

# Arizona Department of Transportation

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Systems Technology Group

## Intelligent Transportation System Design Guide



March 2019

# Arizona Department of Transportation

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## Systems Technology Group

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March 2019

Previously Published as “Intelligent Transportation System Design Guide 2015 and 2018”, and  
“Freeway Management System Design Guidelines 1989, 1994, 1999, 2002, 2007, and 2009”

***CONTRIBUTIONS AND ACKNOWLEDGEMENTS***

The 2019 Intelligent Transportation System (ITS) Design Guide is the result of the coordinated efforts of many groups, research organizations, and government agencies. The 2019 ITS Design Guide was prepared for ADOT by a committee representing ADOT stakeholders and the design consultant community.

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# Chapter 1 Introduction

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Intelligent Transportation Systems (ITS) include both rural and urban highways. ITS deployments on urban highways in Arizona are called the Freeway Management System (FMS). In rural and non-freeway areas, deployments may be referred to as ITS for a group of applications, or the specific application such as DMS (Dynamic Message Sign). This Design Guide provides direction to Designers for ITS that feeds ADOT's Traffic Operations Center (TOC).

## 1.1 Purpose of the ITS Design Guide

This guide is to assist Designers to incorporate the basic elements of ITS in their design documents and to facilitate the ongoing implementation of ITS, especially ITS equipment that communicates with ADOT's Traffic Operations Center.

This guide is neither a standard nor substitute for engineering experience, skill, knowledge, or judgment. Actual conditions require the use of engineering judgment in using the direction contained in this guide. This guide is not a substitute for formal documents binding to a Contractor, who physically constructs the system.

At the beginning of a new project, a designer shall complete a review of record drawings and a field review. The record drawings review shall identify projects already completed in the limits of the new project. The field review shall identify the types and locations of existing ITS equipment as a first step to determine what ITS equipment should be added within the new project. The designer shall look ahead at future projects (such as adding lanes or pavement preservation) identified in ADOT's Five Year Plan for impacts to the new project.

All longitudinal projects throughout the state as opposed to spot improvement projects shall add conduit and fiber going forward.

The designer shall use record drawing reviews and field reviews when preparing scoping documents and design phase submittals. For project management direction see ADOT's Project Management Group and Project Resource Office.

The designer shall work with various sections, groups, and entities, that may have jurisdiction or interest during the ITS/FMS design process, such as:

Internal ADOT stakeholders

Bridge Group  
Contracts and Specifications  
Districts  
Engineering Consultants Section  
Environmental Planning  
Geotech  
IDO Division (Infrastructure Delivery and Operations)  
Information Technology Group  
JPA Section (Joint Project Agreement)  
Multimodal Planning Division Traffic Monitoring  
Operational Traffic and Safety Group  
Procurement  
Project Management Group  
Project Resource Office  
Local Public Agency section  
Regional Traffic Engineers  
Right-of-Way Group  
Roadside Development  
Roadway Engineering  
Systems Maintenance Group  
Systems Technology Group  
TSMO Division (Transportation Systems Management and Operations)  
Traffic Group  
Traffic Management Group  
Utility & Railroad Engineering  
Vision Field Office

External stakeholders

BLM (Bureau of Land Management)  
Cellular providers for DMS communication  
Counties, towns, and cities  
DPS Wireless Systems Bureau  
FAA (Federal Aviation Administration)  
FHWA (Federal Highway Administration)  
Homeland Security  
Local Public Agency  
MAG (Maricopa Association of Governments)  
Maricopa County Flood Control District  
Municipal Planning Organizations and Councils of Governments (MPO's and COG's)  
National Forest Service  
PAG (Pima Association of Governments)  
Railroads  
State Lands  
State Parks  
Tribal lands within or adjacent to project  
Utilities

## 1.2 ITS Goals and Objectives

ADOT operates an expanding Freeway Management System in the urban areas of Phoenix and Tucson, as well as a vast array of intelligent transportation devices in rural Arizona. Goals of ITS on rural highways and FMS (a subset of ITS) in urban highways include:

- maximizing the operational safety and efficiency for the traveling public
- providing motorists, MPOs, counties, and cities with relevant traffic information
- reducing secondary collisions
- operating a system that provides a service and builds credibility with the public

The specific benefits of the Freeway Management System for the motoring public include:

- Reducing environmental impact
- Reducing fuel consumption
- Enhancing productivity
- Saving lives through emergency response
- Integrating regional traffic management systems
- Centralizing management of the freeway system
- Providing advance warning information for the traveling public

ITS and FMS reduce the impacts of congestion. Congestion occurs when the demand exceeds the capacity, or when capacity is reduced. Congestion occurs when the capacity of the travel lane is reduced by:

- crashes
- disabled vehicles
- debris
- adverse weather
- construction
- maintenance
- special events

The designer shall provide communications redundancy for all FMS (urban freeway ITS). Preferred redundancy is accomplished through a physical dual fiber-optics trunkline system. Another redundancy option is a technological alternate path, such as an alternative looped freeway conduit path, using wireless communications and/or Ethernet Based Internet Protocol (IP) technologies. If the designer is not versed in communications technologies, including fiber-optics, wireless and Ethernet Based Internet Protocol (IP) technologies, then the designer shall add a professional who is, to the design team.

## 1.3 ADOT Regional Connectivity Networks

In the two largest metropolitan areas of the state, ADOT facilitates the sharing of information between ADOT and local agencies by promoting regional connectivity, as shown in Table 1.1. The ADOT FMS and



local jurisdictions ITS systems share agreements, which are established through ADOT’s Joint Project Agreements Section in the form of a Joint Project Agreement (JPA) or Intergovernmental Agreement (IGA). Additional network documents are available at the respective websites of the Maricopa Association of Governments and Pima Association of Governments.

**Table 1.1 ADOT Regional Connectivity Networks**

METRO AREA	ACRONYM	NAME
Phoenix	RCN	Regional Community Network
Tucson	RTDN	Regional Transportation Data Network

## 1.4 Using ITS Design Guide with Other Documents

The designer shall follow this *ITS Design Guide* and the latest version of several web published ADOT references, including, but not limited to:

- Applicable Stored Specifications
- Arizona Statewide ITS Architecture
- Bridge Group Standard Drawings
- Design Procedures Manual
- Dictionary of Standardized Work Tasks
- DMS Masterplan
- FMS Communication Masterplan
- ITS Standard Drawings
- ITS Test Forms
- Predesign Guidelines
- Project Management Manual
- Local Public Agency Project Management Manual
- Ramp Metering Design Guide
- Roadway Design Guidelines and Construction Standard Drawings
- Standard Specifications for Road and Bridge Construction
- Systems Engineering Checklist (if federally funded)
- Traffic Signal and Lighting Standard Drawings\*

The designer shall consult ADOT Systems Technology Group prior to each submittal for recent ITS developments not yet adopted within these published documents.

\*ADOT’s Traffic Engineering publishes the *Traffic Signals and Lighting Standard Drawings*. These standard drawings contain several standards that may appear to duplicate ITS Standard Drawings. Use the *ITS Standard Drawings* in place of the *Traffic Signals and Lighting Standard Drawings* for ITS applications.

Other applicable references that the designer shall follow include, but are not limited to:

- Federal NEPA Guide
- MUTCD (Manual of Uniform Traffic Control Devices)
- NEC (National Electric Code)

## 1.5 Acronyms

**Table 1.2 Acronyms**

ACRONYMS	DESCRIPTION
AASHTO	American Association of State Highway and Transportation Officials
ADOT	Arizona Department of Transportation
APL	Approved Products List
AQD	Advance Queue Detector
ARC-IT	Architecture Reference for Cooperative & Intelligent Transportation
ASTM	American Society for Testing and Materials
ATOC	Alternative Traffic Operations Center
AV	Automated Vehicle
CCTV	Closed Circuit Television Camera
CLSM	Controlled Low Strength Material
CV	Connected Vehicle
dB	Decibals
DCR	Design Concept Report
DMS	Dynamic Message Sign
DPS	Department of Public Safety
E2C2	Estimated Engineering Construction Cost
FMS	Freeway Management System
GIS	GEOGRAPHIC INFORMATION SYSTEM
Gbps:	Gigabits per second
HDD	Horizontal Directional Drilling
HDPE	High Density Polyethylene
HVAC	Heating, Ventilation, and Air Conditioning
IDO	ADOT Infrastructure Delivery and Operations
IMSA	International Municipal Signal Association
IP	Internet Protocol

ACRONYMS	DESCRIPTION
ITG	Information Technology Group
ITS	Intelligent Transportation Systems
LED	Light Emitting Diode
MAG	Maricopa Association of Governments
MUTCD	Manual on Uniform Traffic Control Devices
NEC	National Electric Code
NTCIP	National Transportation Communications for ITS Protocol
Node	Communications hub for communication equipment and termination of trunkline fiber-optic cables, house inside a climate controlled secure building.
OTDR	Optical Time Domain Reflectometer
OSP	Outside Plant
PA	Project Assessment
PAG	Pima Association of Governments
PEP	Product Evaluation Program
PM	Project Manager
PS&E	Plans, Specifications, and Estimates
PVC	Polyvinyl Chloride
RAD-IT	Regional (meaning Statewide in ADOT's case) Architecture Development for Intelligent Transportation
RCN	Regional Community Network (Phoenix Metro Region only )
RMC	Rigid Metal Conduit
RTDN	Regional Tucson Data Network (Tucson Metro Region only)
SDR	Size Diameter Ratio
SI	System Interchange (Freeway to Freeway)
SMFO	Single-Mode Fiber-optic
TI	Traffic Interchange (Crossroad)
TOC	Traffic Operations Center
TSMO	Transportation System Management and Operations
UPS	Uninterruptible Power Supply
VAC	Volts – Alternating Current
VDC	Volts – Direct Current

# Chapter 2 Freeway Management System (FMS), Urban Freeway ITS

Key FMS field equipment and elements discussed within this guide include:

- Closed-circuit television (CCTV) cameras
- Communications System, interconnecting devices to the Traffic Operations Center (TOC) and others
- Detection system for mainline and on-ramp
- Dynamic Message Signs (DMS)
- Ramp Meters (See the Ramp Metering Design Guide)
- Traffic interchange signals (may need to coordinate with other stakeholders)
- Node buildings
- Wrong Way Detection

ADOT field equipment connected to Traffic Monitoring Group includes WIM (Weigh-in-Motion) and ATR (Automated Traffic Recorder) count stations throughout the state; while pump stations and irrigation controllers are connected to District Maintenance and District Landscape. Additional planned and existing equipment may be identified in the Arizona Statewide ITS Architecture 2018.

## 2.1 Emerging Technology

Newer technology must work with *legacy* technology. Legacy describes technology that was the design practice when installed. The need for consistency throughout the system is sometimes challenged by the need to improve it. This Guide attempts to offer the designer a framework that offers consistency and flexibility for improvement. The designer should be familiar with:

- Existing Infrastructure of FMS devices and load centers
- Fiber and splicing details
- Scope of the project
- FMS field elements
- Connectivity between the field elements and their users

Input from Systems Maintenance, Traffic Management, District, and other end users help to determine scope for design.

Emerging products for FMS infrastructure may be considered in the design provided the designer can document that the product meets ADOT's need for application in specific cases on specific projects. A listing of current ADOT approved products appears on the *Approved Products List (APL)* following the

*Product Evaluation Program* process. The *Product Evaluation Program* process is administered by the ADOT Research Center. Other products that are not in the APL may be approved with documented justification. TSM&O and ITG may also have lists of equipment that synchronize with existing systems. Use the most recent DMS procurement contract and CCTV models. Since CCTV model numbers may change prior to advertising the project, confirm CCTV models specified are still correct prior to advertisement. Confirm the specification for the Ethernet switch is correct prior to advertisement with ADOT’s Information Technology Group (ITG) IT Network Engineer(s) and Systems Maintenance staff. The specifications shall include the required digital diagnostic tools for switch maintenance. FHWA requires certification letters when specifying equipment purchased with federal funds. ADOT’s goal of a statewide fiber optic network is to support emerging technologies such as connected vehicles using 5G or DSRC.

## 2.2 Existing Technology

**Detection:** The Freeway Management System contains a detection system located on mainlines and at interchanges. Mainline detection occurs at a maximum spacing of approximately one mile and at interchanges. Data from these detectors is used to determine travel times and provide traffic counts.

**CCTV Cameras:** FMS operators at the TOC are able to focus the color CCTV cameras with pan, tilt, and zoom capabilities at potential incident locations to confirm incidents.

**Ramp Metering:** Ramp metering uses a controller that can accommodate adaptive ramp metering on the entrance ramps to spread the demand on a freeway segment. See Ramp Metering Design Guide.

**DMS:** Motorist information is displayed using light emitting diode (LED) DMS, and speed feedback signs.

**Thermal camera detection:** Thermal camera detection is placed at exit ramp cross roads (see Figure 2.1 Pole base assemblies shall be break-away unless behind guardrail or barrier if located within the clear zone. See ITS Standard Drawings).

**Node:** Field device cabinets are connected to a node building, which is connected to the TOC. Field devices are connected using a fiber-optic communications system. The contractor integrates devices to the node building, while ADOT IT staff integrates from the node building to the TOC.

As new urban freeways are designed and constructed, it is desirable to incorporate certain FMS features to facilitate future FMS operation. To accomplish this objective, the roadway designer is responsible for the geometric design of on-ramps to accommodate dual lane ramp metering.

The designer is responsible for:

- Layout of detection for the entrance ramp queue loops
- Trunkline communications conduit and pull boxes on both sides of the freeway

Unlike new freeway construction, it is common for FMS elements to be *retrofitted* into existing freeway segments, where the existing FMS infrastructure ranges from non-existent to substantial. Retrofit projects require careful evaluation of existing infrastructure, and the available fiber-optic cable strands in the adjacent completed segment of FMS construction.

The design of detection systems, conduits to connect mainline detection systems, ramp meters, CCTV, DMS, and wrong way detection, is to be initiated in accordance with this document, and the documents listed in Section 1.4. The designer is encouraged to be aware of emerging technologies and their effect on FMS design. ADOT is migrating toward National Transportation Communication for ITS Protocol (NTCIP) compliant devices.

