJDOT *Sample Plans* E-2 and E-3. The block wiring diagram shall indicate the cable letter for each cable extending from the controller to the base of the traffic signal standard. The letters shall be assigned sequentially to cables terminating at the far corner first, then to cables terminating at the next corner as the first group passes through (east corner then north corner; south corner then west corner, as shown in the NJDOT *Sample Plans* E-2 and E-3). The designer shall calculate the wire fill of all conduits to insure conformance to the *National Electrical Code*. The following cable areas shall be used:

Cable	Cross Sectional Area
10/C #14	0.322 sq. in.
5/C #14	0.166 sq. in.
2/C #14	0.68 sq. in.

All the Department's solid state controllers with solid state load switches are also equipped with conflict monitors. In order for the monitor to perform correctly, it is important that a separate neutral be provided for each phase and overlap of the vehicular signals.

The designer shall provide sufficient wire from each traffic signal standard to the controller; however, in order to avoid a redundancy in the wiring system, the following traffic signal faces may be wired in parallel in the base of an individual traffic signal standard:

1. Traffic signal faces of a main street or side street on the same phase, provided there is exclusive left turn signal phase.

2. Traffic signal faces of a minor side street, provided they are on the same phase and most likely they will not be on separate phases or will not have an exclusive left turn phase in the future.

The signal cable shall then be brought directly to the controller. The designer shall observe the following criteria:

1. All vehicular indications shall be wired on a 10/C #14 cable. A 5/C #14 may be used when only one indication is on the pole.

2. All pedestrian indications shall be wired on a 5/C #14 cable.

3. All push buttons shall be individually wired on a 2/C #14 cable.

4. All loop detectors shall be wired with a 2/C (twisted pair) #14 cable. Each loop detector shall have its own twisted pair of detector lead-in wires and shall be connected separately to a channel of the detector unit.

5. Each traffic signal circuit of a load switch must be less than 10 amperes; calculations should be provided for the circuits of more than 7 amperes.

6. Lighting circuits installed as part of the traffic signal installation shall utilize the same conduit system as the traffic signal circuits and conform to Section 11, "Roadway Lighting Systems". The wire size shall be #8 AWG or as required.

12-03.8 Vehicular Detection

The Department installs inductive loop detectors (ILD) as the primary type of detection. A series of short loops shall be installed to cover the area of detection determined by the traffic engineer. Other types of detectors are used only in areas where the loops could not be installed, such as a steel bridge deck.

The installation of inductive loop detectors shall conform to the following guidelines:

1. Under normal conditions a diamond shaped loop, which is approximately 6' x 6' in the direction of travel, shall be utilized to cover the area of detection. The largest loop shall be no greater than 6' x 18'.

2. Loops directly behind the stop line shall always be designed as small as possible to guarantee the detection of motorcycles stopped directly behind the stop line. See Figure 12-B.

3. The designer should first try to use a series of four short loops. Where the area of detection cannot be covered with a four-loop layout, additional loop(s) should then be considered as shown in Figures 12-A through 12-D.

4. The longitudinal spacing between two loops shall be in the range of 5 feet to 16 feet. The spacing shall decrease gradually as a vehicle approaching the intersection reduces its speed.

5. Except in areas of parking, the side edge of a loop shall have a lateral spacing of 3 feet from a curb or pavement edge and 3 feet from a painted double yellow line or a white line.

6. Under normal conditions the front edge of the loop immediately behind the stop line shall be no more than 2 feet from the top of the stop line. The maximum spacing between loops adjacent to the stop line shall be 5 feet. A spacing of less than 5 feet for these loops may be used to meet the requirements set forth in the next item (7.).

7. The distance from the front edge of the area of detection to the intersection shall be as shown on Figures 12-A through 12-D. In the case of a skewed intersection, the dimension shall be measured perpendicular from the extension of the curbline to the front loop. In no case shall any portion of the loop extend beyond the extended curbline into the intersection area. In some cases, depending upon the skew angle, a supplemental loop should be required to insure that vehicles overriding the stop line will not leave the area of detection.

