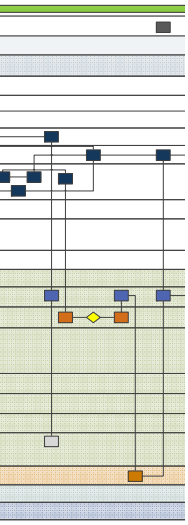
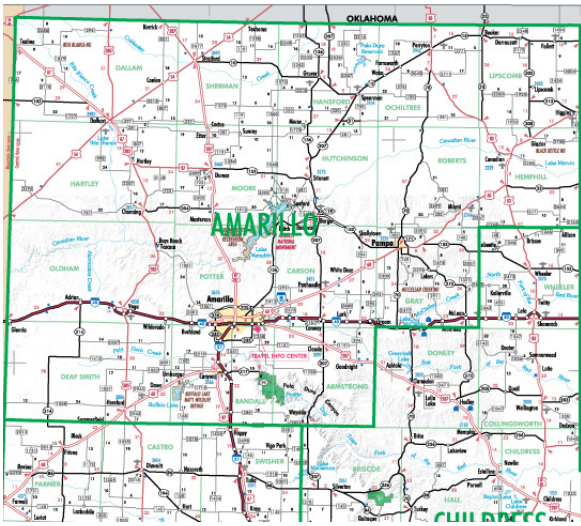
TRANSPORTATION SYSTEMS MANAGEMENT AND OPERATIONS (TSMO)





AMARILLO DISTRICT ITS MASTER IMPLEMENTATION PLAN

March 2021

Texas Department of Transportation

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Disclaimer: ITS Master Plan represents recommended improvements. ITS will be deployed as funding is secured, project prioritization may change without notice.

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Executive Summary

To maximize the benefits of Transportation Systems Management and Operations (TSMO), the Amarillo District (AMA) of the Texas Department of Transportation (TxDOT) developed an Intelligent Transportation Systems (ITS) Master Implementation Plan (MIP). The MIP identifies ITS strategies including software integration, communication, dynamic message signs (DMS), closed-circuit television (CCTV) cameras, roadway weather information systems (RWIS), high water detection systems (HWDS), and truck parking availability that will be implemented to help improve the daily safety and operations of the highway system.

TxDOT selected ITS strategies based on the needs and requirements of the Panhandle region. These strategies were developed into projects and targeted installations of equipment along priority highways within the study area. Implementation is associated with upcoming roadway construction projects and by stand-alone ITS projects over the next 10 years.

Over that period, the Amarillo District's ITS Master Implementation Plan includes recommendations for the installation of 221 new devices, improvements to the Traffic Management Center (TMC) and utilization of additional software features, and the implementation and/or expansion of work zone management, traffic incident management, and information dissemination programs. The total estimated capital cost for these projects is about $17.5 million with the estimated design and study cost at about $2.75 million. The estimated cost of priority projects is about $8.86 million with a design cost of about $1.05 million.

The Master Implementation Plan includes Geographic Information System (GIS) and Keyhole Mark-up Zipped (KMZ) files with georeferenced project information for the projects recommended in the plan. TxDOT will use these files, along with the tables in this report, as a starting point for programming the ITS projects.

Introduction

This Intelligent Transportation Systems (ITS) Master Implementation Plan (MIP) identifies traffic management and safety strategies that will help to increase safety on roadways and improve operations on corridors in the Amarillo District (AMA). The primary objective of this plan is to document the Amarillo District's existing ITS assets, and identify ITS needs and priorities for implementation over the next 10 years.

The MIP defines recommended deployments and system enhancements over the next 10 years along priority corridors within the Amarillo District's 17 county study area. The AMA District has some unique weather challenges and also shares borders with 2 adjoining states, New Mexico and Oklahoma.

The primary corridors, which encompass the City of Amarillo and surrounding counties in the study area are listed in **Table 1**, and are also highlighted in blue in Figure 1, the Study Area map. By collaborating with partner agencies and implementing data-driven decisions as a result of this ITS MIP, the Texas Department of Transportation (TxDOT) will improve the safety and mobility of the traveling public in the Amarillo District.

Table 1: Project Limits of Study Corridors

Highway	Begin	End	Length (mi)	Existing ITS Devices
I-40	TX/NM State Line	Gray County Limit-East	143.93	Yes
I-27	I-40	Randall County Limit-South	33.48	Yes
US 287	TX/OK State Line	Armstrong County Limit-East	96.15	Yes
US 60	TX/ OK State Line	Deaf Smith County Limit-South	155.08	Yes
US 87	TX/ NM State Line	Randall County Limit-South	156.85	Yes
Bus I-40	I-40	0.57 Mi East of FM 1912 / Masterson Rd	20.00	Yes
US 54	TX/NM State Line	TX/OK State Line	91.5	No
SL 335	-	-	39.97	Yes

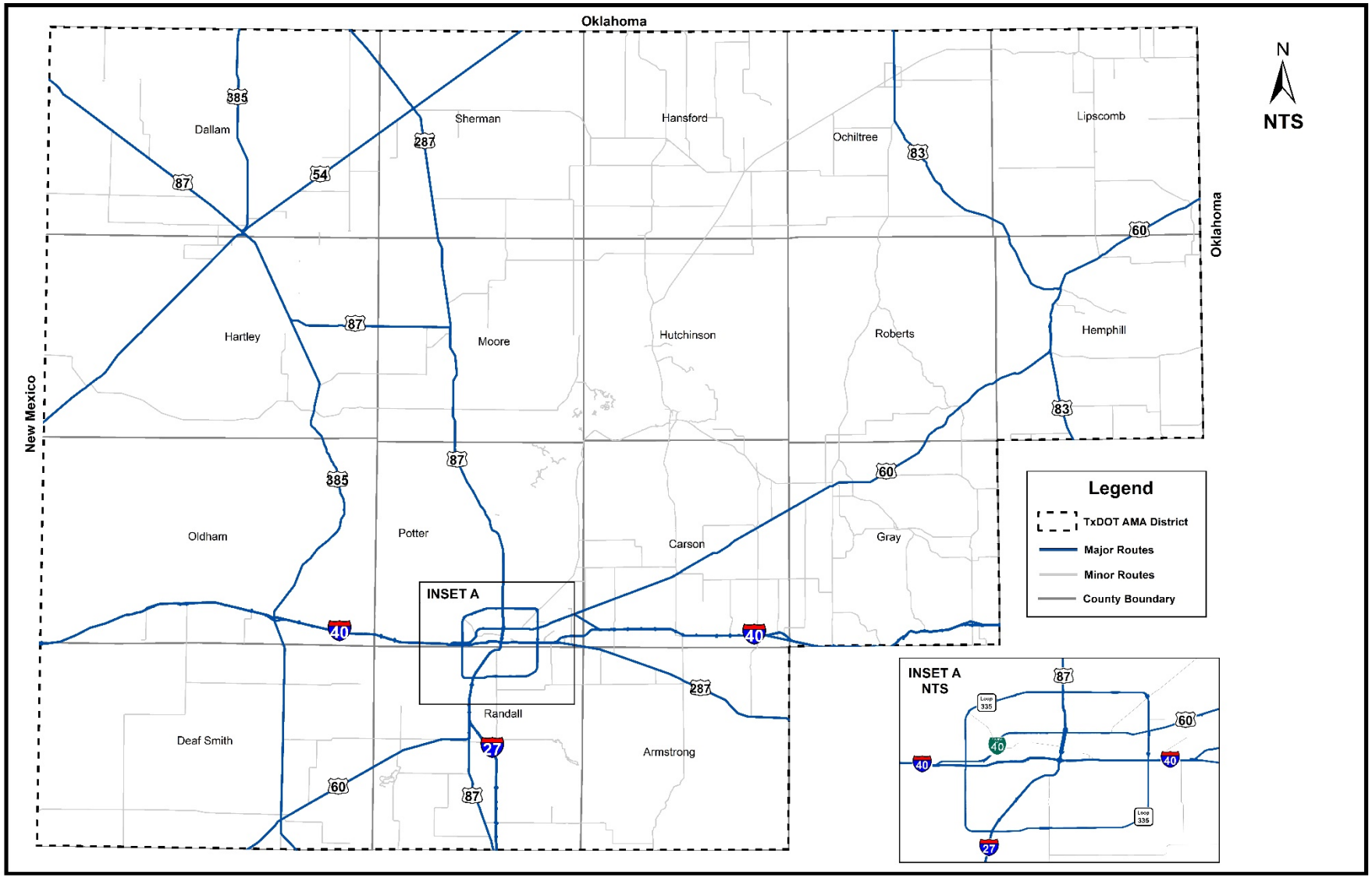

Figure 1: Study Area

Existing Conditions

Understanding the existing conditions of the system is key to effectively proposing ITS traffic management and safety strategies for the Amarillo District. The existing conditions were documented in three distinct ways. First, stakeholder feedback, collected through an existing conditions workshop, highlighted TxDOT goals with input from the City of Amarillo and other stakeholders to improve the current system and gather concerns about everyday operation of existing ITS devices. Second, the development of an inventory, which identifies and quantifies the current ITS devices deployed in the study area, provided insight into the current ITS state of the practice in AMA. The third method was to recognize the areas of opportunity for the deployment of ITS traffic management and safety strategies by reviewing the District Safety Plan, reviewing the operation of the roadways and engaging in a stakeholder work session with District staff to discuss potential new deployments.