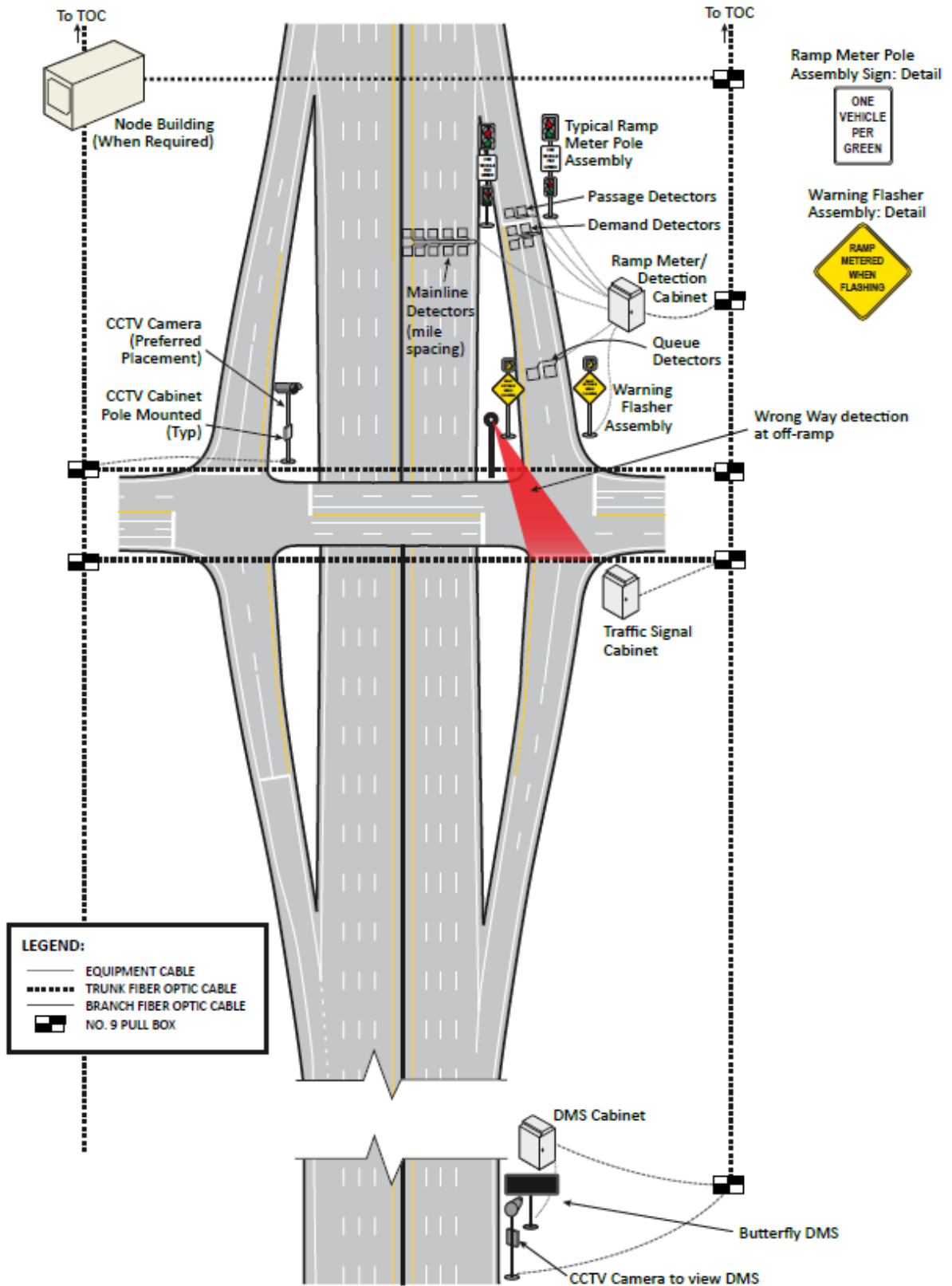


Figure 2.1 Typical FMS (urban freeway ITS) Interchange

# Chapter 3      Incorporating Freeway Management System Design

A full FMS (urban freeway ITS) project may be implemented either as a *stand-alone* project along an existing section of freeway where no civil improvements are involved or as an *integrated* project with civil improvements, typically a mainline construction or widening. The FMS infrastructure includes the following field elements, with the design of each addressed later within this Guide:

- Communications Trunkline Conduit System – Chapter 4
- Mainline Detector System – Chapter 5
- Equipment Cabinets – Chapter 6
- Dynamic Message Signs (DMS) – Chapter 7
- Closed-Circuit Television (CCTV) Cameras – Chapter 8
- Communication Nodes and Node Buildings – Chapter 9
- Fiber Outside Plant (OSP) Design and Modeling – Chapter 10
- Wrong Way Detection – Chapter 14

Other ITS such as Traffic Signals, Weigh-In-Motion (WIM), branch communications to pump stations and irrigation controllers are addressed elsewhere at ADOT.

In many instances the proposed FMS (urban freeway ITS) infrastructure, whether in a roadway project or in a stand-alone project, will border a local jurisdiction. The FMS designer should invite (see Section 1.1) the local jurisdictions to the project kickoff meeting. Coordination with any applicable local jurisdictions should be a standard item on the progress meeting agenda. If applicable, the FMS designer shall coordinate with local jurisdictions and the ADOT Joint Project Agreement Section shortly after receiving the Notice to Proceed.

All submittals shall include plans, specifications and Engineer's estimates (PS&E) for distribution by the designer. Progress meetings, as well as comment resolution meetings, shall be held for each project. The designer must submit estimates in the ADOT E2C2 format and provide a schedule detailing the 21 milestones tracked by ADOT Project Resource Office. Requests for utility service drops are the responsibility of the designer, and will require on-site meetings with the utility company providing service. The designer shall submit a Systems Engineering Checklist.

This section outlines basic designer responsibilities and is intended for information, but it is not all-inclusive.



## 3.1 No existing FMS Infrastructure with a New Roadway Project

The FMS (urban freeway ITS) infrastructure elements shall be considered as an integral part of any new freeway design.

Minimum requirements equals trunkline conduits and pull boxes:

As a minimum in each project, the designer shall include trunkline conduits and pull boxes. These elements are placed below ground per ITS Standard Drawings and, as such, should be constructed as part of earthwork and by taking into account future freeway widening. Pull box locations and lateral crossings of the freeway should be strategically placed to accommodate future devices. The designer shall consider the criteria presented in this Guide, and other referenced documents (see Chapter 1) for placement of the infrastructure.

Minimum requirements plus fiber optic cable:

When communication trunklines of fiber optic cable to TOC are included in the design, the designer shall add the corresponding ramp and mainline detection. Types of detection include saw-cut loops and thermal cameras. Designer shall complete plan sheets for conductor schedule, pull box schedule, and contents of cabinets.

Minimum requirements plus elements:

When elements of the roadway design (such as retaining walls, sound walls, long bridges, or median barrier) make it impractical or excessively costly to complete the necessary installation during a future FMS implementation project; elements of the FMS design (such as ramp meters, cabinet foundations, DMS foundations, CCTV foundations, or special conduit connections) shall also be provided within the roadway design.

Ideally include all of the above in the new roadway project: trunkline conduit, pull boxes, fiber optic cable, and elements plus a fully designed Freeway Management System.

## 3.2 ITS/FMS Infrastructure Stand-Alone Projects

When ITS/FMS infrastructure is designed as a stand-alone project, the designer bears a greater responsibility for coordinating with ITS Stakeholders (see Section 1.1) such as Systems Technology Group and Utilities.

Scope for a stand-alone ITS/FMS project includes but is not limited to:

- an estimate (that includes all anticipated devices)
- a discussion of design alternatives
- a Systems Engineering Checklist
- preliminary device locations in sketch format
- identification of any special considerations, such as local agency involvement, special clearances needed, and special geographic and access concerns
- an estimated project schedule for design and construction
- environmental, utility, and right-of-way clearances
- 3-3 inch conduit (Figures 4.4, 4.4.1)

Prior to the kickoff meeting, the designer shall meet with the ADOT PM and System Technology to discuss stakeholders, statements of work, schedule, scope, and budget. Traffic control for design activities are the responsibility of the designer, including traffic control for CCTV surveys and field surveys. Special field surveys may be needed for specific devices such as DMS, detection systems, and Node buildings. Where unique structural designs are required, the designer shall coordinate and obtain applicable approvals from the ADOT Bridge Group.

The designer shall meet with District construction stakeholders to determine traffic restrictions during construction. The designer and District construction stakeholders shall walk through the project to discuss appropriate traffic control for construction activities before Stage IV 95% design submittal.

If ITS/FMS infrastructure is existing, the construction schedule shall minimize downtime to the operating system. A phased construction approach is one way to improve the amount of time the ITS/FMS can be operating to support Traffic Management. Existing infrastructure, that must be moved, shall be replaced with the most current technology. The designer shall prepare an initial cutover plan:

- detailing downtime restrictions of operating ITS equipment
- requiring the contractor's preparation of a detailed cutover plan following inventory
- requiring liquidated damages for extensive downtime

During post design, the designer shall review the contractor's cutover plan.

The environmental clearance shall allow for earth disturbance by trenching and boring for conduit and fiber. If the project disturbs existing pavements, a Materials Memo from ADOT Materials Group is required. If the project includes DMS foundations, a Geotechnical report is required.

If projects occur on or adjacent to Native American lands, special permits or requirements may be required. Special permits or clearances may be required for crossing or locating facilities within certain

bounds beyond railroads, parks, flood control districts, airports and connections to city facilities. The designer must be aware of these items and budget for them in the schedule. A JPA or IGA may be needed to reimburse costs for enhancements desired by outside agencies and/or shared communications infrastructure (i.e., conduit and fiber-optic cabling systems).

Designers shall identify the need for any utility potholing necessary during design to minimize conflicts or to determine exact locations of utilities. Potholing needs shall be aggregated, compiled by the designer, and submitted to the Project manager for evaluation and establishment of the procedure to obtain potholing or determine if another measure is more appropriate in response to each situation. Designers shall be responsible for determining "prior rights" of any utilities encountered within the project limits and determine appropriate mitigations. The development and issuing of overhead power line plans (lock down) required by any utility in the course of obtaining utility clearance or new power provisions, shall be the responsibility of the designer.

Designers shall be specific about utility locations, easements, and blue staking. Design of power line extensions shall be completed before the start of construction.. Designers shall follow the Dictionary of Standardized Work Tasks.

The designer's continued involvement through construction, as part of post design services, may be required. In the event post design services are requested of the designer, such activities typically include:

- participating in project Partnering
- assisting with equipment submittal review
- responding to Requests for Information (RFIs)
- attending construction meetings as needed
- providing alternative designs in response to field conditions
- visiting the project site
- reviewing shop drawings, loop testing, and fiber test results
- production of record drawings from Department-furnished redlines, in conformance with the Record Drawings policy of the Project Resource office

### **3.3 Replacing FMS/ITS Infrastructure because of a Roadway Project's Impact**

For corridors where ITS/FMS infrastructure is existing, Roadway Construction projects shall minimize downtime to the operating system. A phased construction approach is one way to improve the amount of time the ITS/FMS can be operating to support Traffic Management.

Existing infrastructure, that must be moved, shall be replaced with the most current technology. The designer shall prepare an initial cutover plan:

- detailing downtime restrictions of operating ITS equipment
- requiring the contractor's preparation of a detailed cutover plan following inventory
- requiring liquidated damages for extensive downtime

During post design, the designer shall review the contractor's cutover plan.

Designer shall check existing ITS infrastructure such as conduits, pull boxes, and splice enclosures. Designer shall consider 2-phase construction with phase 1 for inventory repair, DMS foundations, and protection of DMS foundations. Designer shall check the lead time of fiber optic cable and other long lead time items to consider it in the time of phase 1. An example project is 101 Shea to 202 Red Mtn. In this project the ITS work was completed ahead of the Roadway work to minimize downtime to the operating system.

# Chapter 4 Trunkline Conduit System

## 4.1 Trunkline on Both Sides of the Freeway

The preferred FMS (urban freeway ITS) communications system consists of three 3-inch trunkline conduits parallel to the mainline freeway along both sides of the freeway to accommodate:

- fiber optic communication cables
- power cables
- future expansion of the FMS

FMS conduits that are not part of the trunkline conduit system are called *branch* conduits. Branch conduits connect the trunkline network to the various field cabinets and devices.

The conduit path shall be chosen to provide a continuous conduit system as shown in Figures 4.1 and 4.2. Any deviation from the conduit systems, as shown in these figures, shall require documented justification. Conduit and innerduct runs shall be continuous from pull box to pull box.

A single trunkline (only one side of a freeway) is not recommended. In situations where the design of full FMS encounters an existing freeway segment with trunkline previously installed on only one side of the freeway, the design shall include installation of trunkline conduit on the side without conduit, resulting in a redundant trunkline system.

Single-sided trunkline fiber shall require documented justification. Conditions that may result in single-sided trunkline conduit include:

- rural highways
- limited right of way
- limited budget

For rural highway ITS, a folded ring network on one side of the highway, is one way to increase redundancy.

## 4.2 Location of Trunkline in Freeway Right of Way

The trunkline conduit system shall be located in the freeway right of way. The designer will field verify the recommended FMS trunkline conduit location while balancing the following factors:

- close to the right-of-way line
- visible from the road
- slopes
- avoiding future widening impacts
- cross sections
- in proximity to retaining/sound walls or barriers
- vulnerability to theft
- avoiding utilities and outside utility easements
- maintaining landscaping irrigation systems
- maintenance force access to the trunkline conduit system at pull boxes
- avoiding repeated wheel-loads

When the freeway is on an embankment section; place field equipment, such as controller cabinets, at the top of the slope to provide visibility of the FMS equipment from the cabinet. In any case, the trunkline conduit system shall not be placed below the slopes. The trunkline conduit system should be placed above slopes to avoid drainage issues.

#### **4.2.1 Connections to FMS Communication Nodes**

Two sets of three 3-inch conduits (to each trunkline on either side of the freeway) shall be routed separately to the communication node building (see Figure 4.3). Two sets of conduits provide redundancy; while separate routing avoids both sets being severed simultaneously in the event of errant excavations.

These conduits (which should be shown on plans) may be installed in various locations, including:

- under the mainline freeway via directional drilling
- along the crossroad at a bridge underpass
- attached transversely to overpass bridge structures

One 3-inch conduit (for each trunkline set between the trunkline and the node building) shall have two 1-inch innerducts with detectable pull tape installed.

#### **4.2.2 Connections to FMS Trunkline Termination Points**

The designer should coordinate the lateral and vertical placement of trunkline conduits at project limits with adjacent design projects to ensure continuity of the conduit system and to ensure separation from other facilities.