8. When a loop is used mainly as a system loop or a dual function loop (local intersection detection and system detection), it shall be a 6' x 6' rectangular shaped loop and installed in the center of the traveling lane in which volume counts are to be taken.

9. A force-off loop and motion loop shall be of rectangular shape and installed at locations determined by the traffic engineer.

10. All loops shall be identified alphabetically and in sequence as a vehicle approaches the intersection.

The designer shall field check each intersection to select proper loop locations. This field check shall consider driveway locations, pavement conditions, manhole locations, width and skew of the roadway, power sources and other electrical equipment that will interfere with proper loop operation.

In summary, the final decision concerning the size, shape, spacing and location of loop detectors for proper traffic control is a combination of analytical procedures and application of good engineering judgment.

When detection is needed on bridges, the use of probes, preformed loops, microwave, video and infrared detectors shall be investigated.

12-03.9 Junction Boxes

18" x 36" junction boxes shall be used for the traffic signal.

17" x 30" junction boxes may be used only for loop wires and loop detector lead.

Junction boxes shall not be installed in handicap ramp areas. The placement of junction boxes should also avoid sidewalk areas whenever possible.

In order to facilitate cable pulling and splicing, a junction box shall be installed adjacent to traffic signal standard(s), the controller, loop detectors and at each end of conduit crossings under roadways.

The location of conduit crossings should be so arranged that the junction boxes at terminals of such conduits could also be used as service points to the above noted facilities. Junction boxes are designed to accept a maximum of six conduits. In cases where the number of conduits and cables are in excess of the junction box capacity, except in front of the controller where two junction boxes may be installed, the design should be re-examined.

12-03.10 Incoming Service

The secondary service, obtainable from the local utility company's pole or manhole, shall be used to service the complete installation at each intersection. Standard services shall be single phase, 3-wire, 120/240-volt, #6 AWG wire shall be installed. When service is obtained from a manhole, the designer shall consult the utility company for the size, location, material and termination of the service conduit, and the installation of the service wire, which usually is provided by the utility company.

The designer shall prepare a written preliminary request for service to the local utility company indicating the required service and obtain their written approval including any utility company assigned request number. Information on the continuous load and payee of the energy charge shall also be provided in the letter.

12-04 EXISTING TRAFFIC SIGNAL

When an existing traffic signal is affected by the construction, they shall be revised as follows:

1. Where possible, all existing equipment should be left in place while the proposed signal is constructed. The designer shall provide a scheme of the construction to verify that the equipment can be left in place. A scheme shall be provided for each stage of construction, which includes detailed temporary wiring and any safety protection, if required.

2. A temporary signal shall be included in the contract whenever an existing signal must be removed prior to the completion of the new signal.

3. If a signal is being removed as part of the design and not replaced, the designer shall indicate the stage of construction that the signal will be removed.

4. When an existing signal is part of a “system”, the ITS Engineering Unit shall also be notified and the system aspect of the signal shall be their responsibility.

12-05 TRAFFIC SIGNAL DESIGN CONSIDERATIONS

The designer shall investigate and provide a report of a total system design concept in each project. The Department currently utilizes several types of traffic signal systems as follows:

1. Closed Loop - continually monitoring a minimum of 30 local intersection operations and system performance. The system is also capable of traffic responsive operation and providing maintenance reports.

2. Time Base - Time base coordination, when installed at a group of intersections, provides a coordinated system without the use of interconnecting cables.
3. Isolated Intersection Control - Isolated intersection control is only utilized when coordination is not required.

4. When the design of a project includes the installation or modification of a computerized closed loop traffic signal system, the ITS Engineering Unit shall be contacted for the proper system design criteria.

12-06 TRAFFIC SIGNAL PLANS

All plans shall be completed in accordance with Section 16.4 and 16.6 of the NJDOT *Procedures Manual*.