Existing Conditions Workshop

Identifying and addressing stakeholders' needs and opportunities is an important factor for the success of ITS traffic management strategies. An existing condition workshop was conducted in conjunction with the Transportation Systems Management and Operations (TSMO) kick off meeting on January 16, 2020, at the Amarillo TxDOT office. This meeting was attended by the TxDOT District TSMO Steering Committee, TxDOT Traffic Safety Division, TSMO support staff, and the AECOM TSMO development team. Stakeholders in the meeting identified the data currently collected through the existing ITS devices, current operations issues, and challenges with past technologies. The group determined the significant goals of which proposed project upgrades and ITS initiatives should be implemented by the District. The following summarizes the major findings identified in this meeting:

- ITS inventory consists of closed-circuit television (CCTV) cameras and dynamic message signs (DMS).
- Fiber optic communication, vehicle detectors (radar/microwave) have not historically been part of the AMA ITS system.
- Roadway weather information systems (RWIS) were used in the past but not currently part of the ongoing District technology efforts.
- Speed and travel time data is collected through a third-party system, INRIX, through a state-wide plan currently used by TxDOT but is not currently being disseminated to the traveling public.
- City of Amarillo maintains all traffic signals within the city limits.
- Opportunities should be identified to share resources with the City of Amarillo.
- TxDOT operates a basic TMC in the Transportation Operations office during regular office hours of 8:00 AM to 5:00 PM, Monday through Friday.

The **Amarillo District ITS Implementation Plan Workshop** was conducted via an online virtual meeting on April 29, 2020. This meeting was attended by 20 Stakeholders which included staff from TxDOT AMA District Transportation Operations, TxDOT Traffic Safety Division, FHWA, Amarillo Metropolitan Planning Organization

(MPO) staff, Regional Planning staff, Potter County Sheriff, cities of Amarillo and Pampa along with the AECOM TSMO development team. The purpose of this meeting was to introduce the Stakeholders to the current TSMO and ITS efforts of identifying the existing deployments in the region and discussing challenges such as working with 2 adjacent State DOTs and enforcement agencies. At the conclusion of the meeting, participants were surveyed to identify the ITS goals, needs and priority corridors as seen by the key stakeholders in the region.

In response to the question, "Rank the Following **ITS Goals**, in order of importance, for the next 10 years, with 1 being the highest priority and 6 being the lowest", the goal of "Improve Highway Safety" was identified as the highest priority. The results of the survey are shown below listed in order of ranking:

Table 2: ITS Goals - Survey Results

ITS Goal	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Rank 6	Average Rank	Total Respondent
Improve Highway Safety	10	2	0	0	0	1	1.54	13
Dedicated ITS Funding	2	5	1	4	0	1	2.85	13
Improve System Reliability	1	4	2	4	2	0	3.15	13
Regional ITS Coordination with other Stakeholders	2	4	3	0	1	3	3.23	13
Deploy new ITS Strategies/Technology	1	2	2	3	4	1	3.77	13
Develop Performance Measures of ITS System Effectiveness	0	2	2	0	5	3	4.42	12
Other (please specify)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1

In response to the question, "Prioritize each of the corridors below regarding ITS deployment, with 1 being the highest priority", the 13 responses from senior staff at TxDOT – AMA stakeholders responded as follows:

Table 3: Priority Corridors - Survey Results

Highway	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Rank 6	Rank 7	Rank 8	Rank 9	Rank 10	Average Rank	Total Respondent
I-40	10	0	0	0	1	0	0	0	0	0	1.46	13
I-27	2	6	4	1	0	0	0	0	0	0	2.31	13
US 287	0	1	3	7	1	0	0	0	0	0	3.67	12
SL 335	1	2	2	3	1	2	1	0	0	0	3.92	12
US 87	0	0	2	3	2	5	0	0	0	0	4.83	12
US 60	1	1	0	0	4	2	3	0	0	0	5.09	11
BUS I-40	0	1	0	1	1	2	6	0	1	0	6.17	12

In response to the question, "List the importance of each of the ITS needs below for the Amarillo District as either High, Medium, or Low", the stakeholders responded as follows:

Table 4: ITS Need Priority - Survey Results

ITS Goal	High	Medium	Low	Total Respondent
ITS Operation	7	5	0	12
Deployment of Devices to Fill in the System Gaps	7	4	0	11
ITS Maintenance	6	6	0	12
Stakeholder Connectivity (City departments, police, fire, EMS, news stations, etc.)	6	5	1	12
Truck Delays/Congestion	6	5	1	12
Replacement of Existing ITS Components Reaching End-of-Life	5	6	1	12
New Technology Deployment	5	4	3	12
Roadway Reconstruction	4	6	1	11
Other (please specify and rank)	N/A	N/A	N/A	1

- ITS expansion should focus on improving safety and operations by replacing end of life cycle CCTV and DMS devices as well as deploying devices to fill in the gaps for continuous highway monitoring.
- Deployment of new technologies including vehicle detectors, roadway weather information systems (RWIS), traffic signals performance measures and truck parking availability should be explored.
- The report should assess the use of Bluetooth equipment which is not currently being used as a data collection system since travel time is calculated by INRIX.
- Enhancing communication systems will be considered for reliability of the existing radio communication.
- ITS equipment and infrastructure should be consolidated and minimized inside TxDOT cabinets for easier troubleshooting and maintenance.
- All CCTV cameras in the system should be digital.
- Opportunities should be identified to share ITS systems with the City of Amarillo and other stakeholders.
- Improve dissemination of current traffic conditions as well as planned closures.

Existing ITS Device Inventory

Existing ITS Device Table

Based on stakeholder feedback during the existing conditions workshop, the inventory prioritized the analysis of the following ITS devices: CCTV cameras, DMS, and traffic signals. The existing ITS equipment inventory database, provided by TxDOT, was reviewed and summarized in **Table 5**, which accounts for each of the CCTV cameras, DMS, Overheight Vehicle Detectors (OHVD), Video Vehicle Detection Systems (VIVDS), and traffic signals currently owned and maintained by TxDOT. A more complete matrix of the existing device, categorized by roadway and construction phase, can be found in **Appendix A.**

Table 5: Existing ITS Device Summary

	Cameras	DMS	Over Height Detectors	Video at Signalized Intersections	Traffic Signals (TxDOT Maintained)	Traffic Signals (City of Amarillo Maintained)
Quantity	20	13	1	20 *	68	242

* - Videos installed at intersections are maintained by the City of Amarillo

Georeferenced Maps

A KMZ file was developed to show existing and proposed CCTV cameras and DMS devices on a map. The KMZ file provides details on the proposed device recommendations, including type of devices, Control-Section which in which each will be installed (with Job when available), proposed installation year, and latitude/longitude of the devices. Concurrently, a GIS file was developed to store and present all existing and proposed ITS devices.

The KMZ and GIS files are intended to be living documents; tools to assist TxDOT in planning and maintaining the ITS network. **Figure** 2 and **Figure** 3 present the locations of the existing CCTV and DMS devices.

The figures are generated from the GIS files and are for illustration purposes only. In these figures, the resolution of the map does not allow for the display of all the equipment existing, under construction, or proposed ITS equipment. The KMZ and GIS (.MXD) files include equipment for the entire district. Some locations have multiple devices, and in these cases, more than one point is layered over another. These points can be expanded in the GIS or KMZ file. For more information, including the project name, associated segment, equipment involved at each point, the GIS or KMZ files should be used.