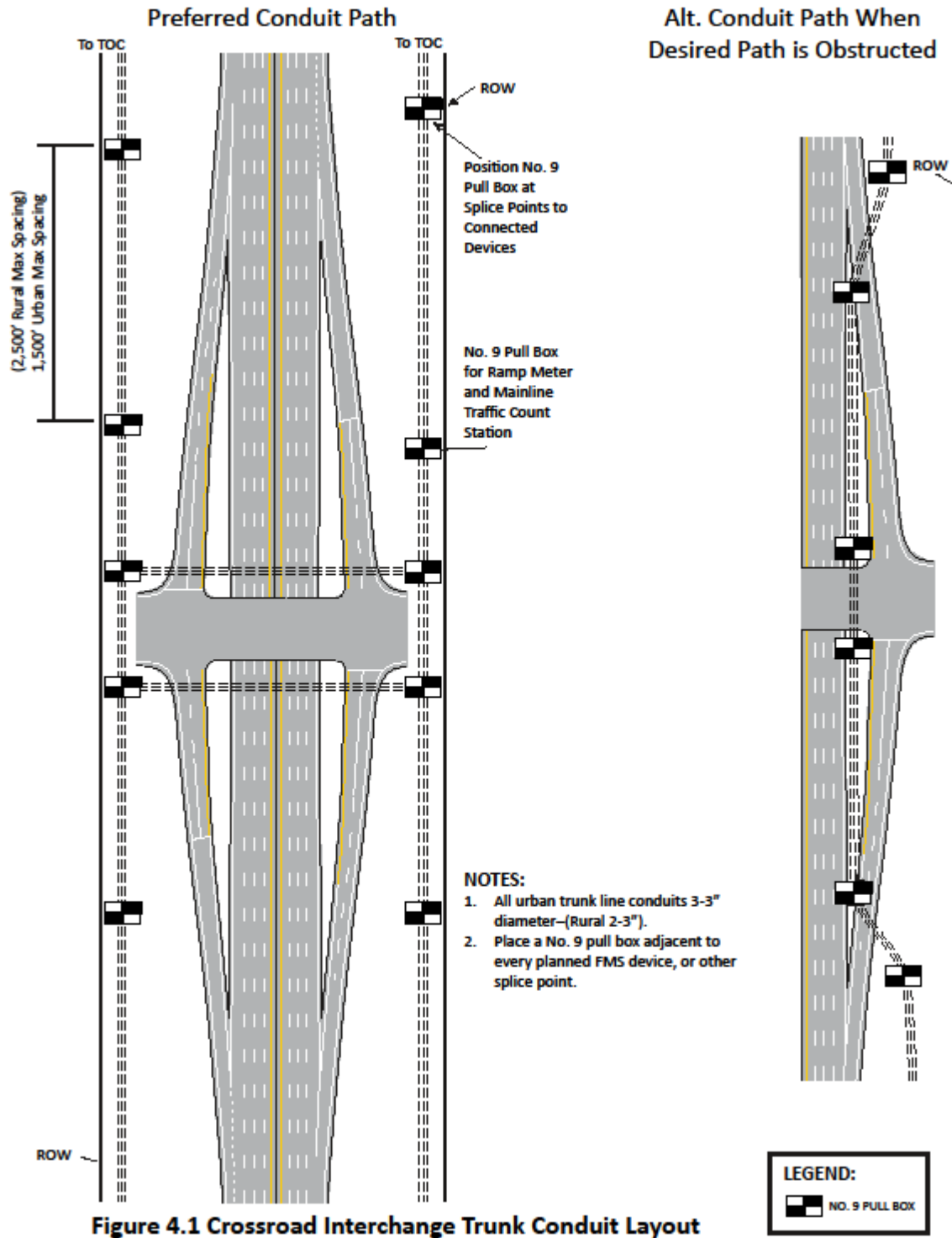
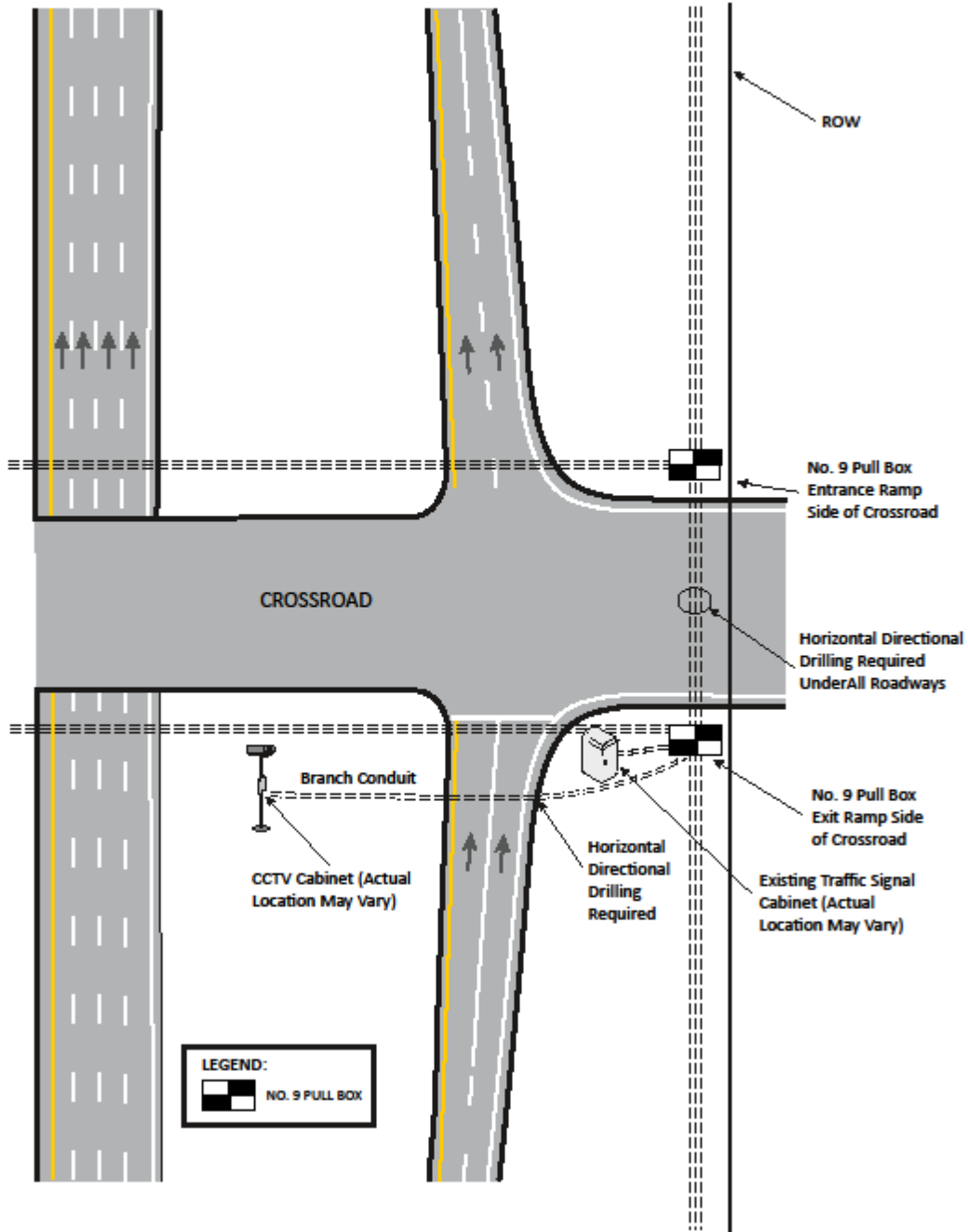


Figure 4.1 Crossroad Interchange Trunk Conduit Layout (FMS urban freeway ITS)



**Figure 4.2 Trunkline Conduit Locations at Crossroad Interchanges**



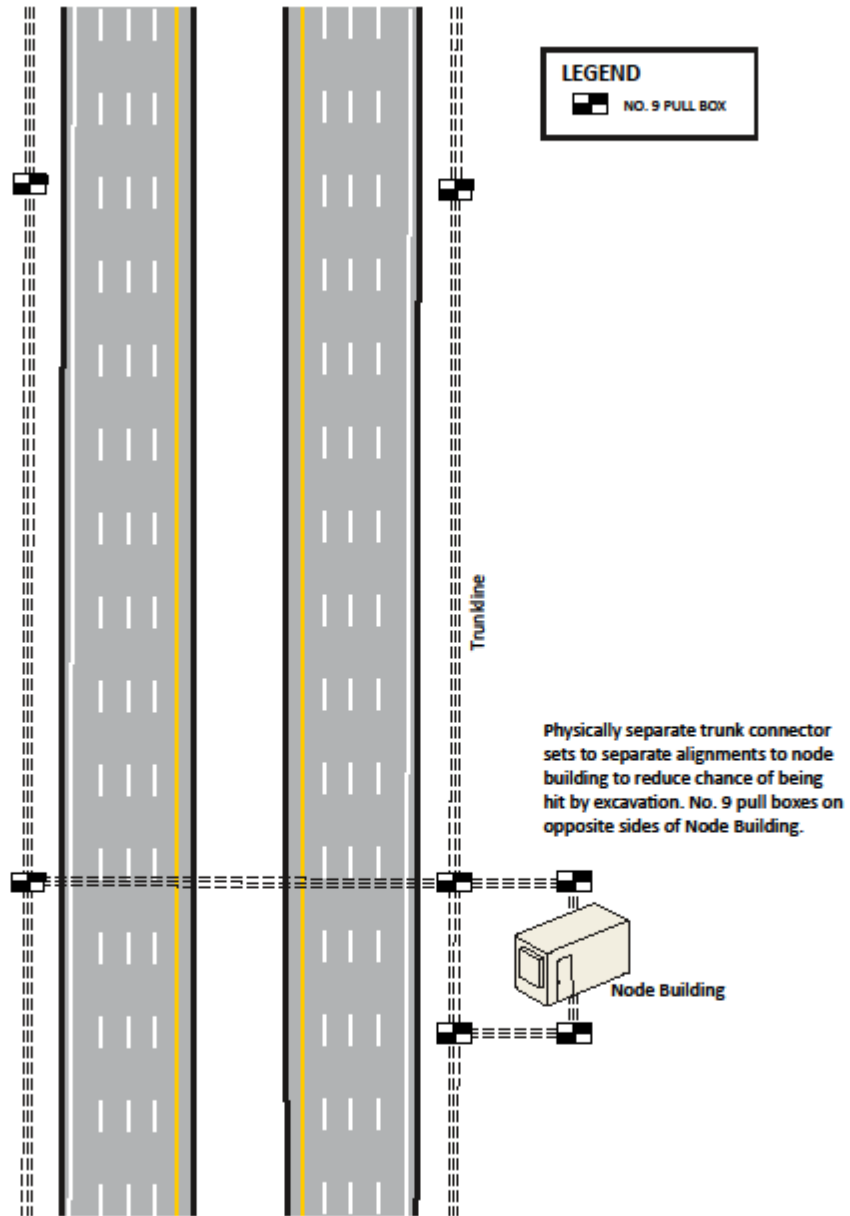


Figure 4.3 Conduit to Node Building

## 4.3 Trunkline Conduit Array and Layout

The installation of new trunkline conduit along existing urban highways (Phoenix: Loop 101, Loop 202, Loop 303, SR-24, SR-51, US-60, I-10, and I-17; Tucson: I-10 and I-19) shall be consistent with a three-inch conduit array. This three-inch conduit array has been used extensively in the existing conduit system, and is considered to be the ADOT standard. Conduit size, trenching/backfill, and directional drilling, are among the most expensive, yet important, elements of the FMS. Section 4.5.1.3 provides further discussion of trunkline conduit orientation, including vertical and horizontal configurations. If local agencies wish to install fiber optic cable in ADOT right of way, they will need to request approval from ADOT Systems Technology and complete or amend an IGA (Intergovernmental Agreement).

## 4.4 Trunkline Conduit Co-Location with Lighting Power Conduits

Certain segments of the FMS trunkline may include a fourth conduit, for roadway lighting, if the available width between the edge of freeway and right-of-way is so constrained that separate trenching is not possible. Co-locating FMS and lighting is discouraged and is allowed only with documented justification. In all cases, lighting circuit conductors shall not share the same pull box with FMS fiber cables and power conductors.

## 4.5 Conduit Materials and Construction Methods

### 4.5.1 Underground Conduit

Underground conduit systems are typically constructed with either PVC or HDPE. All conduits shall have smooth inner and outer walls. PVC conduits are rated by wall thickness and crush resistance. Schedule 40 is typically used for all PVC applications. PVC is used when trenching conduit, while HDPE is used for directional drilling conduit. HDPE conduit is rated for crush resistance and tear resistance. HDPE is subjected to significant pulling tension when installed by directional drilling or boring methods. HDPE conduit shall have a minimum rating of SDR 11. (Size Diameter Ratio, equates internal diameter and wall thickness to a universal rating indicating level of resistance to tear and crush forces.)

### 4.5.1.1 Conduit Installation for Fiber Cable

The designer is responsible for:

- following the NEC (National Electrical Code)
- designing a conduit system that will facilitate fiber-optic cable installation within and avoiding potential damage to the fiber-optic conduit and cable system. Loss of communications is a critical issue with regard to the FMS (urban freeway ITS)
- specifying that the exerted force on the cable will not exceed 600 pounds of pulling tension during installation
- evaluating existing trunkline conduit system alignments for existing deflection and angle points to determine if the existing alignment is suitable to meet pulling tension limitations, or if alignment adjustments or additional pull boxes are required to mitigate pulling tension challenges

The designer needs previous design or construction experience; or a cable pulling program that calculates pulling tension, to fulfill these responsibilities.

The number of bends includes the sweep into a pull box. 90-degree cumulative turns shall be made of individual elbows. Where complex sites leave no other option, such as into and out of structures requiring near 90-degree turns, a minimum radius of 36 inches is required.

90-degree elbows should be avoided, as they require additional labor and equipment for cable installation, even on short runs. The smallest degree of bend possible should be utilized to minimize cable installation challenges. 360 degrees is the maximum of cumulative bends between pull boxes (see ITS Standard Drawings FM-1.02).

Conduit deflection should not deviate more than one inch horizontally or vertically per 12 inches of running length of conduit (1:12). Long conduit sweeps should be used wherever possible to change conduit direction. The design should stringently adhere to this requirement in order to reduce the pulling tension required during cable installation. There are complex conduit situations that will have to be addressed during design, such as:

- crossings over canals
- tunnels
- transitions into structures, where a 1:12 deflection cannot be achieved

Where long conduit sweeps are not possible, specify standard factory-made conduit elbows of 11 ¼, 22 ½, or 45 degrees with a minimum radius of 24 inches (see ITS Standard Drawings FM-1.06).

### 4.5.1.2 Conduit Traceability and Detection – “Blue Stake”

Requirements for providing magnetic detection for the underground facilities of the FMS have changed throughout the years. The recommended FMS design is to place continuous detectable pull tape, conforming to the ITS Standard Drawings within the conduit system for detectability and to facilitate the future pulling on new conductors and cables.

### 4.5.1.3 Conduit Configuration

The typical three 3-inch trunkline conduit contents, as shown in ITS Standard Drawing FM-1.01, are:

1. The conduit, closest to the freeway in a horizontal array, or on the bottom of a vertical array, is designated for:
  - ADOT single-mode fiber-optic (SMFO) cable
  - local agency fiber-optic cables (approved for installation in ADOT right of way)
  - other ADOT approved device communications cables

When multiple fiber cables (ADOT and/or local agency) are installed in the fiber conduit; they shall be segregated by the use of colored innerducts.

2. The second conduit (center) will be reserved for future FMS purposes and shall contain *detectable pull tape*. This detectable pull tape should be installed in the conduit as part of the initial conduit installation.
3. The third conduit, furthest from the freeway in a horizontal array, or on the bottom of a vertical array, is designated for FMS device electrical power distribution. Other select power cables, where required, such as power to ramp meter poles may also be allowed, within an innerduct array, to separate voltages.

If a project requires multiple innerducts within a conduit, the designer shall:

- verify the outside diameter of the innerduct such that the desired quantity of innerducts will fit in the designated conduit(s)
- specify the outside diameter in the project plans and special provisions

Fiber-optic cable shall not be installed in any conduit containing innerduct, outside of an innerduct. Any existing conduit containing existing fiber-optic cable or existing electrical conductors or other cables that will have innerduct installed as part of a project, shall provide for the removal and reinstallation of existing contents into the newly installed innerduct. The designer shall prepare an initial cutover plan:

- detailing downtime restrictions of operating ITS equipment
- requiring the contractor’s preparation of a detailed cutover plan following inventory
- requiring liquidated damages assessment for extensive downtime

During post design, the designer shall review the contractor’s cutover plan.

## 4.5.2 Conduit Below Pavements and on Structures

### 4.5.2.1 Conduit Installation on Structures: Bridges

The designer shall obtain ADOT Bridge Group approval of any conduit installation within, or attached to, any existing or proposed bridge structure. Attaching conduit and associated hardware to the exposed fascia of new structures should be avoided. Conduit should be incorporated into the structure where possible. Conduits either within or attached to structures shall be rigid metal conduit (RMC).