12-07 TEMPORARY TRAFFIC SIGNALS

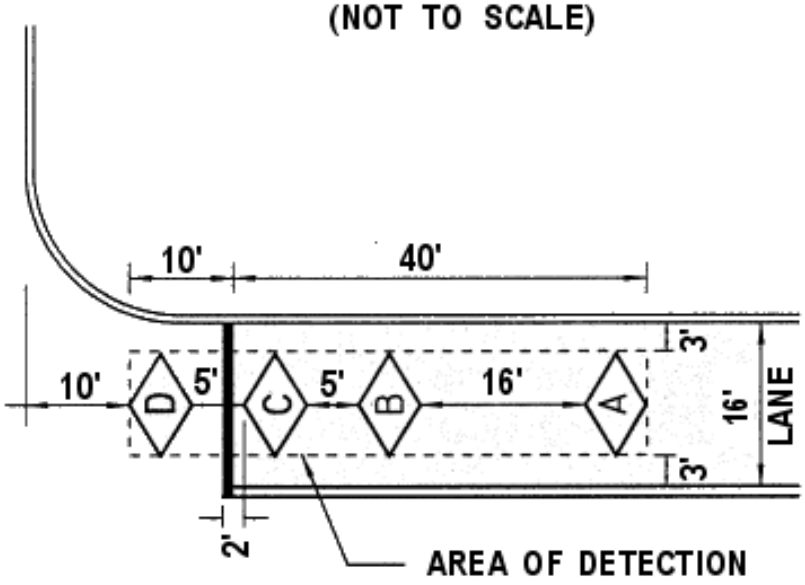
If during the reconstruction of the roadway, an existing traffic signal can no longer adequately control the intersection or the stage construction warrants a traffic signal to safely control traffic, a temporary traffic signal shall be provided for in the plans (NJDOT *Sample Plans* E-4).

The designer shall provided plans, timing, details and certified structural calculations supporting the design and the material to be used. The certification shall be by a Professional Engineer licensed in the State of New Jersey. The plans shall take into consideration the construction staging and any adjustments to the temporary traffic signal system shall be shown.

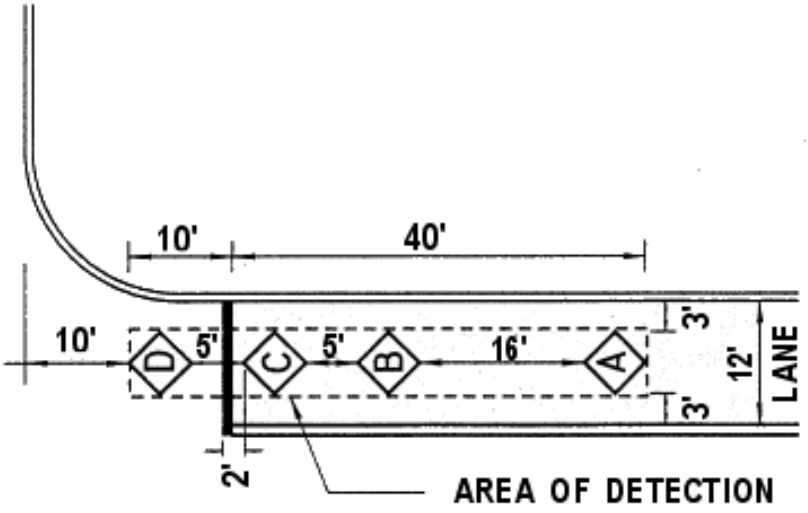
LOOP LAYOUT SINGLE LANES - 12' & 16'

FIGURE 12-A
BDC00MR-4

(NOT TO SCALE)



A - 6' x 10'
B - 6' x 10'
C - 6' x 10'
D - 6' x 10'



A - 6' x 6'
B - 6' x 6'
C - 6' x 6'
D - 6' x 6'

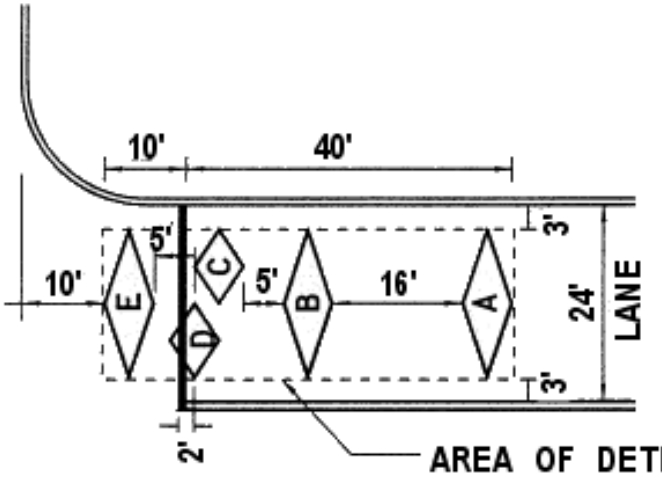
NOTE: ALL LOOP DIMENSIONS ARE NOMINAL.