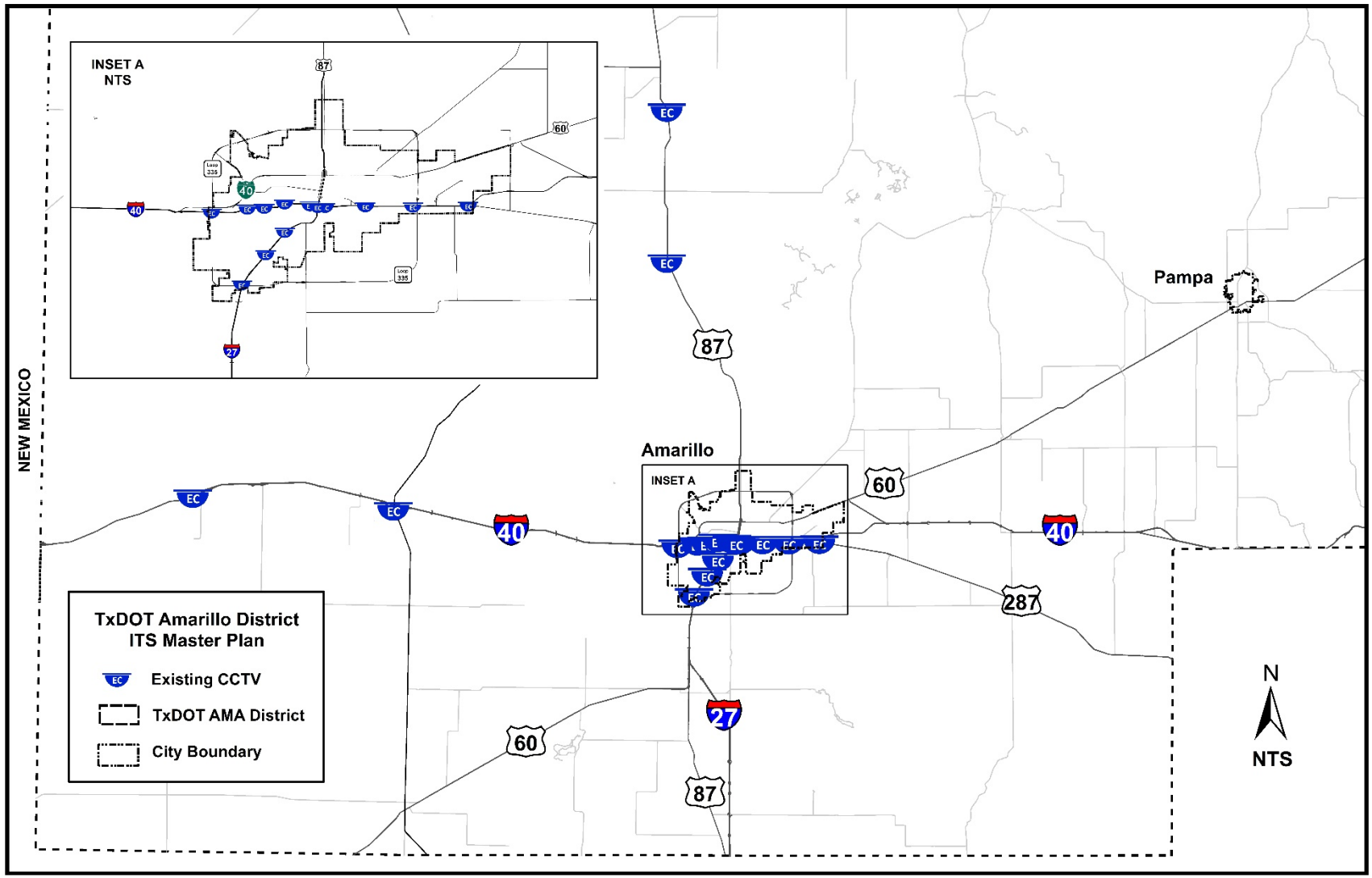

Figure 2: Existing CCTV

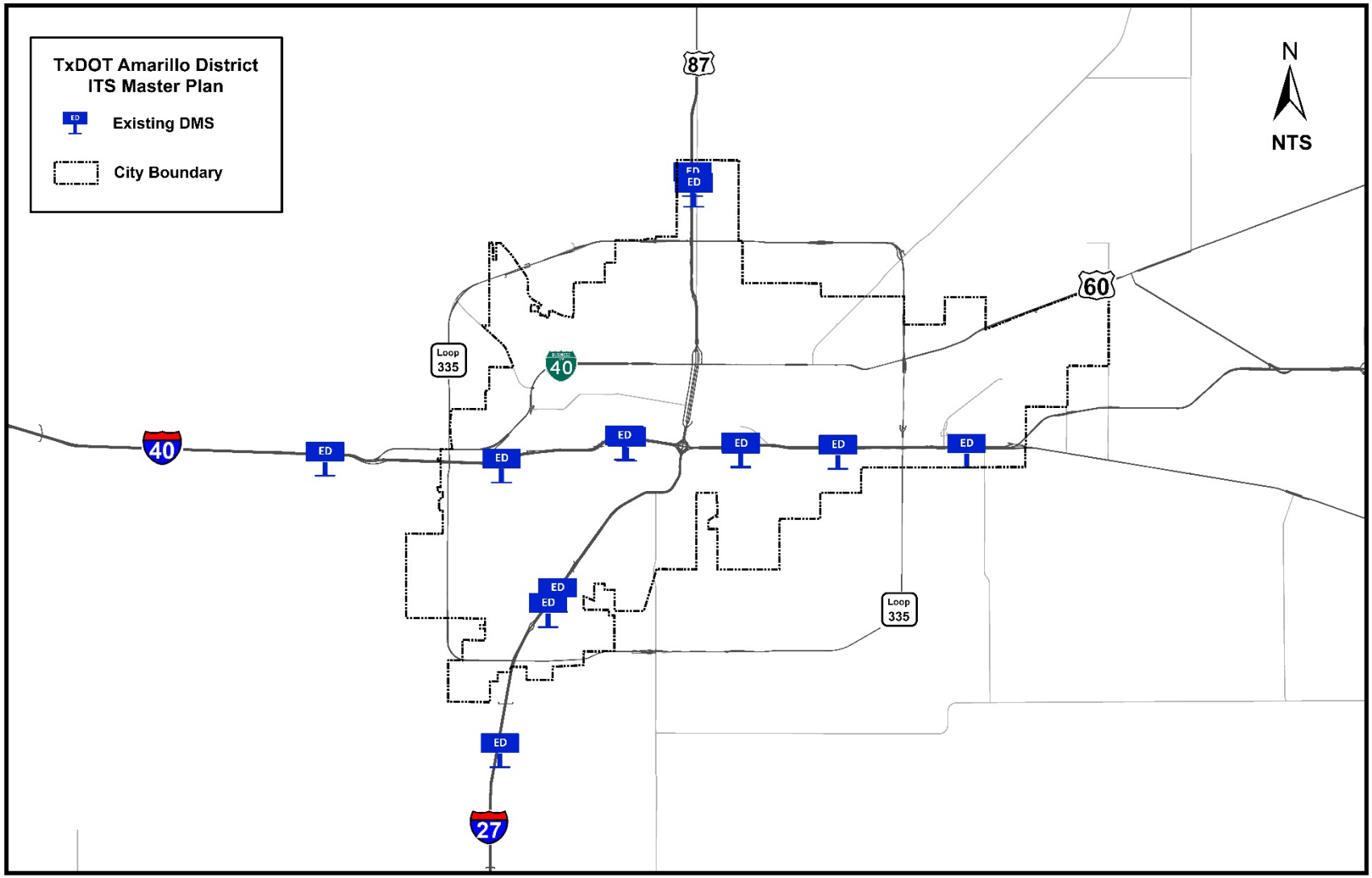

Figure 3: Existing DMS

Existing ITS Device Operational Strategies

The ITS devices in the AMA District are operated and maintained by staff in the TMC in the TxDOT AMA District office. The TMC monitors CCTV and freeway operations and provides incident management and response by displaying messages on DMS. Traffic management strategies are deployed proactively to reduce congestion and enhance safety. The TMC also coordinates with state and local authorities during special events, emergencies, construction activities and daily traffic operations.

Real-time traffic data from CCTV cameras, DMS and INRIX traffic detectors are transmitted to and processed by staff in the AMA TMC. The system is able to use available traffic information to develop and disseminate optimal traffic operation strategies/solutions addressing various traffic needs, such as identifying traffic congestion by speed map displays, incident response and management, interagency coordination, work zone management road weather management, and dissemination of information with DMS messages and Drivetexas.org website.

The AMA District TMC uses Lonestar to operate the existing CCTV and DMS devices. The ITS system is managed in the TxDOT Traffic Operations building at the District Office. AMA has continued to expand and improve the operation of the ITS system and has upgraded their system monitoring capabilities including upgrading a video wall comprised of four 55" monitors, which is shown in **Figure 4**.

Photo Provided by TxDOT AMA District
Figure 4: Video Wall of the AMA Traffic Management Center

Safety

TSMO traffic management and safety strategies can be applied to reduce the number of crashes and congestion along the roadways by improving incident response and advanced traveler information. Areas with a high density of traffic crashes were identified and reviewed by creating heat maps as described below.

Crash data was obtained from the TxDOT Crash Records Information System (CRIS) for the years 2016 through 2019. The crash records were further refined by querying the data sets to show records related to specific crash factors (e.g., severity, type of crashes). Once queried, the crash data was processed in ArcMap and converted into a series of heat maps, which are shown in **Figures 5**, **6** and **7**.

Figure 5 shows all reported crashes in TxDOT Amarillo District from 2016 to 2019. The urban areas show major concentration of accidents. The major clusters of crashes were identified in the Amarillo metropolitan area.

Figure 6 shows the density of the fatal crashes in the study area. The cities with relatively high density of fatal crashes include Amarillo, Dumas, Borger, and Hereford.

Figure 7 shows the density of crashes of vehicles traveling in opposite directions. These types of incidents included crashes along undivided highways, wrong-way turns, entrances to parking lots, and vehicles traveling the wrong direction on freeway ramps.

As shown on the heat maps, regardless of their types, most of the crashes were identified within or close to the vicinity of the urban areas in the study area. The metropolitan area of Amarillo, where four major highways (IH 27, IH 40, US 60 & US 287) intersect and carry significantly heavier traffic than other urban areas, has the highest density of crashes. From a safety perspective, various types of ITS devices that can potentially help reduce the number of crashes in the aforementioned areas were evaluated and documented in this report.