Intermediate Metal Conduit (IMC) shall not be used for any FMS applications. Since this conduit is often hidden, it is imperative that the conduit system does not fail. Where required for aesthetic reasons, RMC shall be painted, as approved by ADOT Bridge Group, to match the color of the existing bridge structure. Any necessary painting shall have materials and construction requirements spelled out in the project Special Provisions.

For new bridge structures intended to convey the FMS trunkline, the RMC conduit system shall be installed inside the box girder cells or under the bridge deck between the exterior and first interior girders. Details of exact location and method on conduit installation shall be coordinated by the FMS designer with the bridge designer, and ADOT Bridge Group. Designers shall ensure adequate expansion couplings, allowing for conduit movement in all planes. Expansion couple devices should be provided at the same locations of bridge movement points, and conform to the ITS Standard Drawings.

No. 9 pull boxes should be placed on either end of every structure where the FMS conduit trunkline is to be installed. The ITS Standard Drawings depict the conduit transition treatment between structures and No. 9 pull boxes. Conduit hanger placement details for I-beam and concrete box girder bridges shall be as shown in the ITS Standard Drawings. The elevation of the conduit through the structure should approximate the elevation of the conduit placement in the trench, in order to avoid sharp directional changes. The use of 90-degree conduit elbows to transition the conduit from the trench to bridge grade is not acceptable.

For bridges over 1,500 feet in length, install No. 9 pull boxes with slack on each end and include ADOT Bridge Group in the decision whether one or more junction boxes should be included in the structure to allow cable-pulling equipment access. The designer shall evaluate the accessibility of the area under, on, or within the bridge to determine the appropriate location(s) for the intermediate pull boxes.

Although not recommended, some bridges may require field devices, such as CCTV and controller cabinets, to be structure-mounted. These devices, along with the pull boxes and associated conduit system, require special design of barriers, platforms, and pull boxes to accommodate the required field equipment. Structure-mounted CCTV design shall address vibration that impacts the camera image.

### 4.5.2.2 Conduits Crossing Ramps at Traffic Interchanges and System Interchanges

It is preferable to install trunkline conduit as close to the right-of-way line as possible. Hence at traffic interchanges, the trunkline conduits should be installed along the outside of the exit ramp, underneath the crossroad, and along the outside of the entrance ramp. In cases where this routing is not possible, trunkline conduit may cross the exit ramp, run alongside the mainline or inside the entrance and exit ramps (crossing the crossroad either below pavement or on structure, (see Figure 4.1), and finally cross the entrance ramp back to the outside of the entrance ramp. The *preferred* conduit path should be gradual (1:12 deflection) to avoid use of factory conduit bends.

**Table 4.1 Alternate Ramp Conduit Crossing Cases**

ALTERNATE RAMP CONDUIT CROSSING OPTIONS		
CASE A	Preferred	No conduit bends, maximum deflection of one-inch per foot of conduit.
CASE B	Acceptable	Maximum bend of 22½ degrees; 11¼ degrees bend preferred.

### 4.5.3 Trenchless Conduit Installation

The designer shall be familiar with ADOT Standard Specifications to identify where trenchless conduit are required. Installation locations include:

- under any existing pavements
- railroads
- graphic slopes

Trenchless conduit is required to minimize damage to existing surface features or accommodate grade differentials. Jack and bore, also known as auger boring, may be required by railroads.

The designer may use customized project-specific bid items that specifically distinguish, measure, and pay for trenchless conduit installation separate from other installation methods, or may opt to measure and pay for all conduit based on size and type, regardless of installation method. Deciding factors include:

- the proportion of trenchless conduit versus other methods
- difficulty of trenchless installation at the specific project location versus comparable difficulty of other methods
- other project-specific factors that may influence a significant difference in cost for trenchless installation when compared to other methods

The use of such customized project-specific bid items require:

- documented justification
- the approval of ADOT Contracts and Specifications
- project-specific Special Provisions specifically stating which bid items are applicable

Warning tape is not required in conduit segments where HDD (Horizontal Directional Drill) methods are used for construction. The designer may refer to the following HDD reference documents for additional information:

- **ASTM F 1962** - Standard Guide for Use of Maxi-Horizontal Directional Drilling for Placement of Polyethylene Pipe or Conduit Under Obstacles, including River Crossings
- **Mini Horizontal Directional Drilling Manual** - Published by the North American Society of Trenchless Technology (NASTT)
- **TR-46 2009** – Guidelines for Use of Mini-Horizontal Directional Drilling for Placement of High Density Polyethylene Pipe - Published by the Plastic Pipe Institute (PPI)

## 4.6 Pull Boxes

ITS pull boxes are used in ground and structure-mounted applications. Two sizes, or types, of ITS ground-based pull boxes are normally used on ITS projects: the box sized *No. 7 ITS Pull Box* and the vault sized *No. 9 Pull Box*. A variation of the No. 9 Pull Box is the Split No. 9 sometimes used with existing fibers and splices.

Per the ITS Standard Drawings, pull boxes on slopes should normally be constructed with the lid level, not tilted to be parallel with the slope. Pull Boxes should be designed to avoid exposing any sides of the pull box that might be a hazard to traffic.

Pull boxes should not be installed within the roadway, within any paved area, or future widened roadway footprint unless each location is compliant with additional load and lid requirements and justification is documented.

Pull boxes should not be positioned in locations that are known or anticipated paths for vehicles, such as maintenance and landscaping trucks, nor in the roadway shoulder or distressed vehicle pullouts. Care should be taken in locating pull boxes to avoid drainage swales. Generally, pull boxes should be elevated above the surrounding terrain between one and two inches.

The designer is expected to field verify the proposed pull box locations to avoid any visible conflicts. Designers are required to field check each new proposed pull box location to ensure that it is not in pavement, on a slope, in a drainage swell or area that otherwise may collect standing water, a hazard to traffic or pedestrians, or in a location where it would likely be in the path of vehicle traffic. Where

necessary to avoid hazardous conditions, the pull box spacing may be reduced and the number of pull boxes required increased.

Delineators shall not be used to mark new pull box locations. All existing ITS pull box delineators shall be removed. Delineators shall be used to mark fiber optic conduit that is plowed and armored in rural applications (see Chapter 12).

All FMS pull box lids shall be labeled “ADOT FMS,” consistent with current practice. (Pull box lids used for rural ITS applications, such as rural DMS and RWIS, shall have lids labeled “ADOT High Voltage”.) ITS pull boxes shall be numbered and geo-referenced on the project plans with a unique number. The pull box numbering scheme should be similar to the ADOT cabinet numbering scheme, e.g., by route, direction, and milepost to the nearest hundredth of a mile. Pull boxes with same milepost, due to close proximity to other pull boxes numbered in the plans, shall utilize an "A, B, or C", suffix. In filling out conduit schedules, designers shall indicate an item is a load center with "LC", and cabinet with "C" prefix.

## 4.6.1 Pull Box Types

Designers are required to run new trunkline conduits from No. 9 pull box to No. 9 pull box. No. 9 pull boxes should be placed outside of the clear zone.

All No. 7 ITS Pull Boxes shall be single-unit, 24-inches in depth, conforming to the ITS Standard Drawings.

### 4.6.1.1 No. 9 Pull Boxes - General

No. 9 pull boxes, conforming to the ITS Standard Drawings shall be installed in the following instances:

- FMS spacing is 1,320 feet, and no more than 1,500 feet along the trunkline to assist installation of fiber-optic cabling within the conduit
- Rural highway ITS spacing is 2500 feet along the trunkline to access devices
- In the vicinity of each mainline detector station, approximately one mile spacing
- Locations where parallel trunklines between adjacent projects need to resolve differences in offset alignments
- Proposed project or future splice points for branch fiber-optic cable to ITS field devices
- Ends of bridge structures and large box culverts

The designer shall prepare a cutover plan for intercepting existing cables present in existing conduit. The designer shall document and justify if intercepting conduits necessitate use of a "split No. 9" pull box. Split No. 9 pull boxes shall conform to the ITS Standard Drawings.



#### 4.6.1.2 No. 9 Pull Boxes – Loading Requirements

Where No. 9 pull boxes must unavoidably, be located within the traveled way, shoulder, other paved surface, or other location where repeated dynamic loads are likely (such as unpaved areas near ramp gores), a special design of a cast iron pull box lid must be conducted by the designer to accommodate the repetitive vehicular loading. The pull box lid design shall incorporate a locking mechanism that will prevent vibration and vehicle traffic from un-seating the lid. This design shall be certified and sealed by an Arizona registered Professional Engineer.

#### 4.6.1.3 No. 9 Pull Boxes – Cable Racking

Fiber-optic cable shall be coiled in No. 9 pull boxes, conforming to the ITS Standard Drawings. The fiber-optic cables are supported on the sides of the pull box with pre-manufactured vertical cable racks called *cable ladders*. Trunkline conduits typically enter the No. 9 pull box from opposite corners, to facilitate coiling.

#### 4.6.1.4 No. 9 Pull Boxes – Torsion Assist Lid

The diamond-plate steel lid for typical No. 9 pull boxes shall be a square shaped lid, conforming to the ITS Standard Drawings.

Projects in areas with existing FMS infrastructure that includes the round manhole lids per previous standards on existing No. 9 pull boxes shall have existing top section, with lid, replaced with the current design of torsion assist square stainless steel lockable lid. The Designer shall replace all such lids on all existing No. 9 pull boxes utilized within the project limits, including any existing No. 9 pull boxes that may otherwise not have any other activity, but contain existing fiber-optic or power cables, or anticipated for future use. The designer shall identify where all existing No. 9 pull boxes are located within the project limits, identify those being reused for the project, and replace top sections with lids if cracked or broken.

Designers shall be aware of, and field verify the plan view dimensions and existing ground conditions around each existing No. 9 pull box to get new lids, and develop strategies for dealing with installation challenges, including the existing box being dimensions other than the current lid top section size. The designer shall be responsible to insure that the project plans account for any odd sized lid section dimensions, to avoid improper fit or ability to snugly rest the new top section atop of the existing under field conditions.

Existing No. 9 pull boxes indicated on the project plans to be retrofit with new torsion assist lid, shall have the lid properly grounded to a ground rod driven into the ground through the sump hole in the bottom of the No. 9 pull box. Existing pull boxes found, during the designer's field inventory, to not

have a ground rod present, shall have provisions in the project plans and Special Provisions for a new ground rod and ground conductors installed to properly ground the new lid.

#### **4.6.1.5 No. 9 Pull Boxes – Splice Closures**

Splice closures for fiber-optic cables shall be appropriate for intended size and quantity of cables and splices. The designer shall be responsible for identifying and incorporating all splice locations and fiber splice details into the project plans and special provisions, including any necessary butt-splice points of all fibers within a cable.

#### **4.6.1.6 Pole Mounted Junction Boxes**

All poles intended to support legacy or proposed non-intrusive vehicle detection systems shall be accompanied by an adjacent pull box. The pull box may be placed in the ground or, in cases of barrier pole mount sites, a special NEMA junction box mounted on the pole near the base of the pole shall be designed and detailed in the project plans and special provisions. Pull boxes in barriers are not preferred.

#### **4.6.1.7 Bridge Mounted Junction Boxes**

Conduit crossings over structures, such as canals, roadway undercrossings, and railroads, that are to be mounted on the exterior of the bridge fascia or abutments shall have secure junction box covers. The junction box covers shall be designed so that special tools are required for the cover plate to be removed to thwart vandalism.

### **4.6.2 Co-Locating Lighting No. 7 Pull Boxes with FMS Trunkline Pull Boxes**

Lighting power conduit may rarely be co-located in the same trench line or alignment as the FMS trunkline due to specific site space constraints, though this is not the preference of the ADOT Lighting Maintenance staff or ADOT ITS Maintenance.

Co-locating new FMS with new lighting or any other infrastructure, ADOT-owned or otherwise, shall follow ITS Standard Drawing.

The only situations where co-locating with other new infrastructure will be allowed will be based on the presented justification by the designer, including any requirements for pull box locations relative to the two facilities.

### **4.6.3 Adjacent Jurisdictions and FMS Trunkline Pull Boxes**

Separate jurisdictional pull boxes shall be used for connecting to adjacent jurisdictions ITS devices along the FMS Trunkline project limits.

# Chapter 5 Mainline Detector System

Data from vehicle detection technology is used in real time for FMS applications and is available for planning purposes. The FMS gathers and uses real-time traffic data including speed, occupancy, vehicle classification, and volume. Stored data is also useful for traffic planning purposes such as monitoring traffic trends and generating other traffic related statistics.

The standard vehicle detection system for the ADOT FMS is loop detectors that are saw-cut into the pavement surface. Where new vehicle detection system technology is being proposed on a project, the designer shall define and document the proposed vehicle detection system technology and communications approach. This documentation shall occur during scoping of the project.

At a minimum the vehicle detection system needs to test for vehicle volumes, speed, occupancy, and classification. Mainline detector system components shall conform to the ITS Standard Drawings.

## 5.1 New Installations

Mainline detector stations are required for the entire urban freeway system. One mainline detector loop station is required per mile in each direction, typically near the entrance ramp detectors, so the mainline and entrance ramp detectors can use a single control cabinet (refer to the Ramp Metering Design Guide). Fiber and conduit shall be installed with every project.

Saw-cut loops shall be used. Each set of detector loops normally consists of two 6 feet x 6 feet square-shaped saw-cut detector loops per lane, separated longitudinally by 12 feet. All loops shall terminate in a No. 9 or No. 7 (24 inches deep ITS Pull Box) at the shoulder. Median pull boxes shall not be used.

## 5.2 Retrofit Projects

Detection Loops in existing pavement:

- **Preformed:** Abandon all preformed loops and replace with saw-cut loops.
- **Saw-cut:** Saw-cut loops may be used if the loops are not damaged. It is the designer's responsibility to test the existing loops for continuity and electrical resistance Meg-Ohm readings. Existing saw-cut loops and lead-ins shall be tested for insulation resistance to ground, series resistance of the loop, and inductance of the loop.
- **Lane Configuration:** If the lane configuration has changed from the original installation or will change with the new design, new loop detectors shall be saw-cut in the pavement surface.

Specifically, if the lane line shifts such that the edge of the existing buried loop is less than 18 inches from the new lane line, then new saw-cut loop detectors in the pavement surface are required.

## 5.3 Loop Detector Requirements

Loop detector requirements are discussed in the *ITS Standard Drawings*, and the *Ramp Metering Design Guide*.

The following procedure is for systematic design of the placement of mainline detector stations:

1. Uniformity in loop detector spacing is desired; therefore, divide the project into approximately equal one-mile segments and identify these points as the location(s) of the intermediate stations. If a location falls on a bridge or in a lane taper, the loop location should be adjusted so that it is beyond the nearest bridge abutment or upstream of the start of a lane taper. When an adjustment is required, the loop spacing should be no more than one mile from any adjacent loop detector station. At least one loop detector station shall be placed in each one-mile section of freeway, including sections where interchanges are more than a mile apart.
2. The mainline loops should be placed adjacent to the ramp meter stop bar. If there is no ramp meter stop bar, the mainline loops should be placed near the paved gore, before the on-ramp joins the mainline. When interchanges are more than a mile apart, an additional loop detector station is required on the mainline away from where merging or weaving occurs.
3. The designer should be aware of the difficulties of obtaining accurate mainline count, occupancy, classification, and vehicle length data in the immediate vicinity of entrance and exit ramps due to the number of merging vehicles and lane changes which commonly occur.
4. Repeat the process for the other direction of travel.
5. A six-foot, square-shaped loop is centered in the lane, with approximately three feet to the lane line. Each set of detector loops shall consist of two 6-foot, square-shaped loops per lane, separated longitudinally by 12 feet.
6. Loops are to be centered in the middle of the lane(s). Auxiliary lane and high-occupancy-vehicle (HOV) lanes must have loop detectors installed similar to general-purpose lanes.
7. FMS detection includes detector loops, lead-in cables, loop sealant, loop splice kits, and loop detector surge protectors to form loop systems in control cabinets. The lead-in cables shall be labeled in the control cabinet and in the pull box where loops are spliced to the lead-in cable.
8. Newly installed saw-cut loops and lead-ins shall be tested for insulation resistance to ground, series resistance of the loop, and inductance of the loop.