12-11

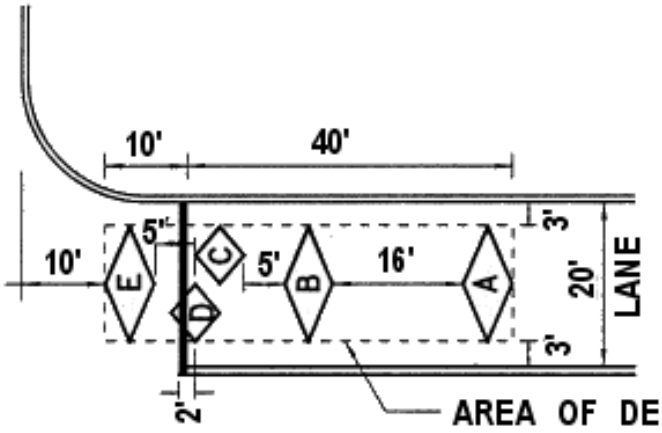
LOOP LAYOUT SINGLE LANES - 20' & 24'

FIGURE 12-B
BDC00MR-4

(NOT TO SCALE)



A - 6' x 18'
B - 6' x 18'
C - 6' x 9'
D - 6' x 9'
E - 6' x 18'



A - 6' x 14'
B - 6' x 14'
C - 6' x 7'
D - 6' x 7'
E - 6' x 14'

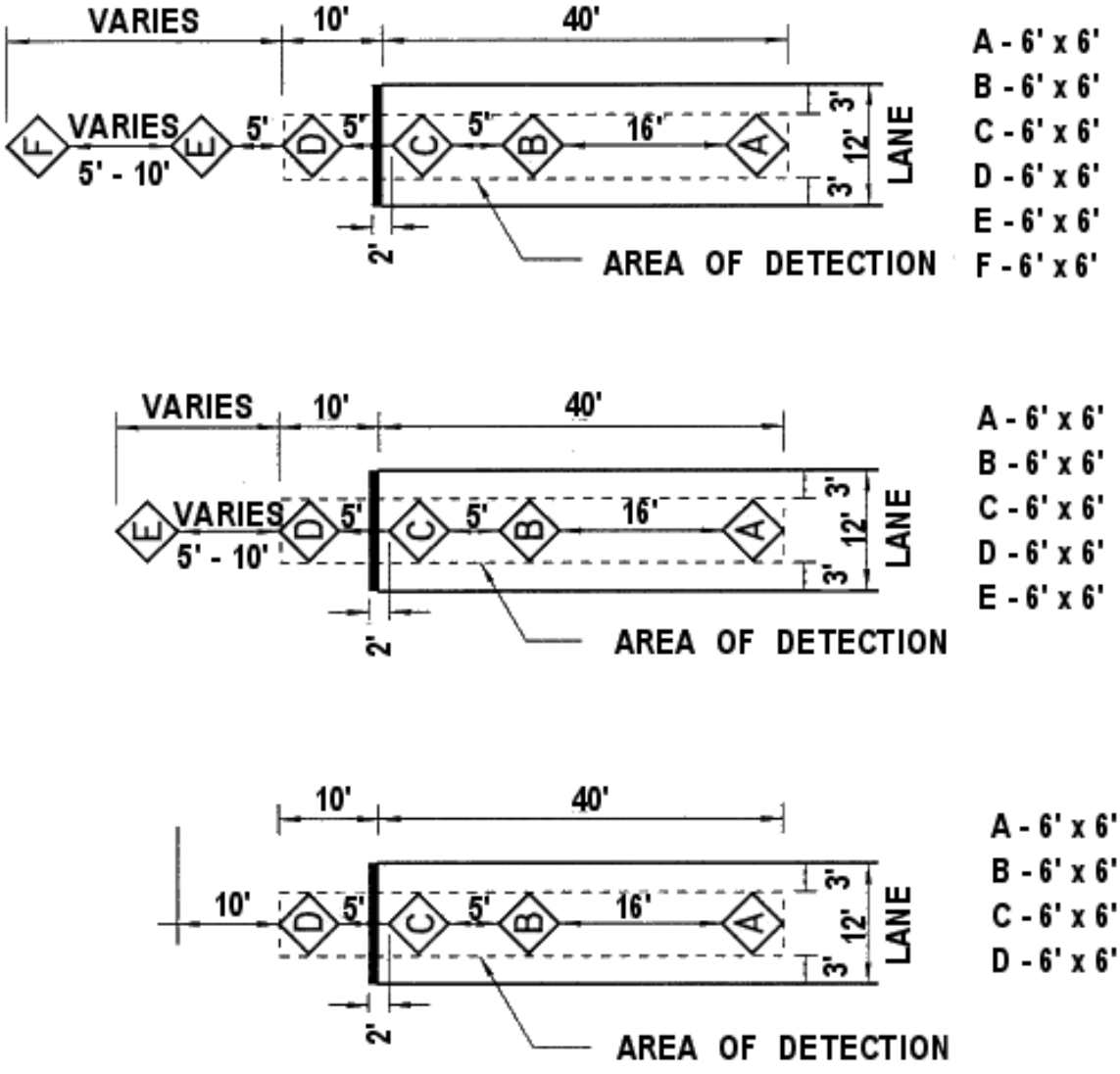
NOTES:
1. ALL LOOP DIMENSIONS ARE NOMINAL.
2. THE DIMENSION FROM THE TOP OF LOOP D TO THE BOTTOM OF LOOP E IS 2'.