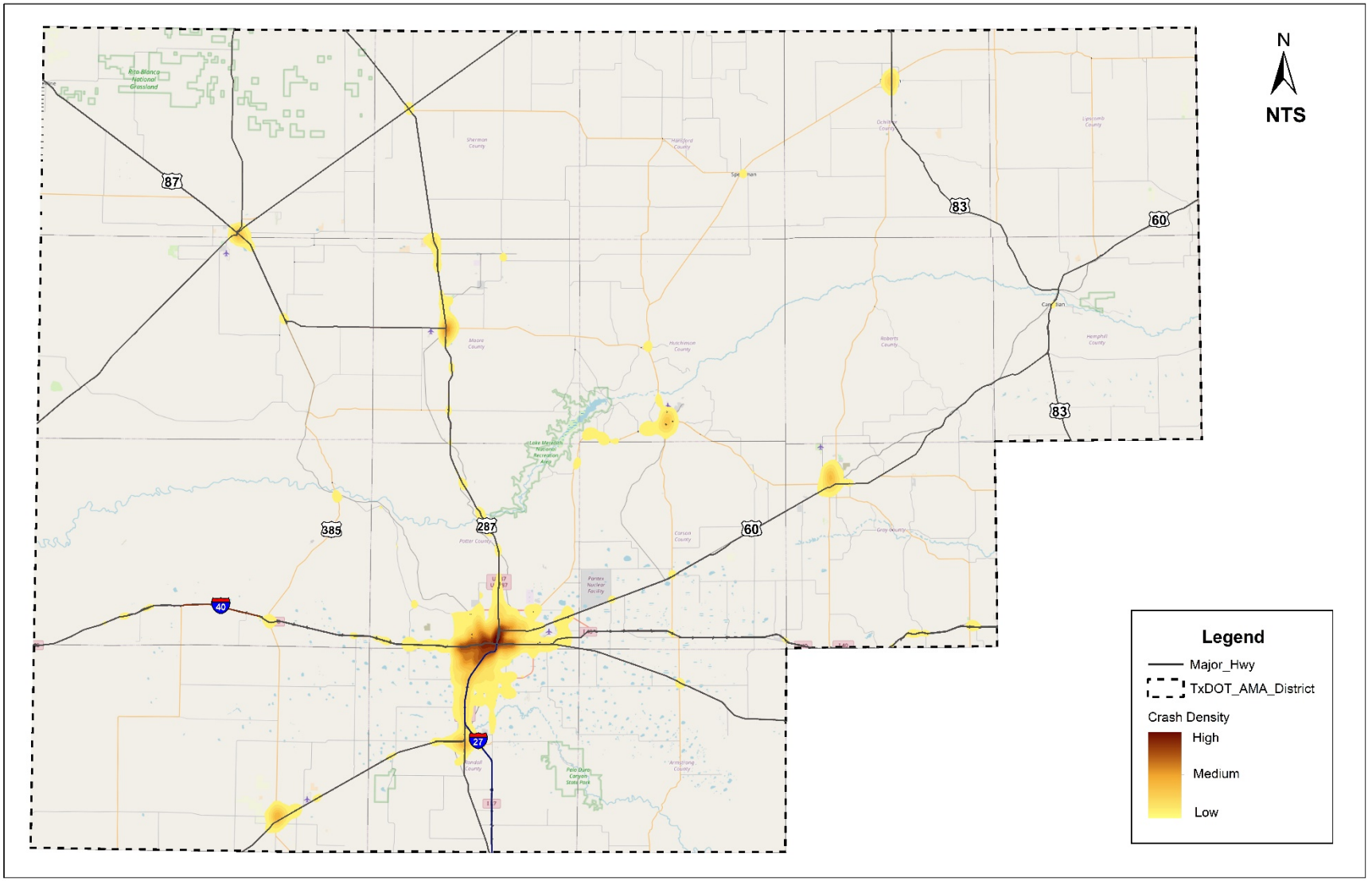

Figure 5: Crash Density - All Types of Crashes (2016-2019)

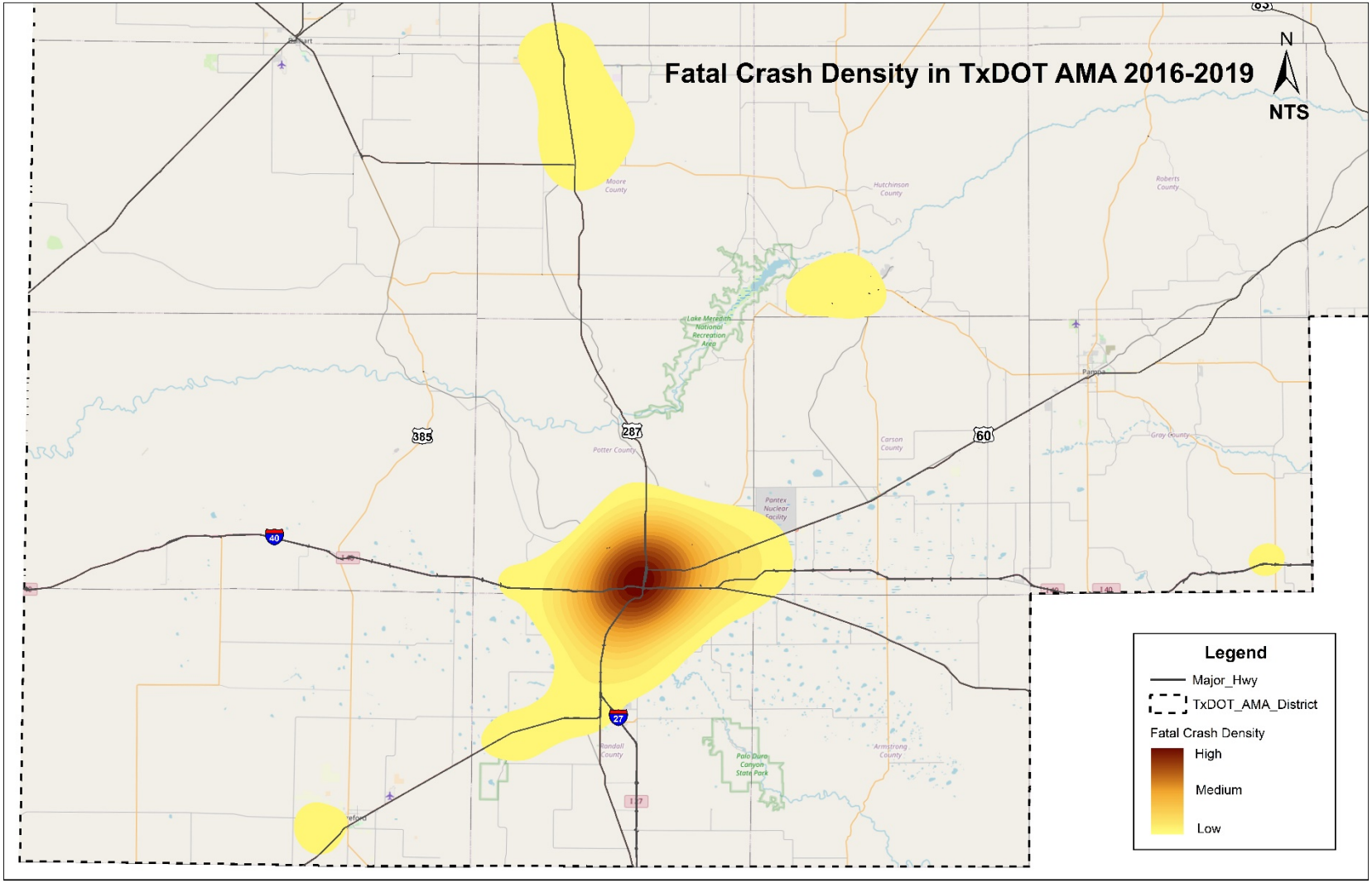

Figure 6: Crash Density - Crashes Causing Fatalities (2016-2019)

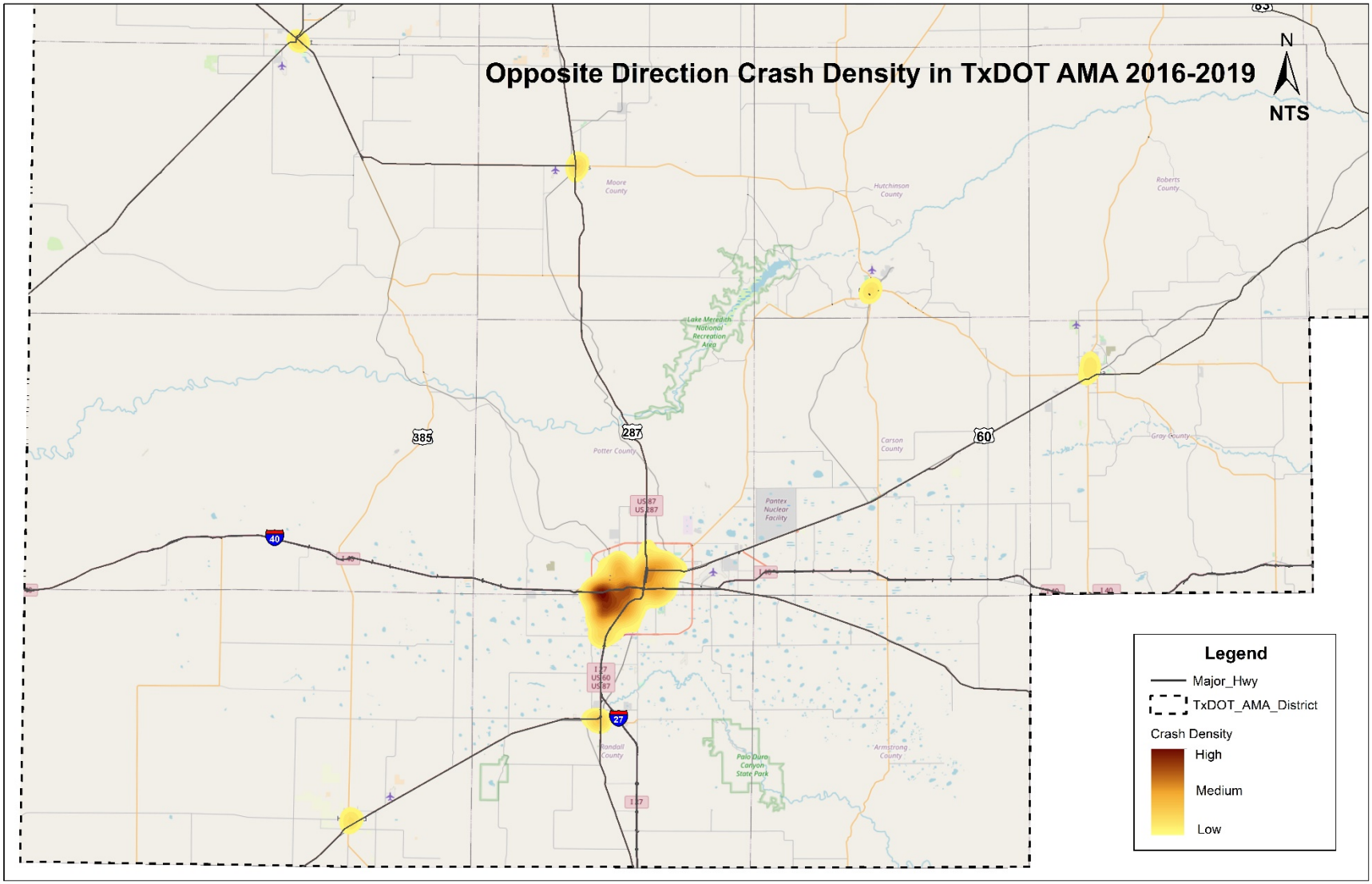

Figure 7: Crash Density - Opposite Direction Crashes (2016-2019)

Expansion of ITS Deployment

In addition to the workshops held in January and April 2020, two more stakeholder meetings were held virtually on August 20, 2020 and September 15, 2020. Participants of these two meetings included: TxDOT AMA District staff, TxDOT Traffic Safety Division TSMO support staff, and the AECOM TSMO development team. The purposes of these two stakeholder meetings were to present the updates to the existing ITS device inventory per the discussion of the previous meetings; and to presentnew ITS components and technologies that will potentially improve safety of road users, efficiency of traffic operation at signalized intersections, and to better accommodate commercial motor vehicle parking.