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## Chapter 6 Equipment Cabinets

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Equipment cabinets are installed along the freeway as part of FMS projects. Equipment cabinets are typically located adjacent to mainline detector stations, ramp meters, CCTV, and DMS. Ramp meter equipment cabinets are shared with mainline detector stations. This chapter describes considerations for cabinet locations, foundations, and contents.

All equipment cabinet foundations shall be numbered and geo-referenced. Each equipment foundation on each FMS project shall be designated with a unique number that is not duplicated. The numbering scheme should follow the typical ADOT cabinet numbering scheme, e.g., by route, direction, and milepost to the nearest hundredth of a mile. Cabinets with the same milepost, due to close proximity to other cabinets at or near the same location, shall utilize an "A", "B", "C" suffix nomenclature. Load centers shall be labeled with an "LC" prefix, and other cabinets shall use a "C" prefix.

### 6.1 Equipment Cabinet Location

Design criteria for suitable controller cabinet location includes the following:

- A. The cabinet is to be placed in the safest possible location, generally along the right shoulder, and to minimize conduit and cable quantities. If no protection (such as, barrier or guardrail) is proposed for the cabinet location, the cabinet shall be outside the *clear zone* such that no protection is needed. See the *AASHTO Roadside Design Guide (RDG)* for *clear zone* requirements. If the cabinet must be placed between the mainline and the ramp and an adequate clear zone is not met, protection is to be provided, as required. Consideration should also be given to probable future widening of the mainline and/or ramps, and consequently any opportunity to install cabinets further from the edge of the traveled way should be considered.
- B. If a guardrail or barrier is present along the right edge of the pavement and the installation of a controller cabinet is required, the cabinet is to be located *behind* the guardrail or barrier as shown in the ITS Standard Drawings.
- C. The cabinet is to be located in order to minimize the length of the detector loop lead-in while also considering probable future widening of the mainline and/or ramps. Loops from several different locations may be terminated in the cabinet: the ramp metering stop bar area, the advance queue detector (AQD) area, and adjacent mainline loops. Designer shall refer to the *ADOT Ramp Metering Design Guide*. The detector card supports a maximum distance between cabinets and their respective detector stations. The maximum depends on the number of loop lead-ins and microHenries. Special provisions shall be developed to identify the anticipated distances and corresponding detector card requirements.

- D. Where non-intrusive detection system technology is used instead of loops, the designer shall check with the vendor to determine distance limitations. Visibility from the cabinet to the specific detection system is to be maintained for ease of calibration and maintenance.
- E. Modifications in the landscaping plan, or noting the need for grubbing may be required to include a safe maintenance vehicle parking area and to ensure visibility of the FMS equipment served by an equipment cabinet.
- F. The position of a combined ramp meter/mainline detector station cabinet is to allow observation of the ramp metering stop bar and at least one ramp meter signal head from the doorway of the cabinet.
- G. Cabinet locations are shown on the project plans.

### 6.1.1 On-ramp/Ramp Meter Cabinets

Every on-ramp from a local agency facility requires detection which will necessitate a Type 341A cabinet, if none are present. Refer to the *ADOT Ramp Metering Design Guide* for guidance on ramp metering concepts. A ramp meter cabinet includes a controller (that allows for adaptive ramp metering), detector cards, power distribution assembly, model 206 power supply module, switch packs, and flasher units.

### 6.1.2 Other Equipment Cabinets: CCTV, DMS, Mainline Detection (see also Chapters 5, 7, and 8)

Locations for cabinets are dependent on the location of each device served, clear zone, and availability of barriers or guardrail. Device positions then determine cabinet and No. 9 pull box locations. Typically, the No. 9 pull box is positioned laterally from each cabinet. Figure 6.1 shows CCTV Cabinet Type 343. Freeway DMS typically use a foundation-mounted DMS control cabinet. A foundation-mounted cabinet, and, where required, a transformer enclosure, would be placed downstream of the structure support pole such that the structure support pole provides protection to the cabinet from vehicles. In special cases, with documented justification, newly installed freeway DMS may include a smaller pole-mounted cabinet. The pole-mounted cabinet would be mounted on the right shoulder traffic "downstream" side. The cabinet design shall be oriented vertically.

## 6.2 Equipment Cabinet Foundation

Materials are required to connect equipment through the foundation to the cabinet to form a fully functional system. Examples of these materials are:

- conduits
- conduit fittings
- elbows
- anchor bolts
- conductors
- connectors
- ground rods
- grounding lugs

The cabinet foundation location shall:

- be consistent with the location of the trunkline pull box and the device served by the cabinet
- have maintenance access
- be visible to devices served
- have drainage features to keep the equipment dry

## 6.3 Equipment Cabinet Contents

Equipment cabinets include cabinet assemblies and control cabinet accessories. Electronic components control the operation of ITS devices served by the cabinet.

Fiber optic branch cable network communication equipment entering FMS control cabinets shall be connected as shown in Figure 6.1. Special provisions describing the details of this arrangement will be required on a per project basis.

Spider fan-out kits and Dooley sumps are no longer used on new installations.

Each cabinet shall be equipped with:

- Ethernet switch
- Power supply including circuit breaker, fuses, power line surge protection device and receptacle
- Fiber splices and termination in a patch and splice module unit
- remote management power strip

All cabinets shall be grounded. The designer shall size the power conductors to comply with NEC requirements:

- 3% maximum voltage drop for feeder circuits, *NEC 215-2(d) FPN No. 2*
- 3% maximum voltage drop for branch circuits, *NEC 210-19(a) FPN No. 4*

With tapped transformers, 5% voltage drop is allowed. Voltage drop calculations shall be provided with the 60% design submittal, justifying conductor sizes, and showing design loads and voltages used in the calculations. Shorter runs, utilizing smaller gauge copper conductors are preferred, as a means of



detering copper theft. Situations where use of existing power sources result in large size copper conductors shall be evaluated by the designer to determine if a line extension by the power provider would mitigate the impact of voltage drop over distance by locating the power source closer to the devices served. The designer shall be responsible for contacting and coordinating this evaluation with the utility, and present the Project Manager with alternatives and associated costs.

All power services shall be metered. It is preferred that the service voltage be 480 volts, metered, and elimination of the 120 to 480 step-up transformer in the load center. However, if only 120/240 service voltage is available, the modified Type IV load center shown in the ADOT Standard Drawings shall be used. The designer shall confirm with the power provider, any additional cutoff devices required by the power provider and accommodate them in the design as necessary.

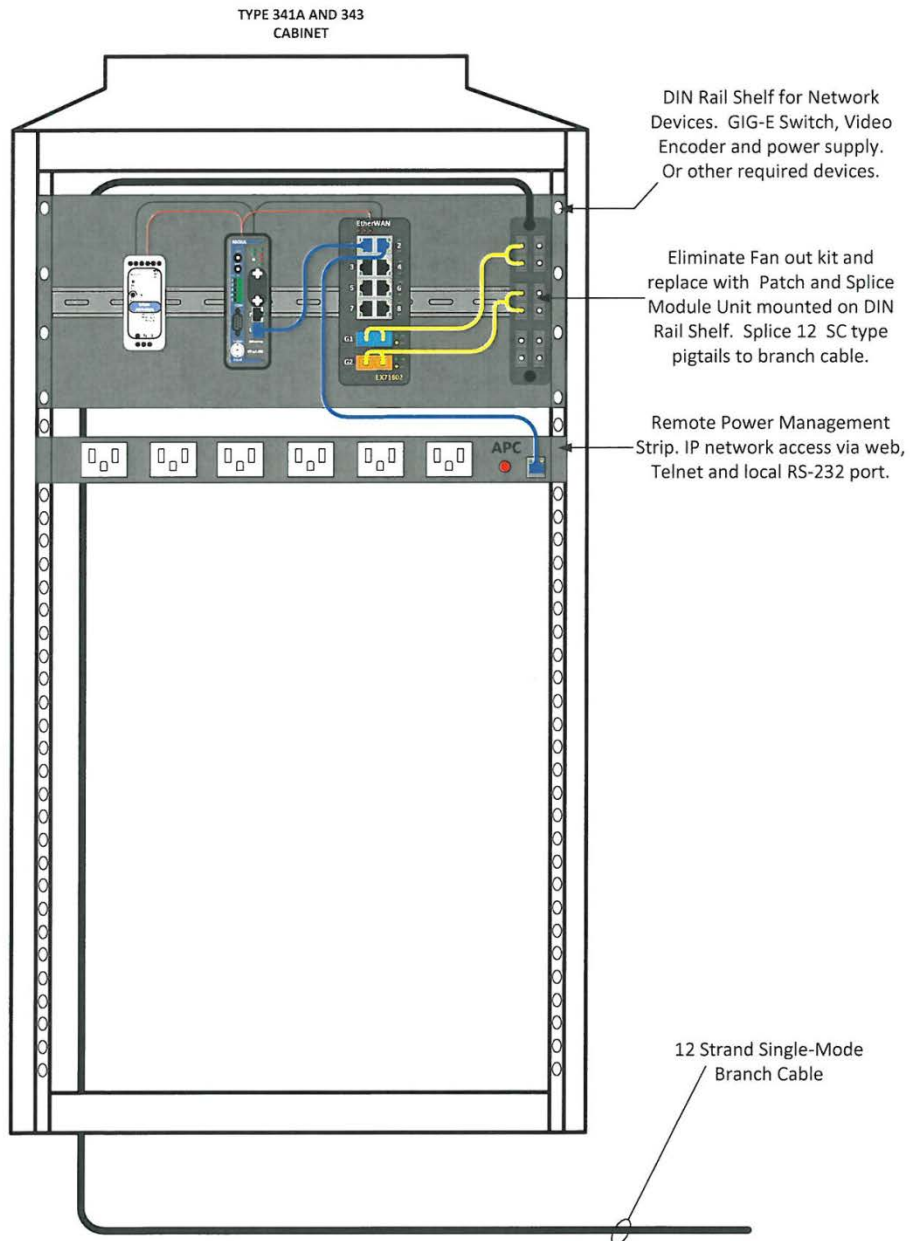
In situations where the project calls for additional devices to be added to an existing load center, the designer shall be responsible for confirming adequate capacity of the existing load center and associated service to accommodate the additional load and submit evidence of such analysis to the Project Manger with the 60% design submittal.

For FMS system implementation, 480-volt power is typically distributed from a load center to each equipment cabinet and stepped down from 480-volts to 120-volts with a step-down transformer located adjacent to the cabinet. A type IV load center cabinet is preferred because it offers the opportunity for both voltage types. The designer shall note that a 25kVa transformer will not fit into the standard ground-mounted stand-alone transformer cabinet.

Designer shall provide wiring diagram for each load center describing the size of all cabinets connected to the load center and associated conductor sizes. A load center table shall be provided by the designer that has:

- load center number
- load center address
- rating of main circuit breaker
- circuit breaker for each FMS device
- its rating
- cabinet number connected to FMS device
- its load
- distance between load center and cabinet
- conductor size
- percentage voltage drop

Designer shall confirm with utility about the location of load centers prior to project advertisement. Power conductors shall be size #4 or smaller for urban highways. Long runs of heavy gauge wire should be avoided because they are most vulnerable to theft. The designer shall use the lightest gauge wire that satisfies the voltage drop requirements.



**Figure 6.1 Fiber Splice Interface**

Multiple FMS devices should be powered from one load center. Situations where excessive distances suggest the use of conductors exceeding size #4 shall consider alternative approaches such as, a line extension by the power provider. Pricing and impacts for approaches shall be documented. A line extension may be a more economical approach - especially since it shifts the burden of some of the voltage drop impact to the power provider. Conductor size #3 shall not be used.

Service addresses for new power services shall be obtained by the designer from the local agency responsible for address assignments, and show the power service address on the project plans and in all correspondence with the power provider. Copies of any and all design sketches from the power provider shall be copied to the Project Manager. Any situations requiring line extensions or power provider work or equipment with a cost to the Department shall be immediately brought to the attention of the Project Manager for guidance on whether such costs will require a separate utility agreement and funding or whether they should be covered in the project under the power service bid items.

The design shall ascertain whether the power provider located within or near a project will require lock-down plans, specific elements of the lock-down plans, and shall be responsible for generating and submitting such plans to the utility for approval.

### **6.3.1 Transformer Cabinet Power Disconnect**

All transformer cabinets shall be equipped with an external power disconnect as shown in the ITS Standard Drawings.

# Chapter 7 Freeway Dynamic Message Signs

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The ADOT Statewide DMS Master Plan was not only a plan of where DMS should be placed on Arizona highways and freeways but also a design guide for DMS.

The FMS designer is to determine if any Freeway DMS locations were previously planned for the mainline corridor that is under design by consulting the Statewide DMS Master Plan and Errata. Criteria for placing Freeway DMS are stated in the Statewide DMS Master Plan. Any deviations shall be documented with justification.

Freeway DMS provide key route guidance and diversion information to the freeway driver; therefore, the proper placement of the signs is essential. Individual DMS locations may be tied to specific diversion routes and their associated exit ramp. DMS sign placements are considered the highest priority and may necessitate the designer to coordinate and arrange for moving other signs, such as guide/destination signs and logo signs. DMS placement requires a power source, communication ability to a node building and TOC, and access by maintenance staff.

Butterfly or “T” structures are the recommended structures for new DMS. The DMS structure shall be designed to accommodate the cone of vision of multiple lanes. If the space required for the butterfly structure along the roadside is not available (because of walls or some other reason); pros and cons of alternatives (such as moving the DMS site or switching to a staple frame) shall be documented by the designer. A recommended alternative shall be presented to Systems Technology Group. A structure for a DMS consists of furnishing all equipment, material, labor, and accessories.

DMS structure foundations:

- require geotechnical soil analysis when soil is rock
- shall be installed during ITS construction phase 1
- shall be drilled shaft

DMS equipment shall conform to the current State procurement contract. DMS shall be full color. DMS shall pass DMS supplier testing, 72 hours subsystem testing, and 30 calendar days system acceptance testing.

DMS on highways throughout Arizona are discussed further in Section 12.1 Rural Dynamic Message Signs.

## Legacy Installations

The reinstallation of any existing DMS on new or modified supports shall require the designer to determine the manufacturer, model, existing mounting support vertical tilt and LED angles to insure reinstallation provides equal or improved DMS visibility. The designer shall provide the Project manager with a visually graphic representation of existing and proposed mounting configurations and resulting LED angles in both the vertical and horizontal planes as evidence of equal or improved visibility. In the event DMS visibility is deteriorated in the proposed configuration, the designer shall submit a documented mitigation strategy to restore DMS visibility.