12-12

LOOP LAYOUT LEFT TURN LANE

FIGURE 12-C
BDC00MR-4

(NOT TO SCALE)



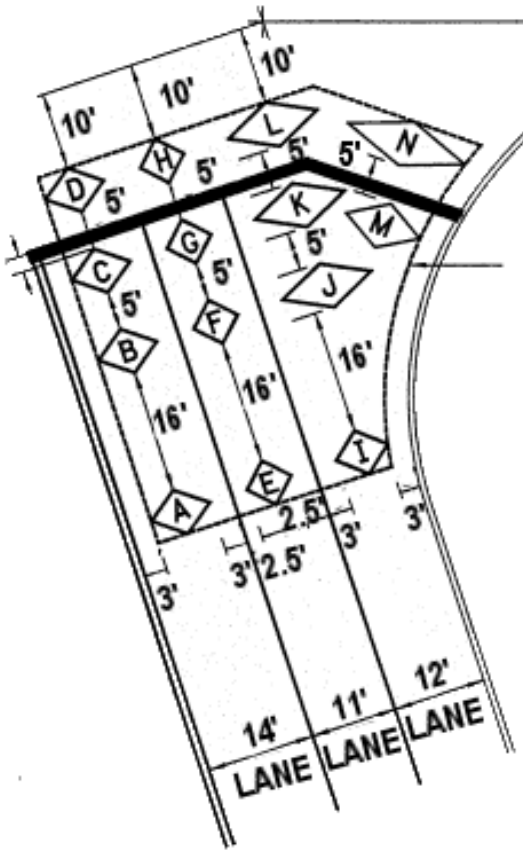
NOTE: ALL LOOP DIMENSIONS ARE NOMINAL.

12-13

LOOP LAYOUT

FIGURE 12- D
BDC00MR-4

(NOT TO SCALE)



AREA OF DETECTION

A - 6' x 8'
B - 6' x 8'
C - 6' x 8'
D - 6' x 8'
E - 6' x 6'
F - 6' x 6'
G - 6' x 6'
H - 6' x 6'
I - 6' x 6'
J - 6' x 12'
K - 6' x 12'
L - 6' x 12'
M - 6' x 7'
N - 6' x 16'

NOTE: ALL LOOP DIMENSIONS ARE NOMINAL

12-14