The following summarizes the major findings identified in this meeting:

- Three proposed CCTV cameras at the northwest quadrant the system interchange of IH 27 & IH 40 were removed, as the existing CCTV camera at the southeast quadrant can cover the entire interchange;
- Spacing adjustments between two proposed DMS devices at 34th Ave. and US 87 were identified.
- With the completion of the Loop 335 expansion in 2025-2026, one important goal is to shift through traffic, especially commercial motor vehicles on IH 27/US 87 from downtown to Loop 335 to reduce congestion and potential safety hazards.
- To achieve the goal mentioned above, it was agreed that travel time devices/technologies be evaluated to inform travelers about the best routes around the City of Amarillo.

Proposed ITS Devices

Expanding the coverage of the existing CCTV and DMS devices is one of the main goals of TxDOT AMA District in the near future. Therefore, additional CCTV and DMS were proposed at various locations within the District based on the following resources and strategies:

- GIS map provided by TxDOT AMA District containing the locations of the existing and proposed ITS devices (by the District);
- Replacement of devices approaching estimated service life within the next 10 years;
- Identify and fill out gaps or blind zones of existing ITS devices;
- Identify projects that are going to be let within the next 10 years and determine what ITS devices can be used.

In addition to upgrading and expanding the CCTV and DMS devices, new ITS devices and technologies were evaluated and proposed. **Appendix B** lists the proposed ITS devices and technologies by location and installation timeframe for TxDOT AMA District for the next 10 years. Details of the expansion of existing ITS devices are discussed in the following section.

Expansion of Existing ITS Device Deployment

Based on the evaluation of the existing ITS network, additional ITS devices were proposed to expand the coverage and fill in the gaps based on TxDOT criteria and engineering judgement. Specifically, additional DMS devices were proposed along highways approaching major interchanges in Amarillo to inform travelers of conditions along their routes. Proposed CCTV cameras and DMS which are shown together, approximately 100 feet apart, allow shared electrical services and TMC operators to verify messages on DMS in remote areas of the District. Existing analog CCTV cameras to be replaced will be upgraded to meet the current TxDOT specification, including the use of IP addressable cameras where appropriate. Furthermore, CCTV cameras will be beneficial at signalized intersections, especially for those with high traffic volume along a coordinated signal system.

Based on the strategies discussed above, a series of maps of the proposed ITS devices was developed in GIS. Figures 8 and 9 present the approximate locations of proposed CCTV and DMS devices for a full build out. As mentioned before, the GIS generated maps are for illustration purposes only due to the restriction of resolution. Details of the proposed devices can be viewed and updated as needed, in the KMZ and GIS (.MXD) files.

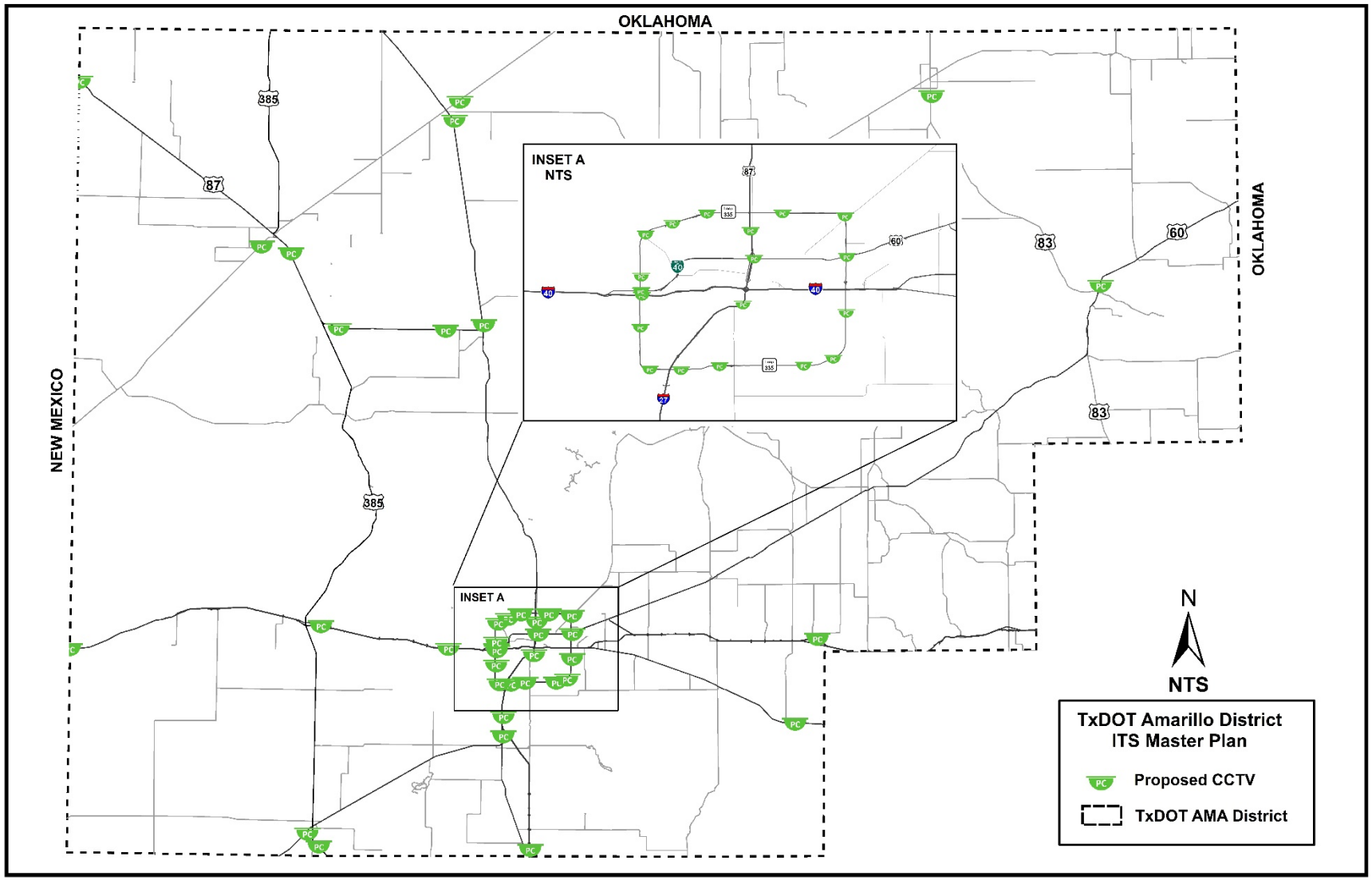

Figure 8: Proposed CCTV

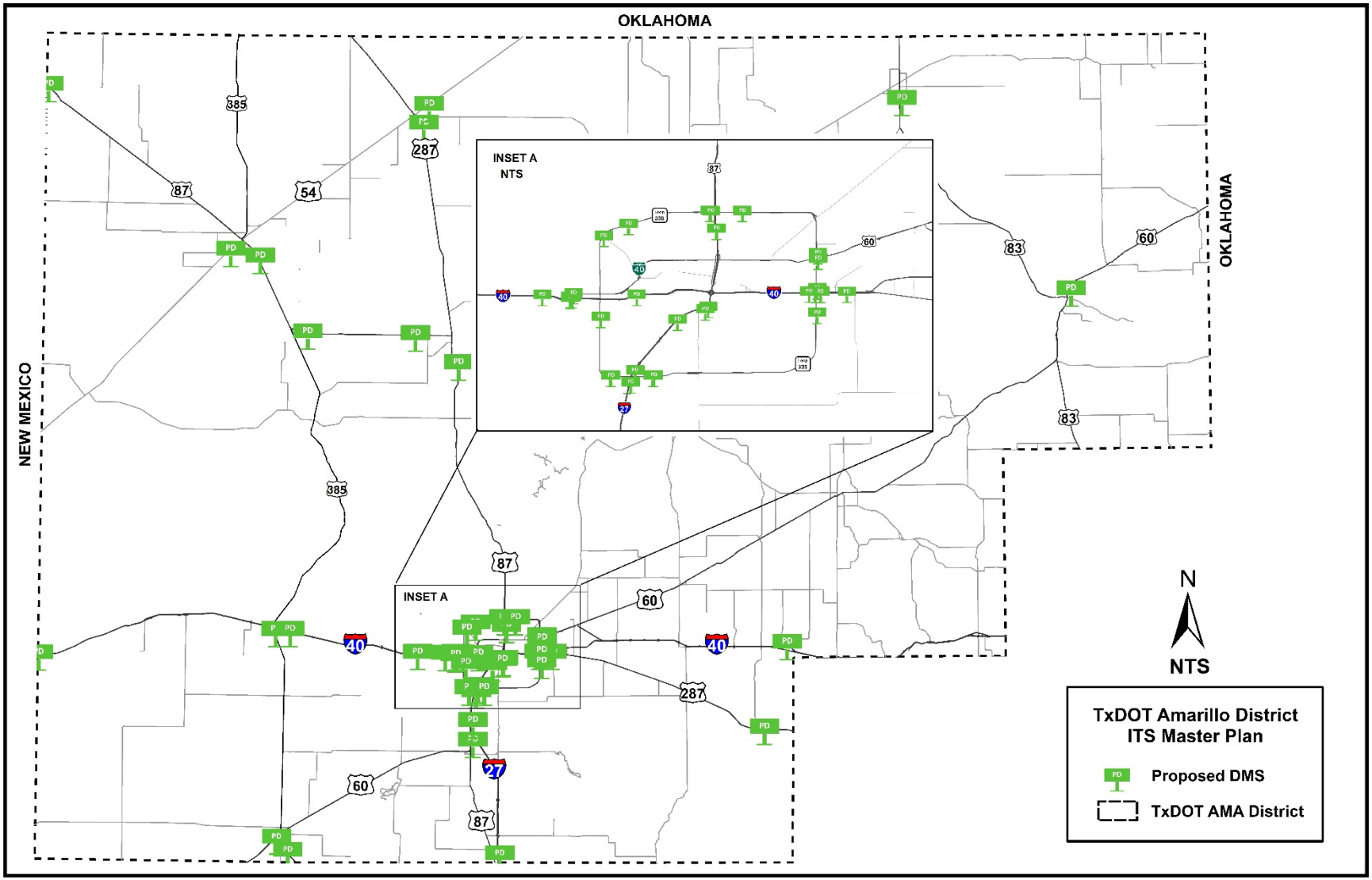

Figure 9: Proposed DMS

New ITS Device Technology

In addition to upgrading and expanding the CCTV and DMS devices, new ITS devices and technologies that can potentially benefit the overall performance of the existing ITS in the AMA district were evaluated and proposed by the TSMO development team, and are shown as below:

- Road Weather Information System (RWIS);
- Comparative Travel Time (CTT) Sign;
- Bluetooth Detection System (BDS);
- Over-height Vehicle Detection System (OHVD);
- Traffic Signal System Communication;
- High Water Detection System (HWDS);
- Wrong Way Driver Detection System;
- Fiber Optic Communication

Road Weather Information System

Road Weather Information System (RWIS) is a real time information system used to monitor and detect numerous weather-related conditions along highway systems. A RWIS is generally comprised of Environmental Sensor Stations (ESS) in the field, a communication system for data transfer, and central systems to collect field data from numerous ESS. The main purposes of RWIS are to enhance the highway authority's ability to conduct roadway maintenance operations in a safe and efficient manner, thus to minimize road users' exposure to hazardous weather-related road conditions.

In order to collect and disseminate timely information about possible extreme weather conditions, a number of RWIS are proposed at locations which either have the highest elevations within the study area, or serve as major junctions of the highway systems. **Figure 10** shows the proposed locations of RWIS.

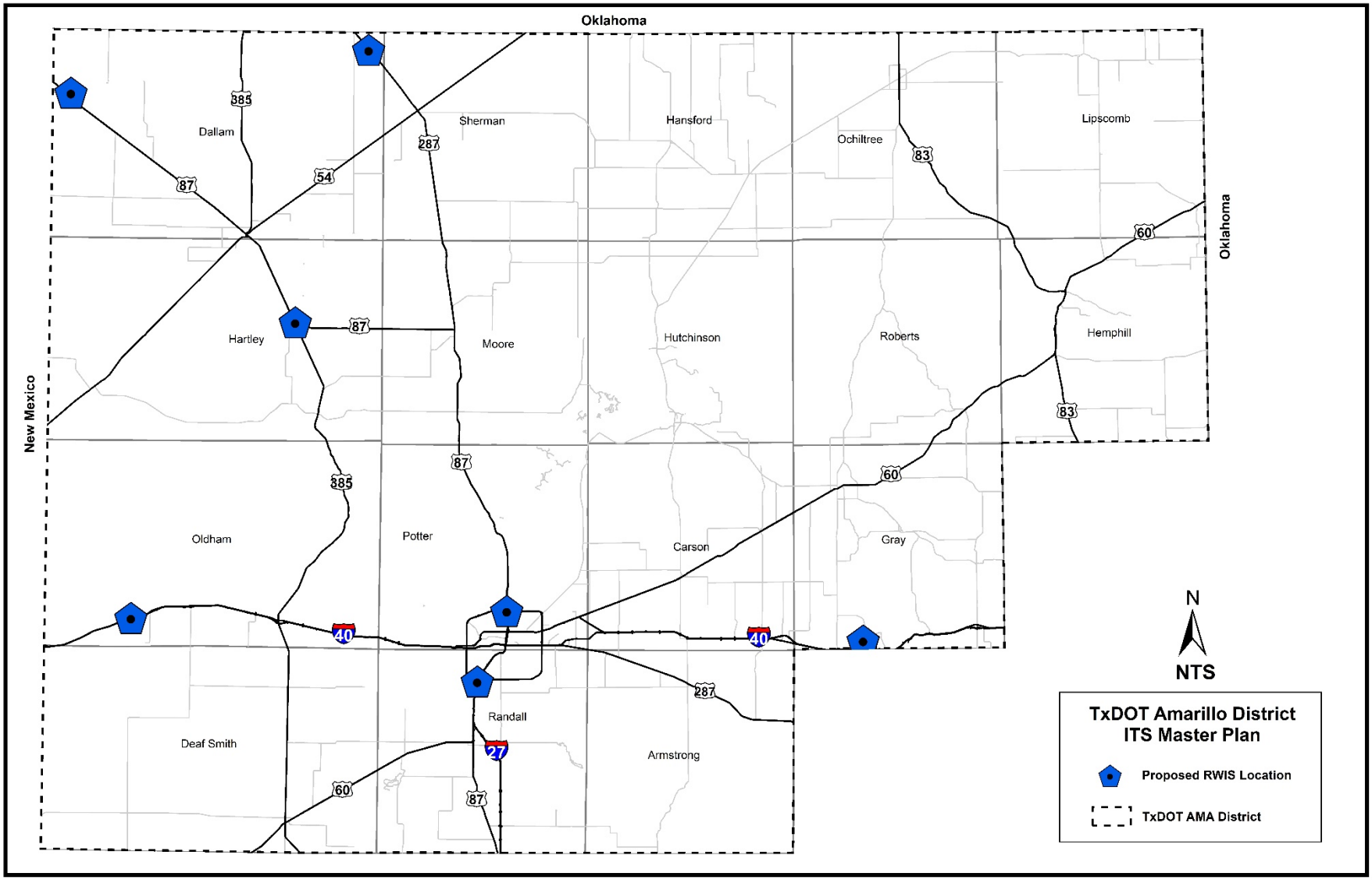

Figure 10: Potential Locations for Installing RWIS

Comparative Travel Time Signs

A Comparative Travel Time (CTT) sign is an on-roadway signage approach to deliver information in advance of a driver decision point, using a combination of text, colors, and representative maps of the roadway system. One of the most important functions of a CTT sign is to present dynamic travel times via different routes to the same destination, thus to facilitate the decision-making process of travelers in terms of choosing the most desirable route. In general, the travel time data can be obtained from either public sources, such as TMCs, or private sources, such as INRIX and NAVTECH.

Figure 11 shows an example of the CTT sign installed along IH 35, between E Palm Valley Blvd and Round Rock Ave in Round Rock TX.

Source: FOX 7 AUSTIN
Figure 11: Example CTT Sign

In the September ITS Stakeholder meeting, the AMA District indicated that with the completion of the Loop 335 expansion in 2025-2026, one important goal is to shift through traffic, especially commercial vehicles, on IH 27/US 87 from downtown to Loop 335 in order to reduce congestion and potential safety hazards. Therefore, the CTT signs are proposed to be installed on NB IH 27, 2 miles prior to SL 335, and SB US 87/US 287, 2.5 miles prior to SL 335. **Figure 12** shows the approximate locations of the proposed CTT signs.