The designer shall be responsible to identify the correct Standard Drawings series for the DMS support structure and cabinet foundations, based on manufacturer of the legacy DMS to be used.

# Chapter 8 Closed-Circuit Television (CCTV) Camera

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The maximum CCTV camera spacing on the freeway is one mile. It is not unusual to have more than one camera per mile. The proper position of cameras and provision for the required conduit and foundations will be accomplished at the time the FMS is designed. CCTV placement requires:

- a power source
- communication ability to TOC such as fiber
- access by maintenance staff

CCTV poles proposed near airfields (public, private, or military) are required to be reviewed by the Federal Aviation Authority (FAA) to determine height limitations and the need for pole-top illumination.

Designers shall:

- contact the FAA to complete Form 7460
- provide pole location coordinates and pole height
- provide documentation to the Project Manager, at the scoping stage
- determine design requirements
- determine mitigation strategies

## 8.1 CCTV Cabinet (see also Chapter 6)

The CCTV controller housed within the equipment cabinet can be operated at or below 90 VAC. The equipment cabinet is pole mounted. The cabinet shall be grounded to the ground system using a bare solid 8 AWG. Fiber splices and termination shall be in the cabinet. CCTV camera poles shall be equipped with CCTV lowering devices.

## 8.2 CCTV Viewing

CCTV placement shall provide the ability to view:

- DMS and read the messages
- continuous coverage of the freeway mainline
- all traffic interchange ramps and gores
- all system interchange ramps from termini to termini
- all interchange ramp junctions with crossing arterials (typically signalized intersections)

There are two typical locations for CCTV placement, namely:

- at the interchange-- allowing for visibility of the arterial roadway (especially regionally significant roadways), ramps, and the mainline freeway

- at the midpoint between interchanges-- desirable for observing the mainline where the interchange CCTV view is blocked by the arterial overcrossing, or where additional cameras are needed to view roadway geometrics or DMS messages

Possible roadway conditions that require additional cameras for limited ability to view:

- Near the point of intersection (PI) of horizontal curves that restrict visibility to less than ½ mile
- At locations with recurring congestion, and other high interest areas
- On the crests of vertical curves
- Freeway sections where vertical walls restrict visibility, especially around horizontal curves
- Sight lines obstructed by guide signs, lighting and traffic signal poles

The ability to read messages posted on DMS is a priority for placement of CCTV cameras, and may require:

- Mounting a camera at a lower height
- Installing a camera on the same side of the freeway as the DMS to be within the optics of the DMS

Freeway widening projects with existing FMS shall add additional CCTV to provide the capability of reading DMS messages, if messages are not legible to TOC control room operators via existing CCTV. The designer shall develop a graphic documenting that the proposed location and elevation of the CCTV allows for reading DMS messages. The designer shall identify:

- the manufacturer, model, and optics of any DMS (new or existing) to be viewed by the CCTV
- the horizontal and vertical spread of the optical system for that model
- the vertical tilt and horizontal angle of the DMS relative to the roadway
- the height of the proposed CCTV
- the characteristics of the base elevation of the proposed CCTV location

The designer shall be responsible for conducting a field verification of the visual images expected from each new CCTV, based on the specific location and camera mounting height, on existing roadways. Past field verification methods included bucket truck and drone. The purpose of the field verification is to visually document the anticipated views. Such field verifications shall be capable of reaching the proposed CCTV mounting heights at the proposed CCTV locations. The designer satisfies the "ability to view" requirements, by providing the Project Manager with images of the:

- freeway
- ramps
- DMS (existing or proposed)
- items that may impact or obstruct sight lines, such as walls, lighting poles and fixtures, sign structures, and future obstructions (such as new overcrossings, or pedestrian crossings)

The designer shall be responsible for coordinating the field verification with all applicable stakeholders, such as the Project Manager, operations/maintenance staff, and District Permits staff. The designer

shall provide all equipment, vehicles, devices, and traffic control used in facilitating field verification. When scheduling field verification the designer shall mitigate impacts to traffic and identify availability of stakeholders required by the Project Manager.

The designer shall recommend camera sites based on review of field verification images meeting camera criteria. If all the camera criteria can not be met, alternate sites shall be proposed and field verified by the designer.

## 8.3 CCTV Maintenance

Maintenance accessibility requires the CCTV pole be located so that a maintenance vehicle can park within reasonable proximity without necessitating a lane closure or blocking traffic. Where crossroads go over the freeway, the area near the bridge abutment may be a level accessible area well suited for a CCTV pole. A maintenance vehicle can often be positioned partially on the sidewalk if the area behind the walk is clear of landscaping. The area immediately adjacent to the CCTV pole, an approximately 10 foot radius around the pole, should be clear of obstructions and landscaping that may inhibit maintenance staff accessibility to the:

- pole
- pole-mounted cabinet
- transformer pad
- operation of the camera lowering device

Typically, an approximately 10 foot radius, shall be leveled and covered with compacted decomposed granite or decorative rock, matching the surrounding area. When leveling is not possible, the designer shall retain uphill soils and landscape materials from intruding into the level area around the pole. Locations of CCTV poles with ground materials other than decomposed gravel shall be discussed with the Project Manager. The designer shall make provisions in the project documents for leveling and sufficient preparation and treatment of the area around the CCTV pole, including repair of any disturbed irrigation infrastructure.

The designer shall specify in the design documents:

- the type (barrel, dome) and mount of the contractor-furnished camera planned for each particular location
- whether to retrofit a new lowering device on existing CCTV pole installations, or not
- whether to replace existing CCTV, or not
- after the installation of the DMS (to ensure message legibility) the CCTV pole foundation shall be marked in the field and approved by the Engineer prior to construction
- the contractor shall deliver one new-to-ADOT-model CCTV to the TOC so that new-to-ADOT-model CCTV integration with existing camera software can be confirmed.



Designers shall see the ITS Standard Drawings for typical CCTV pole and cabinet configuration. CCTV cabinets shall be mounted on the pole supporting the camera with necessary transformer cabinets located using the same criteria as in Chapter 6.

## Chapter 9 Node Buildings and Communication Nodes

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Communication nodes occur at field devices, node buildings, or at the TOC. Communication nodes receive and transmit data. Data that is received by the TOC provides the status of devices, while data that is transmitted from the TOC makes changes to field device controllers.

Node buildings are located at:

- 15-mile intervals on the FMS (urban freeway ITS) network
- 25-mile intervals for rural networks (see Chapter 12)

A node building is:

- an environmentally controlled secure structure at a field site
- a concentration point for where field device messages are received and transmitted along fiber-optic communication cable trunkline to and from the TOC

New node buildings are modular pre-cast buildings with dimensions such as 12'x15'. Node buildings contain several racks (such as 3 racks for ADOT and 3 racks for others) of electronic equipment for node to field and node to TOC communications. This equipment supports multiplexing video and data signals as well as switching equipment to provide redundant paths of communications for the transmission of field device data and images to the TOC. New node building interiors include:

- a wall mount technician table
- accessible utility outlets
- over temperature switch that uses power distribution panel and strips
- lighting protection
- level 2 surge protection
- grounding system
- two air conditioning units
- uninterruptible power supply, batteries, and automatic bypass switch
- circuit breaker panel board
- cable management channels and routing
- racks, drawers, and chassis
- load center power interface
- wiring

New node buildings shall include the design of the:

- access control system
- building automation system

The designer shall coordinate the Access Control System design and the Building Automation System design with ADOT.

Each potential site should be evaluated to ensure it is clear of any future expansion such as auxiliary lanes, connector-distributor roadways, or frontage roads from ADOT's 5 year plan and other planning documents.

Considerations for node buildings include:

- Floodplain elevation
- Maintenance access including level and accessible all-weather drive, for maintenance vehicle access
- Security
- Distance exceeding clear zone from roadway
- Level, firm, and compacted material for foundation
- Reinforced Portland cement concrete foundation base, with edge footings on all four sides designed and sealed by an Arizona Registered Professional Engineer
- Conduits through foundation and floor of modular building, no wall penetrations
- Exterior texture and color — coordinate with ADOT District
- Heating, ventilation and air conditioning controls, no window AC units
- False floor designed for 250 pounds per square foot total load
- Rack-mounted UPS and power disconnects
- Power source
- Snow loads in higher elevations
- Grounding and Bonding

# Chapter 10 Fiber Outside Plant Design and Modeling

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New projects are required to build trunkline fiber-optic outside plant (OSP) infrastructure. The central core Phoenix FMS fiber-optic cable network has already been connected to the TOC. The STOC node in Tucson may require additional connectivity to the fiber-optic OSP infrastructure. New FMS devices coming on-line will require connectivity to the TOC via new and existing fiber-optic cable and node buildings, requiring project plans and specifications to:

- Verify source and destination of existing spare dark fiber strand proposed to be spliced with new fiber, beginning at the TOC, through every intermediate node building, and ending at the new fiber connection
- Account for dB loss when splicing to dissimilar fibers, splices, and connectors
- Require a rigorous record drawing documentation process, where contractors must document all splice and path loss data
- Determine the path loss and proper installation of the fiber-optic OSP infrastructure through OTDR/power meter testing of all fiber strands in new cables
- Document existing fiber-optic OSP infrastructure
- Document how fiber-optic OSP infrastructure shall be extended to achieve connectivity to existing node buildings and the TOC

## 10.1 OSP Architecture Model

Ideally, an architecture model of the fiber-optic OSP infrastructure (i.e., origination points, cables, splice closures, hubs, nodes, and devices) would accurately depict the following:

- Geographic Information System (GIS) based model of the OSP
- Splice data at every splice point
- Capability to trace a fiber path from the origination point to every FMS device

This OSP architecture model involves two types of data: GIS and tabular:

- GIS data is needed to track the physical location of the OSP. GIS data aids in locating OSP infrastructure quickly when there is a failure on the network. Tabular data tracks the lengths of fiber runs to ensure that fiber losses are accounted for in the design.
- Tabular data describes every fiber strand splice or termination at each node point, i.e., termination point (TOC, node building, or FMS device) or splice closure (No. 9 pull box), including cable foot markings.

## 10.2 Fiber Splice Tables

Table 10.1 and Figure 10.1 through 10.5 depict examples of five levels of detail used to describe the OSP architecture model.

**Table 10.1 OSP Model Description**

LEVEL	MACRO TO MICRO	DESCRIPTION OF COVERAGE	HISTORICAL EXAMPLES
1	Macro	Overall FMS Communications Diagram	Fig. 10.1
2		Access Point-to-Access Point	Fig. 10.2
3		Splice Point-to-Splice Point	Fig. 10.3
4		Splice Detail	Fig. 10.4
5	Micro	Individual Splice Table	Fig. 10.5

For current plan sheet examples, designers shall review recently completed record drawings on ADOT's ROAD website. Typical plan sheets may include:

- Node building rack elevation
- Node Communication includes patch panel detail inside node building
- Node Communication circuits to field devices
- Trunk fiber assignment detail
- Node to Node connection block diagram

Fiber-optic splice information is the foundation of the OSP database. This information is useful in different forms to different users:

- Designers and System Managers typically need network information, at a macro level view. They concentrate on connecting individual devices to the TOC via the overall network. Details from the macro to the micro level are necessary to design and manage the system. Figure 10.1 through Figure 10.4 illustrate the typical design progression from system, nodes, freeway segments, down to cable segments.

- Contractors and ADOT operations/maintenance staff typically need information focused on one specific problem area, usually a splice closure or termination point, hence a micro level view. Finding a specific problem area typically involves a search of documents starting at the macro level and moving to the micro level to “zero in” on the problem.

The smallest level of interest is a single splice closure point. An example of a single splice detail, showing the splices before and after construction, is shown in Figure 10.5.

Fiber buffer tube assignments, per 12-fiber tube, within a typical 144 strand fiber cable shall be:

- 1 - 2 ITS Devices, DMS, CCTV, Ramp Meters
- 3 Node backbone
- 4 Traffic Signals, Pump Houses, Wrong Way Detection-
- 5 - 9 Future Use
- 10 - 12 Inter-Agency, Cities, RCN, 911-backup

Similarly, fiber buffer tube assignments, per 12-fiber tube, for a legacy 96 strand fiber cable shall be:

- 1 - 2 ITS Devices, DMS, CCTV, Ramp Meters
- 3 Node backbone
- 4 Traffic Signals, Pump Houses, Wrong Way Detection
- 5 - 6 Future Use
- 7 - 8 Inter-Agency, Cities, RCN, 911-backup

**Table 10.2 Fiber Tube Assignments**

144 SMFO	USE	96 SMFO
1	its	1
2	its	2
3	node	3
4	its	4
5	future	5
6	future	6
7	future	
8	future	
9	future	
10	others	7
11	others	8
12	others	

Limit of 12 devices on a single fiber pair. These 12 devices shall all be of a similar type such as, all DMS, or all CCTV.

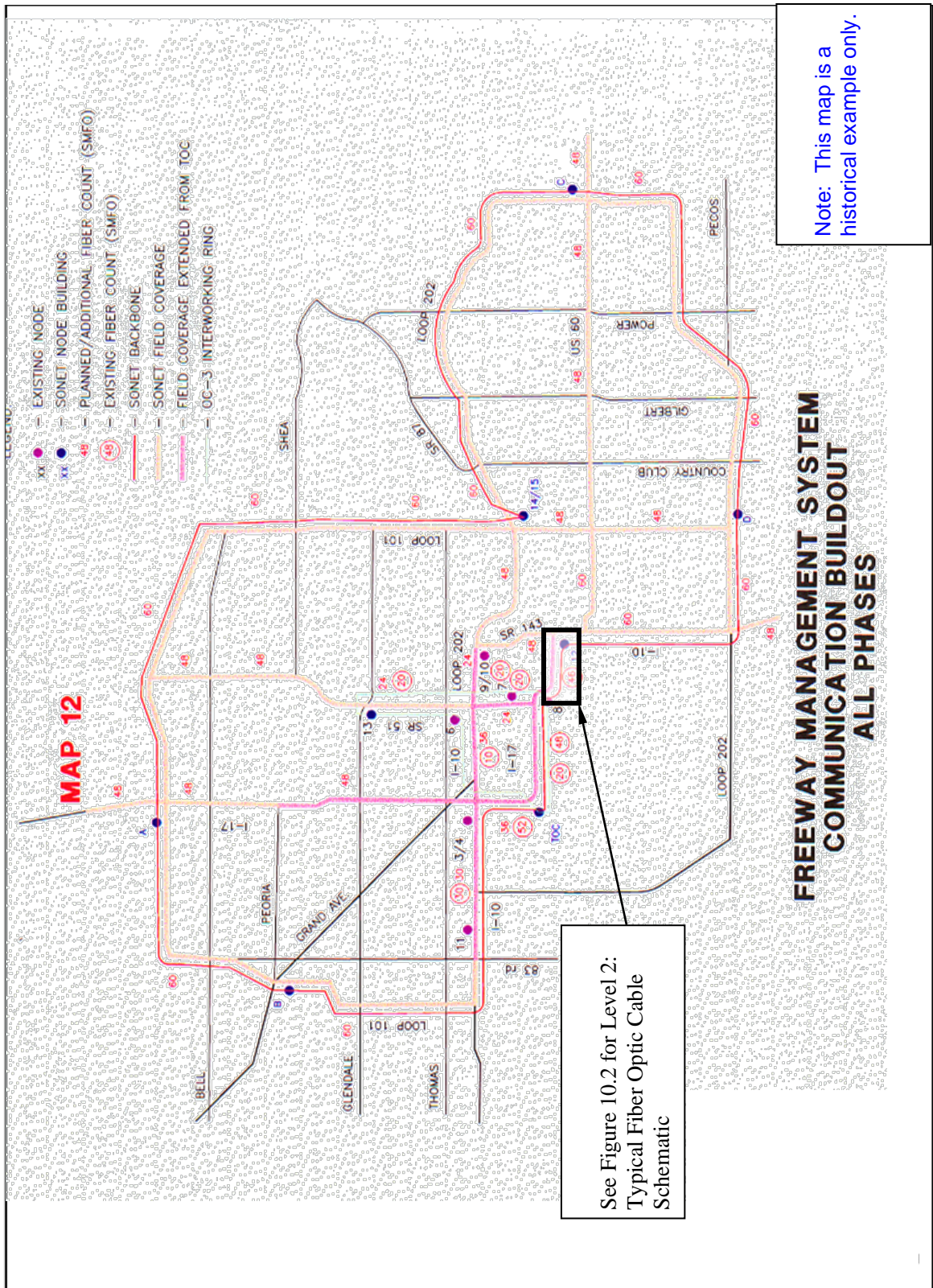


Figure 10.1 Historical Level 1 Typical Fiber Optic System-wide Schematic

999

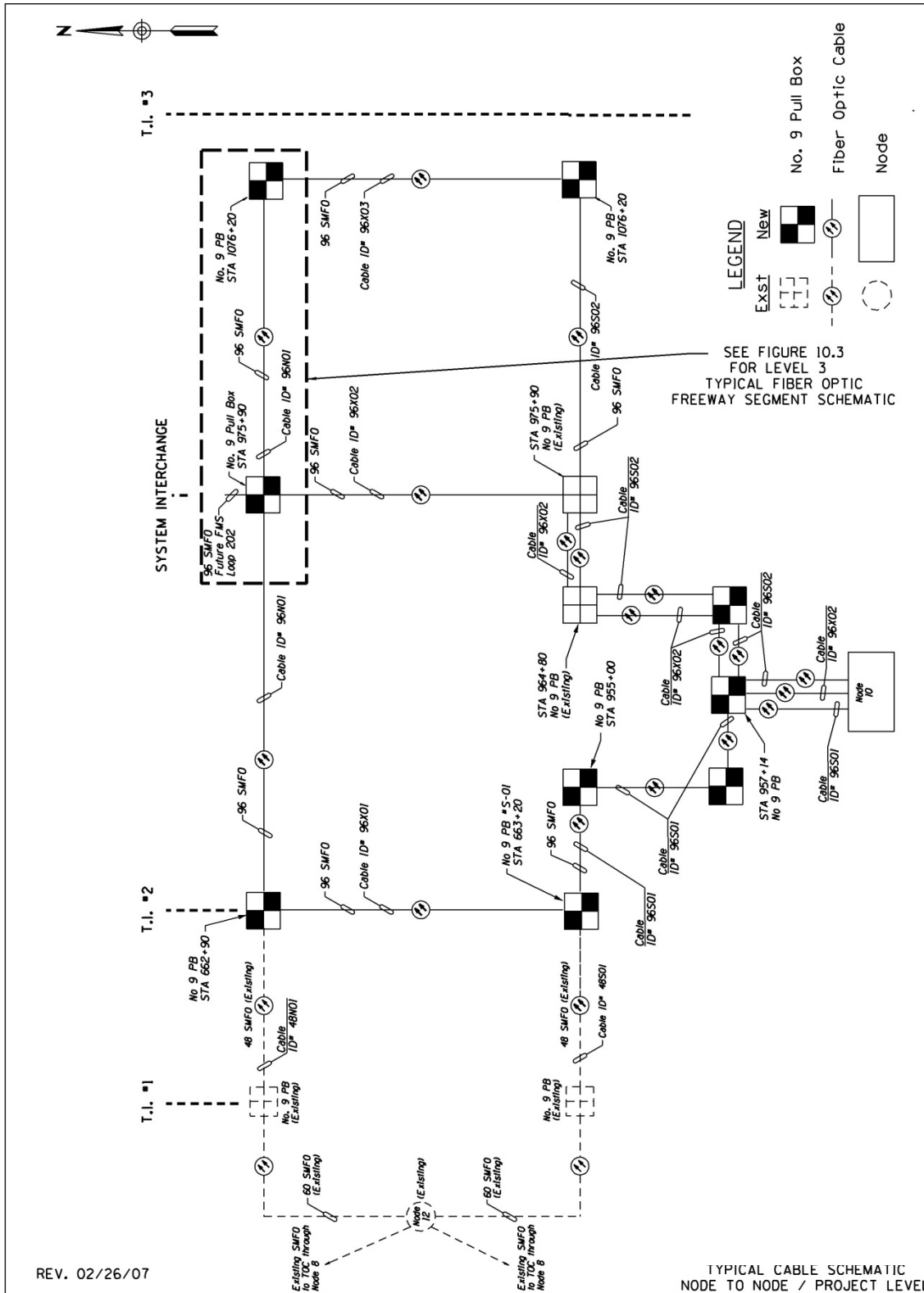


Figure 10.2 Historical Level 2 Typical Fiber Optic Cable Schematic



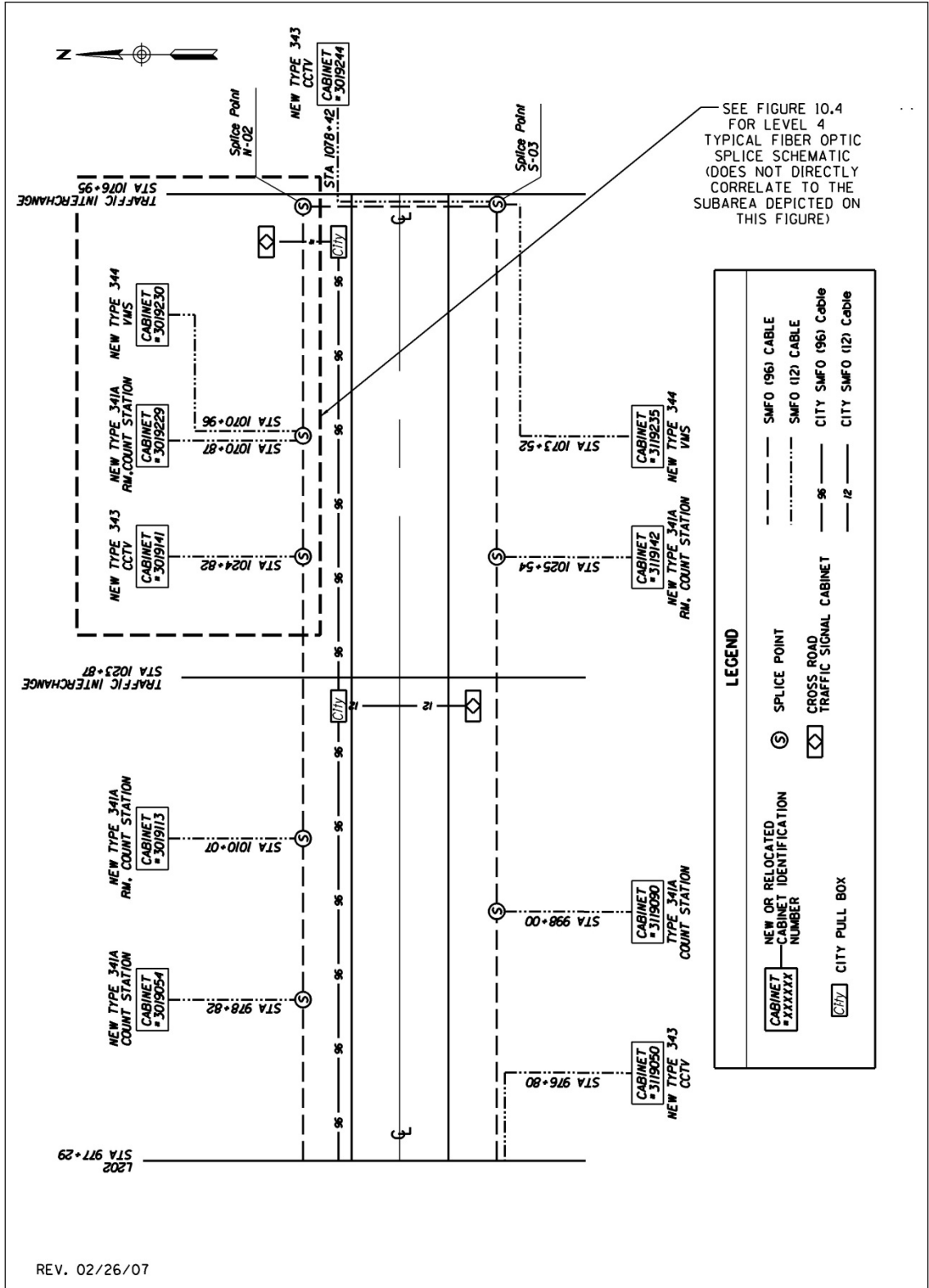


Figure 10.3 Historical Level 3 Typical Fiber Optic Freeway Segment Schematic

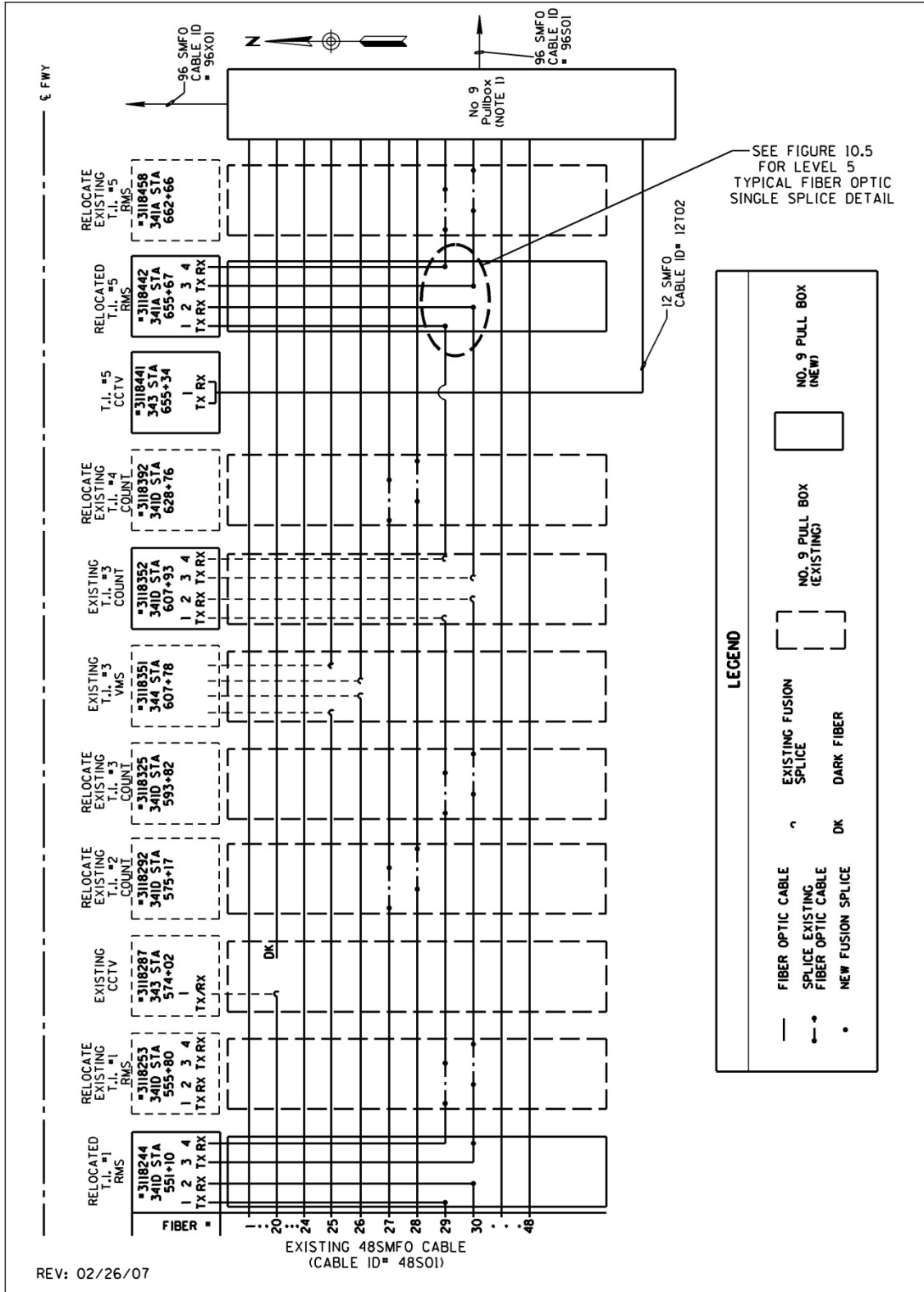


Figure 10.4 Historical Level 4 Fiber Optic Splice Schematic

*Typical Field Work Order for Splicing at a Single Location*

CABINET 3118442		
SPlice DETAILS		
SPlice LOCATION STA 655+67-WB		
Cable #4	8SMFO	Cable #4
Cable ID 48 SO1	To	Cable ID 48 SO1
From No. 9 @	Cabinet	To No. 9 @
628+76	3118442	662+66
Fiber	Fiber	Fiber
	1	
	2	
	3	
	4	
	5	
	6	
	7	
	8	
	9	
	10	
	11	
	12	
29		29
30		30

**Before Construction**

CABINET 3118442					
SPlice DETAILS					
SPlice LOCATION STA 655+67-WB					
Cable #4		8SMFO	Cable #4		
Cable ID 48 SO1		To	Cable ID 48 SO1		
From No. 9 @		Cabinet	To No. 9 @		
628+76		3118442	662+66		
Cable Ft Marking		Cable Ft Marking		Cable Ft Marking	
In	Out	In	Out	In	Out
5300	N/A	100	183	N/A	5400
Fiber		Fiber		Fiber	
29		1			
30		2			
		3		29	
		4		30	
		5			
		6			
		7			
		8			
		9			
		10			
		11			
		12			

**After Construction**

**Figure 10.5 Optional Level 5 Fiber Optic Single Splice Detail**

# Chapter 11 Testing

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FMS construction culminates with a series of tests that confirm the full functionality of each component, subsystem, and the overall FMS. The designer must understand the rationale for these tests, the actual test requirements and procedures, the required test equipment and how the tests are reported in a written document to the Engineer. ITS Test Forms can be found on [azdot.gov](http://azdot.gov).

FMS tests are crucial to the successful completion of the FMS construction. ADOT has gained considerable experience with the testing and results of these key tests. The designer shall refer to successful past projects for specific testing requirements, and pass/fail criteria. Items not covered shall have a project specific Special Provision developed by the designer to specify testing procedures and criteria, and approved by stakeholders. Starting at Stage III (60%), project submittals must include all the test procedures required for the project. It will be the designer's responsibility to coordinate with the ADOT PM to confirm the test procedures.

## 11.1 Stand Alone Test

The Stand Alone Test is intended to verify that the functionality of each FMS device (one by one) is fully compliant with the FMS standards. This test is conducted in the field at each individual FMS device location. The device must be proven to operate per specification, independent of interconnection to the FMS software through the communication network. This test does not involve ADOT Traffic Operations Center Control Room staff.