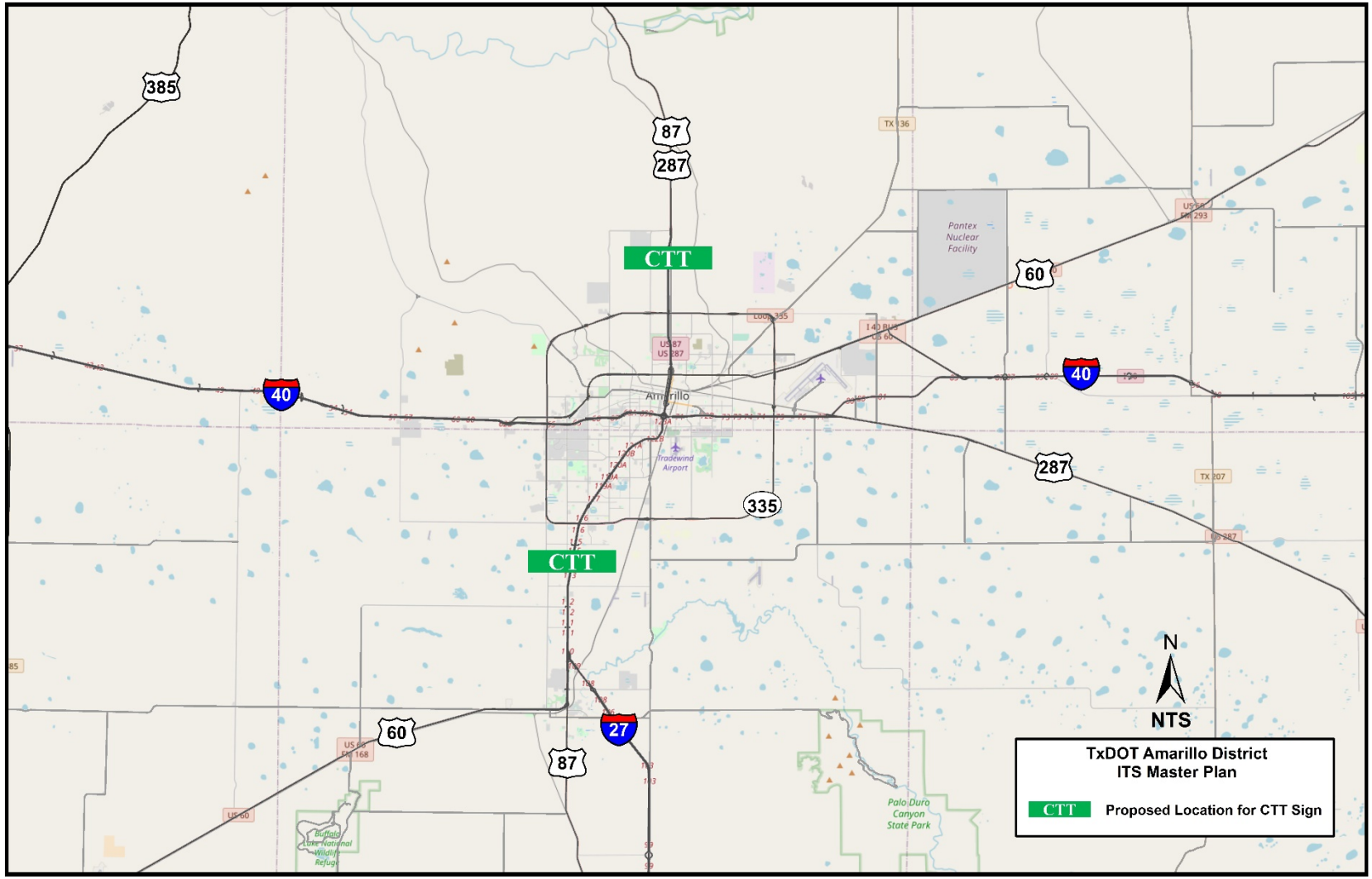

Figure 12: Proposed Locations of CTT Signs

Traffic Signal Communication

Signal timing errors, such as drifted offsets or malfunctioning detection, are difficult to detect in controllers without communication. Appropriate communication between the TMC and traffic signals in the field can significantly increase the efficiency of traffic signal operation by monitoring and fine-tuning signal timing plans remotely in the TMC. Ideally, it is recommended that broadband radio communication should be used between the TMC and all traffic signal controllers the District maintains, together with installing CCTV cameras at critical intersections to identify and report incidents/accidents. **Figure 13** shows the locations of signals maintained by TxDOT.

Truck Parking Availability

The interstate and Texas state highway systems in the study area carry significant amount of Commercial Motor Vehicles (CMV). To provide information to these vehicles on availability of parking will allow them to plan their route and rest prior to continuing to travel along the highways, existing parking areas in the study area that can accommodate CMV overnight parking are evaluated and summarized in this report.

Additionally, CCTV cameras may be installed at such facilities to monitor real-time truck parking availabilities, and this information can be disseminated to truck drivers through DMS devices or smart phone-based third-party applications. **Figure 14** shows the locations of those parking facilities.

High Water Detection System

A High Water Detection System (HWDS) detects real-time water levels for surface roadways and deliver warning alerts via LED-enhanced traffic warning signs and plaques, to warn approaching drivers of road flooding.
In the Stakeholder meeting, TxDOT noted two possible locations in Amarillo where flooding is likely to happen due to heavy rainfall: the interchanges of IH 40 & S. Washington St., and the IH 40 & Bell St. The HWDS are proposed at these two locations as shown in **Figure 15**.

Other ITS Devices and Technologies

Besides the aforementioned ITS devices and technologies, which aim to address the most common and practical needs of the AMA District, there are other ITS devices that can be considered by the District as needed. These devices include but not limited to:

- Bluetooth Detection System
- Fiber Optic Communication
- Over Height Vehicle Detection
- Wrong Way Driver Detection