## 11.2 Subsystem Acceptance Test (SST)

The SST verifies the communications system and device firmware with the respective FMS equipment for each subsystem such as CCTV cameras, DMS, ramp meters/detection stations and thermal cameras. Databases for each device type are typically updated and communications circuits are integrated at the TOC by ADOT. Communications with each device in the network is then monitored from the TOC by ADOT for a 72 hour test period, using test software specifically for the ADOT FMS databases.

## 11.3 System Acceptance Test

The final test is a 30 calendar day full System Acceptance Test, comprised of the proper operation of the overall system. The System Acceptance Test is typically conducted by the Traffic Operations Center Control Room Staff to verify the system operates as expected in day-to-day operations.

# Chapter 12 Rural Applications

There are a variety of Rural Highway ITS applications such as:

- Rural Dynamic Message Signs (Rural DMS)
- Truck Escape Ramps Detection and Warning Systems
- Rural Closed-Circuit Television (CCTV) Cameras
- Dust Warning System
- Direct Bury Fiber

Each rural ITS application has various stages of maturity and development. The following sections address those which have a mature evolution, suitable for providing specific direction. The others should be considered "in development" and subject to eventual evolution to a suitable level for direction. In the meantime, those applications are subject to the direction of the Project Manager to the designer.

Additional rural ITS applications	Managed by ADOT
Remote Weather Information Systems, RWIS	TSMO Traffic Management
Weigh-in-Motion, WIM	MPD Traffic Monitoring
Node network equipment	ITG staff at the Traffic Operations Center
Speed Feedback Signs Variable Speed Limit, VSL signs	TSMO Safety
Rural Traffic Signal Interchange communication	TSMO Systems Maintenance

## 12.1 Rural Dynamic Message Signs

Rural dynamic message sign (Rural DMS) differ from the urban highway applications in several ways:

- Size and Type of DMS
- Support Structures
- CCTV Provisions
- Communications Provisions
- Power Provisions

Determining the site of the rural DMS includes:

- Identifying all the stakeholders specific to the DMS site, such as:
  - State and Federal Parks
  - Various Native American governments
  - the ADOT District
  - ADOT operations/maintenance staff
  - Authorized representative of the power utility
  - ADOT utility staff
  
- Inviting all stakeholders to a field meeting at each proposed site to determine suitability of the site based on the following criteria:
  - availability of power
  - ability to communicate to the TOC
  - visibility to traffic
  - the location that will maximize the purpose of the DMS
  - aesthetics
  - environmental restrictions related to cultural sites
  - proximity to other signs
  - accessibility to maintenance staff
  
- Completing the following tasks at the field meeting:
  - bring previously reviewed records or plans of existing features and right-of-way locations
  - make observations
  - conduct field measurements
  - take site and stakeholder photos
  - prepare other documentation, in support of evaluating and documenting the site characteristics
  - confirm line of site to a specific mountain top
  - note signal strength of a specific cellular carrier at a field site
  - obtain GPS coordinates of a rural DMS site
  - confirm method of power provision:
    - conduit size
    - overhead or underground
    - conduit contents
    - responsibilities of ADOT versus utility
  - confirm power location

The District in which the DMS is to be located shall have input and any concerns, suggestions, or requests by District shall be respected, noted, and accommodated as directed by the Project Manager.

Rural DMS may require maintenance pads adjacent to the paved shoulder, for sign access, depending on Type, and support arrangement. All rural DMS equipment shall be safely accessible for ADOT to maintain and operate.

DMS equipment includes:

- DMS
- support structure
- cabinet
- power facilities

### 12.1.1 Size and Type of DMS

DMS shall be procured by the contractor. ADOT's DMS contract offers a variety of DMS sizes. In some cases, the decision as to which Type of DMS depends on roadway classification, or whether use of an existing support structure influences DMS size due to structural limitations. For example:

- Interstate highways and certain wide or high speed state highways may use the large Freeway Front Access DMS, similar to those used in the metropolitan area FMS application.
- The next smaller size, Intermediate front access, may be directed for use on butterfly supports where the speeds may be lower or the highway of less width. Large Arterial size signs may be used roadside, but are limited in character size - a consideration when associating message recognition with traffic speed.
- The Small Arterial size signs are scaled for arterial street applications, with limited message size.

### 12.1.2 Support Structures

Recent DMS structures include the single post or "butterfly" for a reduced cost and shall be designed as part of the project. Butterfly or "T" structures are the recommended structures for new DMS. The DMS structure shall be designed to accommodate the cone of vision of multiple lanes. If the space required for the butterfly structure along the roadside is not available (because of walls or some other reason); pros and cons of alternatives (such as moving the DMS site or switching to a staple frame) shall be documented by the designer. A recommended alternative shall be presented to Systems Technology Group. A structure for a DMS consists of furnishing all equipment, material, labor, and accessories. Rural DMS applications have utilized a variety of support structures, including the typical 2-legged "tubular" DMS support structure familiar to the urban FMS system (also referred to as a "staple"). Support structures shall be evaluated and certified by an Arizona registered Professional Engineer when deviating from the use of standard drawings for structures.

Existing 2-legged tubular structures were designed to support a single or double overhead large DMS. Existing legacy support structures were designed and used for specific manufacturers and models of DMS.



All DMS have unique

- weight
- wind loading
- vertical mounting angle characteristics

that generally prohibit the transferable use of an existing structure for a subsequent different DMS support situation without structural verification. Any structural verification of any existing structure shall start by obtaining and evaluating the record drawings from the original installation. The designer shall, in no case, assume the installed support conforms to any issued standard drawing at the time of design, or project plans, as they do not represent subsequent field adjustments or other potential allowed variations. A field visit is required to determine the angle of the DMS and other site specific details.

Designers shall be aware that a variety of combinations of rural DMS types and support structures other than the overhead tubular support have been deployed. Prior installations have used roadside 2-legged supports for Intermediate and Small DMS, and overhead support applications of multiple Intermediate DMS.

The designer shall evaluate position of the support structure, relative to the LED aspects of the specific subject DMS, and account for sufficient visibility to approaching traffic in terms of angle of the support relative to the roadway alignment.

Support structures that cannot be placed outside of the clear zone applicable for the field situation at hand shall be provided with sufficient protection in the form of barrier, guard rail, or crash barrels.

### **12.1.3 CCTV Provisions**

Rural DMS typically employ CCTV for the purpose of viewing the roadway and for viewing the face of the DMS to confirm the message has been properly displayed. Over the years, various forms of CCTV mounting, placement, interface equipment and connections have been used. Recognizing the dynamic nature of the CCTV concept for rural DMS, the designer shall confer with the Project Manager at project initiation to determine the type and approach to CCTV to be deployed on a project, and to determine which components are to be contractor furnished and installed. The designer shall confirm CCTV model numbers prior to advertising.

### **12.1.4 Communication Provisions**

Rural DMS communications, over the years, have used telephone lines, cellular, and radio technologies to various levels of success for the DMS and CCTV connections. New rural DMS shall use fiber or cellular for communications and CCTV images between the TOC Operator and the DMS. The use of multiple

technologies is a result of variations in bandwidth needs between the two applications, and is subject to revision as new technologies and capabilities are deployed.

Designer responsibilities at project initiation include:

- Coordinate with the Project Manager and identify stakeholders
- Identify which technologies are to be used at which locations and in which manner
- Clarify designer field responsibilities prior to field meeting of the rural DMS

Wireless communications requirements are presented in more detail in Chapter 13, Wireless Communications.

### 12.1.5 Power Provisions

Rural DMS final locations are influenced by the availability or the ability to provide power. The designer shall make a preliminary evaluation of the proposed rural DMS site based on the original milepost location at project initiation, to determine if power is observed in the field in the vicinity of the desired location. The preference is to locate rural DMS near a suitable power source, considering the ability to provide the desired level of load and voltage as determined by the specific quantity and Type of DMS to be operated.

If power is not readily available at the preferred location, a utility company may provide power, such as a "line extension", extending their power infrastructure to the DMS, at a cost paid by the Department.

The designer shall determine:

- any and all costs for the provision of power at all rural DMS sites
- provide such information to the Project Manager

Stakeholders' preferred DMS location might not be affordable based on the cost to provide power. The DMS location may need to move closer to a power source to stay within the project budget. Costly power arrangements, as determined by the Project Manager, may require a separate execution of a Utility Agreement to compensate the utility outside of the bid items for the project's construction.

All rural DMS site selections shall include field confirmation between the designer and an authorized representative of the power utility to both:

- physically be present
- agree to the location and method of power provision

Some power entities dealing with rural locations may require fees to meet, review plans, or evaluate and design service provisions. Such situations require the designer to coordinate activities with:

- the Project Manager
- the ADOT Utilities and Railroad (URR) representative assigned to the project

The ADOT URR representative shall assist the designer in determining what utility entity applies in a specific location, and who the contact person is. Both the ADOT URR representative and the designer will be copied on all dealings with any utility.

Any situations that imply the need for acquisition of easement outside of established ADOT right-of-way shall be immediately brought to the attention of the Project Manager for direction. It is preferable that such situations be avoided. Easements require environmental evaluation and documentation and represent additional "environmental footprint", possibly adding delay and costs to the design process. Power provisions, not involving easements or costly arrangements, are covered under the bid items as Force Account items reimbursable to the contractor during construction.

Service addresses shall be obtained by the designer from the entity responsible for address assignments in the geographic area of the DMS. This may be the county, town/city or other authority. In some case, typically along Interstate highways, a milepost designation will be used. In all cases, the designer shall be responsible to verify with the power utility the acceptability of the address format such as milepost, street address or GPS coordinates to avoid delays in power company dealings during construction. The designer shall confirm with the Project Manager the form of power service and load center type such as:

- Type II Load Centers, to allow for additional future circuits for other ITS features
- Meter pedestals
- Transformers, to boost or reduce voltages, as site conditions require

The designer shall be familiar with multiple forms of power provision, conduct voltage drop analyses and size conductors and power equipment accordingly. Even in the most rural of environments, other utilities may exist. The designer is responsible for:

- identifying
- locating
- showing all utilities on the plans

Utility logs are available on-line from ADOT URR, and shall be supplemented by Design Blue Stake research. Ultimately, this information is necessary to obtain utility clearance from ADOT URR prior to bid.

## **12.2 Other Rural Applications**

### **12.2.1 Truck Escape Ramp Detection and Warning Systems**

ADOT has deployed detection and fixed frame cameras at some truck escape ramps.

### **12.2.2 Conduit and Fiber Optic Cable**

A new rural application is plowed and armored fiber optic cable on one side of the roadway. This new rural application requires 4 foot delineators. Also called direct bury fiber, one rural project (H7984) used two 1 ¼ inch cable instead of one 3 inch cable. See Chapter 4 for urban applications of conduit and fiber.

## Chapter 13 Wireless Communications

Wireless ITS communications may be an alternative to the installation of fiber optic trunk line or other suitable hard-wire cable when the following conditions occur:

- Right-of-way temporary construction easement needed,
- Lack of right-of-way
- Restricted right-of-way
- Environmentally sensitive areas
- Temporary installations
- Construction zone applications

Wireless solutions may apply in urban environments, especially for difficult to connect or temporary applications.

If wireless communications are required, the designer shall add:

- A Radio Frequency (RF) Engineer to the design team. The RF Engineer needs experience in designing wireless communications systems, including radio propagation modeling and prediction, microwave path analysis, interference analysis, and frequency coordination. Wireless designers shall provide supporting qualifications and references of existing jobs and projects, upon request of the Project manager.
- Contractor Qualifications to the Special Provisions. The designer shall develop project special provisions that require that the contractor shall provide a Communications Technician with experience in deployment of RF communications systems and test equipment. Minimum specified qualifications shall be two years of progressively responsible experience in the Radio Frequency (RF) technology including installation, maintenance, and repair of electronic and radio communications systems and programming, tuning, and aligning mobile, portable and fixed radio equipment. Project special provisions shall require supporting qualifications and references of existing jobs and projects, upon request of the Engineer.

Wireless communications vary from:

- Low bandwidth, point to multi-point systems
- High bandwidth, point-to-point systems

Point-to-multipoint systems communicate with multiple locations/devices from a single access point radio.

For reliable radio transmission, most systems require direct line of sight between antennas. The distance is limited by:

- power
- frequency
- free space loss

As the frequency increases, line of sight becomes more critical.

## 13.1 Licensed vs. Unlicensed Wireless

Licensed radio systems are the preferred type. Licensed radio systems will minimize problems with radio emissions or interference from other systems. Licensed frequencies from the FCC can be acquired by frequency coordination and administrative paperwork.

Unlicensed systems may be used for short range links. The use of spread spectrum may work since spread spectrum is designed for tolerating interference.

## 13.2 Site Survey

All design projects involving wireless communications shall require a detailed site survey.

This survey shall analyze:

- the terrain
- line of sight

This survey shall identify and locate sources of:

- frequency in use
- RF requirements
- other wireless devices that are close enough to interfere with the communication
- interference that can degrade performance

This survey shall measure:

- signal strength
- signal quality
- noise levels

At the conclusion of this survey, a report shall be developed by the designer to detail:

- the communication links
- bandwidth performance
- results with “heat” and coverage maps

The report shall be provided at Stage III (60%), for review and approval. Deficiencies in the procedures or results shall require mitigation.

## 13.3 Installation and Testing

The designer's project plans and special provisions shall require the contractor to:

- perform a line of sight survey prior to installation of each RF link

- Identify any obstructions or other factors that would affect the RF communications
- perform a RF test to verify each RF link meets the project performance specifications provided by the designer before permanently installing the radio, to prevent the installation of radios that do not perform to specifications

The designer shall develop project special provisions for the contractor to use an Ethernet bit rate tester with the RFC 2544 option to test for:

- throughput
- frame loss
- latency
- packet jitter
- burst-ability

A radio link stress test will be performed to verify that the radios will pass payload traffic within project specifications determined by the designer's RF engineer. The RF budget shall provide greater than 20 dB of fade margin per link.

# Chapter 14 Wrong Way Detection Pilot

Thermal Cameras detect wrong way driving at exit ramps through cross road installation on:

- existing ADOT maintained interchange signal mast arms
- new Type H poles when interchange signals are maintained by local agencies

Results from The Pilot Wrong Way Driving Detection System were not available to include and will be addressed in the future. The Pilot Wrong Way Driving Detection System consists of the following:

- Thermal Camera Detection System including
  - Thermal Ethernet and BPL (broadband over power line) cameras which detect up to 6 mainline vehicle lanes
  - Cables
  - Conduit
  - Detector cards
  - Expansion and Interface cards
  - Mounting system
  - Accessories
  - 2 amp minimum power supplies on the
    - Mainline freeway
    - Exit ramp
    - Interchange
- Illuminated Wrong Way sign assemblies including 15 amp circuit breakers
- Closed Circuit Television Cameras
- Single Mode Fiber Optic Cable
- Media Converters and as needed
  - Breakaway base
  - Cabinets
  - Conductors
  - DIN rail
  - Enclosures
  - Extenders
  - Fiber patch cords
  - Fiber termination units
  - Foundations
  - Innerducts
  - Isolator cards
  - Poles
  - Pull boxes
  - SC connectors
  - Splice Closures
  - Traffic Signal Wire



Figure 14.1: Thermal Image



# PROTOTYPE DEPLOYMENT

## WRONG-WAY DRIVER ENTERS THE RAMP



15-448