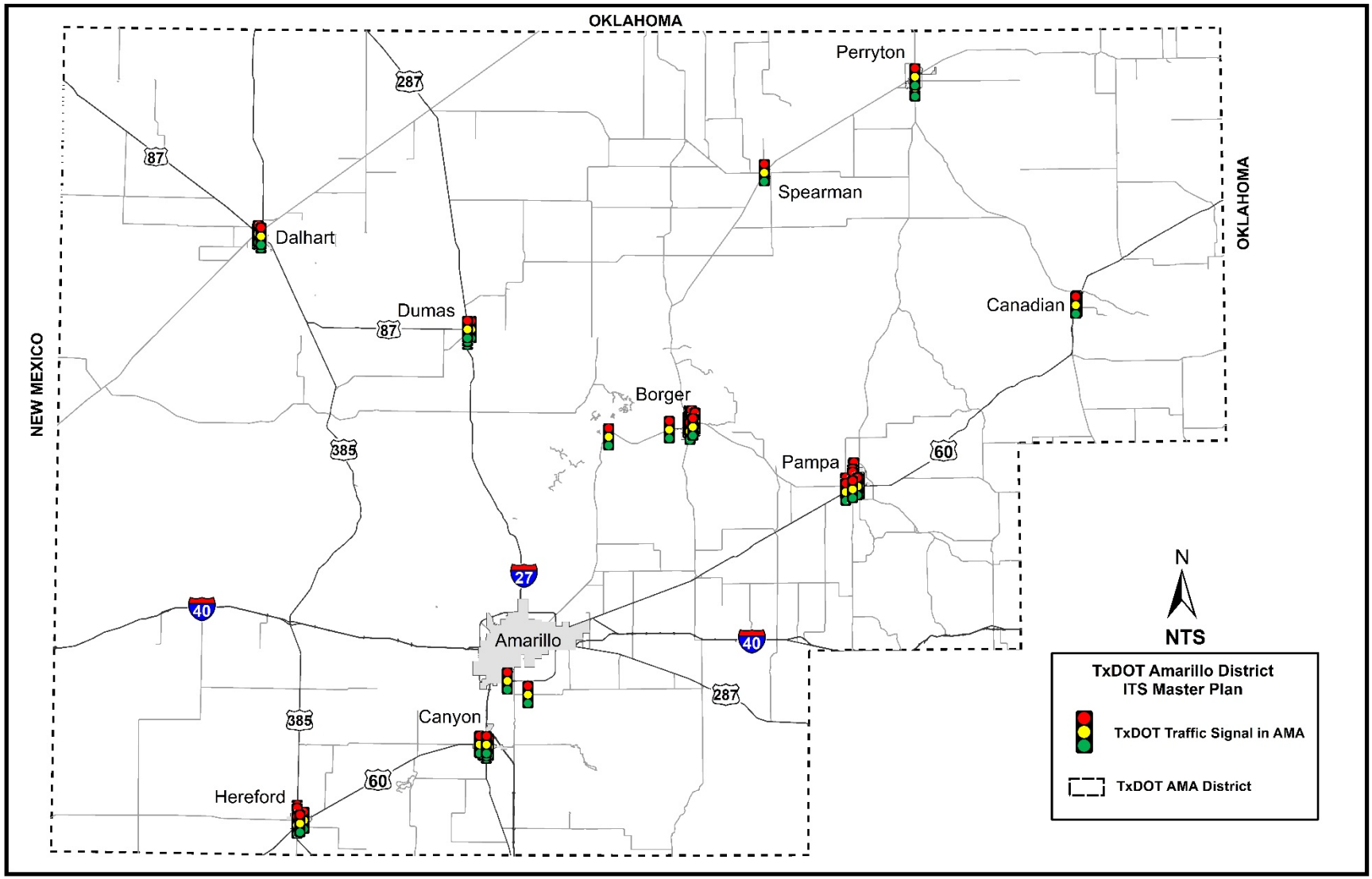

Figure 13: TxDOT Traffic Signal Locations

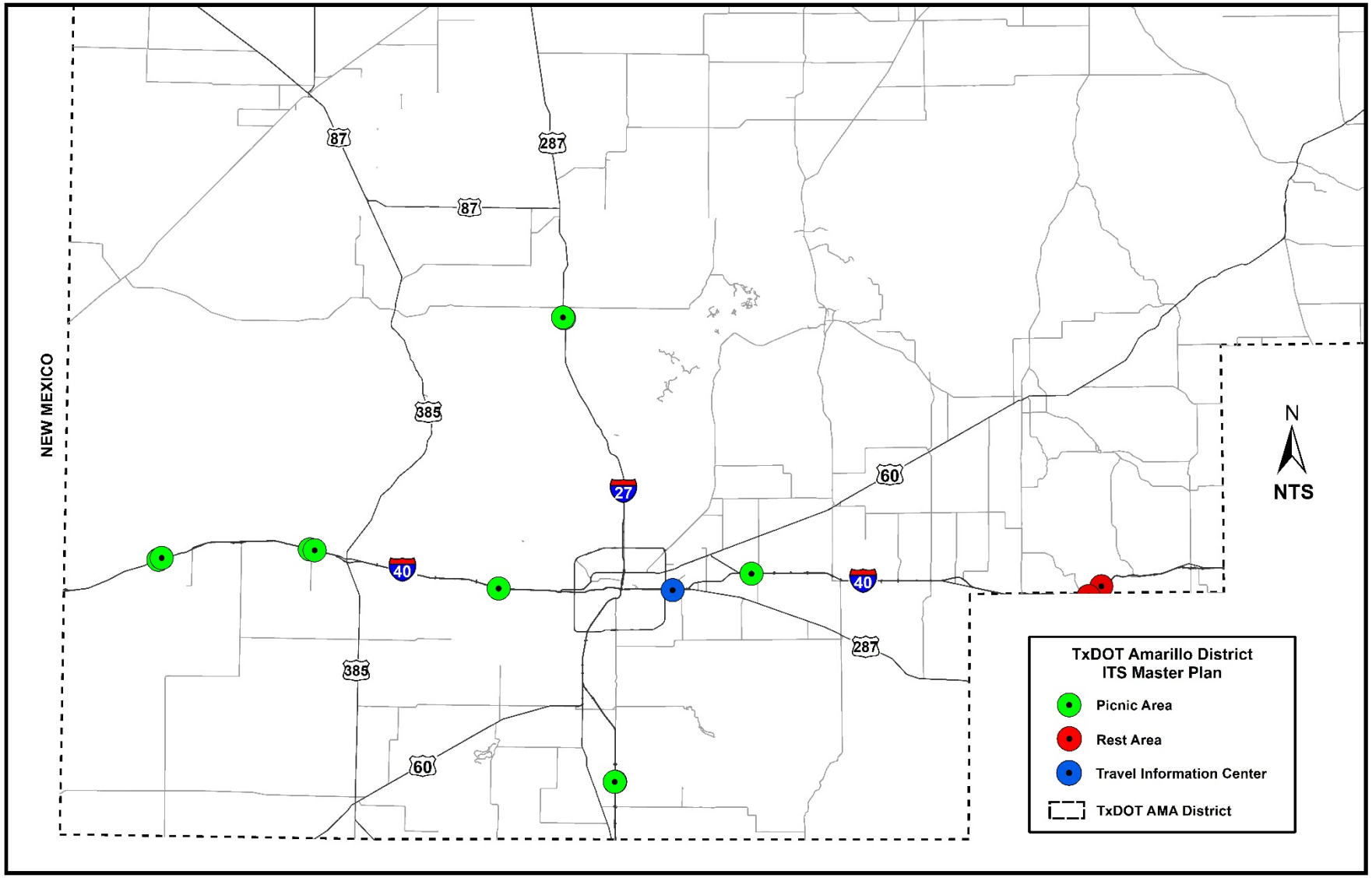

Figure 14: Potential Commercial Motor Vehicle Parking Facilities

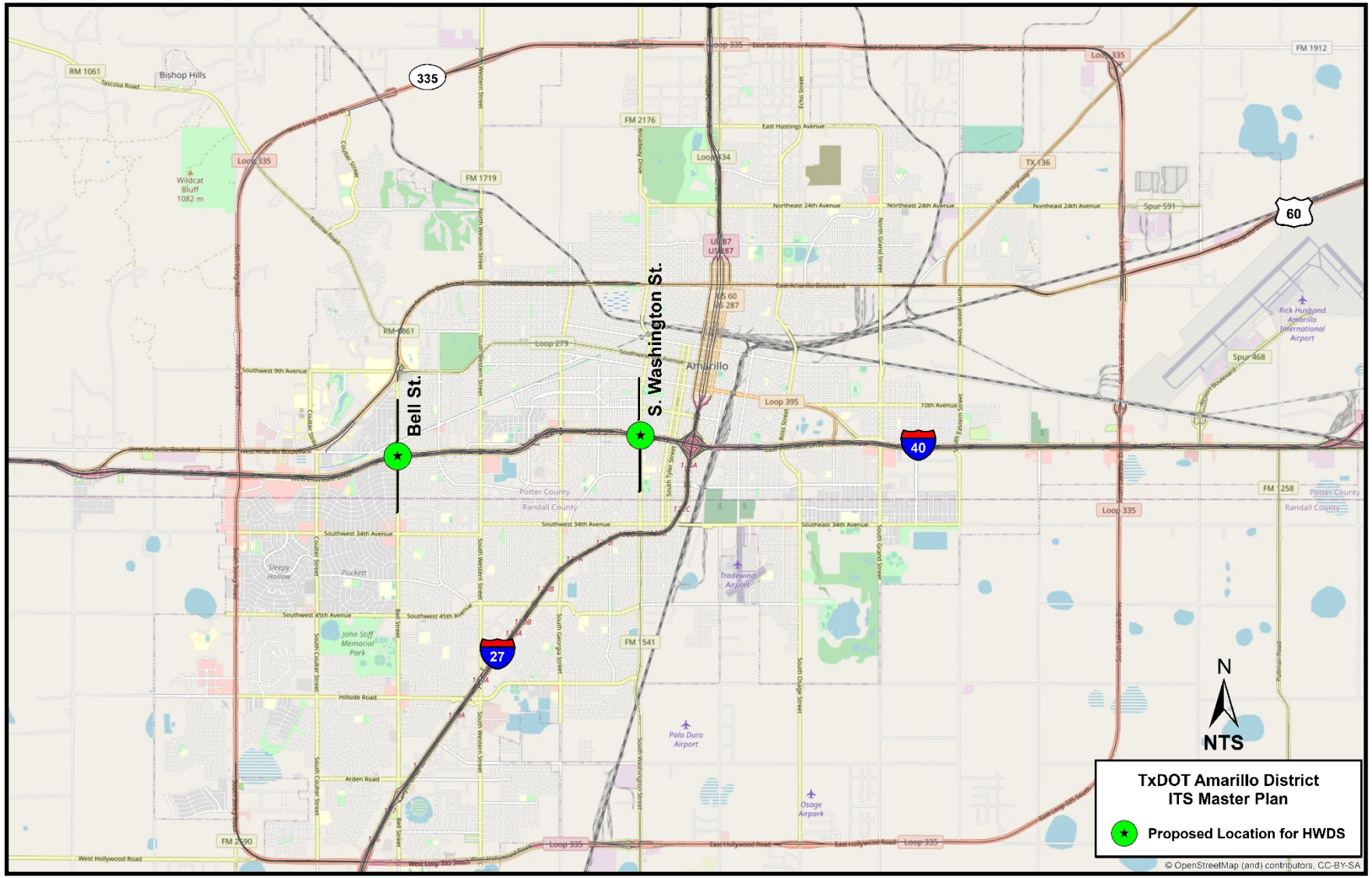

Figure 15: Proposed Locations for High Water Detection System

Proposed ITS Devices Operational Strategies

With the additional ITS devices proposed in the future, additional staff will be needed in the TMC or other corresponding departments to operate the system efficiently. Additional effort of operating the upgraded ITS may include, but not be limited to: monitoring and processing data collected by the RWIS devices and sharing countermeasures with corresponding agencies and road users; traffic data providers to obtain real-time travel time information and disseminate it to the CTT signs on the highways; and additional traffic monitoring cameras.

Additionally, the compatibility of proposed ITS devices with the Lonestar ATMS platform need to be thoroughly evaluated to ensure a smooth performance; all new ITS devices and technologies that are installed by the AMA District should be added to the Lonestar subsystem.

ITS Communication

Due to the size of the Amarillo District and the considerable amount of rural/undeveloped area, implementing a fiber optic cable network is likely to have a very high cost-to-benefit ratio. In lieu of fiber optic cable, modern wireless communication technologies offer good performance at more reasonable costs. There are two options for high-speed wireless communication for ITS devices in the Amarillo District:

- For those ITS devices within range of existing or planned wireless communication networks (e.g., within the Metro Amarillo area) 2.4 or 5.8 GHz ITS radio networks provide sufficient bitrates for high-definition video transmission, as well as supporting devices with lower bitrate requirements such as traffic signals and DMS. Current TxDOT specifications allow for dual band radio transceivers which can transmit at both frequencies. Since these are unlicensed frequencies, any user may utilize them without approval or registration with the Federal Communications Commission (FCC). Modern radio technology allows "frequency hopping" which allows the devices to automatically select the best frequency within a given range, usually resulting in good performance. In some cases, radio frequency (RF) interference may be problematic if there are several other users attempting to utilize these same frequencies within a given area. Although unlikely, if RF interference becomes a problem in certain areas, the District may choose to conduct a spectrum analysis to determine the spectrum ranges which have lower interference.
- For those ITS devices out of range of existing or planned wireless communication networks (e.g., those in rural areas far from any District facilities) then a good alternative is 4G LTE cellular communication. Although cellular communication typically does not provide enough bitrate for full high-definition video transmission, it can provide lower quality video and is sufficient for data telemetry to signal controllers, DMS, RWIS, and other devices with low data consumption needs.
- The November 18th, 2020 FCC ruling regarding the 5.9 GHz spectrum provides the upper 30 MHz (5.895 to 5.925 GHz) of that band for C-V2X (cellular vehicle to everything) communication. Should AMA decide to implement V2X technology, that licensed band range is available for this purpose. Device specifications should be established to utilize that portion of the 5.9 GHz band, if they are to be used.

Safety

One of the most important purposes of upgrading the ITS devices and operations is to improve the safety of road users. It is expected that with new ITS devices strategies successfully deployed in the field, road users will be able to obtain important traffic data, such travel time, incident occurrences and severe weather warnings in a timely manner, thus assisting the decision-making process, provide situational awareness, and reduce the number of crashes/incidents.

ITS Strategies

By collaborating with the regional stakeholders, TxDOT developed a list of ITS strategies and identified project segments that could be implemented during the next 10 years in the Amarillo District. In alignment with TSMO goals, these strategies leverage existing or developing technologies to provide information to the traveling public, enhance safety, and manage traffic. TxDOT will implement many of these ITS strategies as part of projects adjacent to or along major corridors in the district. Based on the district's priorities and professional judgement, TxDOT selected 9 strategies to implement in the study area at the concept workshop on November 5, 2019.

Table 6 shows the recommended TSMO strategies for implementation in the Amarillo District in the next 10 years.

Table 6: Recommended TSMO Strategies

Strategy	Explanation	Components/System Requirements
Roadway Monitoring	Monitoring the roadway system using cameras to identify traffic incidents, congestion, and system performance.	- Additional CCTV cameras to reduce "blind spots" in the existing system - Video analytics to detect lane closures, stalled vehicles, incidents, wrong-way vehicles, etc.
Roadway Weather Information System (RWIS)	RWIS include a roadside field component, environmental sensor stations (ESS), to collect atmospheric data such as temperature, humidity, visibility, wind speed and direction, and lightning detection. ESS are also capable of collecting pavement data. Central RWIS hardware processes data from the field units to display data at the TMC, where it can be publicly disseminated.	- Environmental Sensor Stations (ESS) to disseminate adverse weather conditions to road users via DMS, TxDOT, and project websites; social media, Highway Advisory Radio (HAR), third-party applications - Maintenance staff may use RWIS data to assist in making decisions on winter maintenance operations
Truck Parking Availability	Providing information to commercial vehicles on availability of parking will allow them to plan their route and rest prior to continuing to travel along the highways. Information, including real-time availability of parking at designed lots, can be provided to long haul truckers as they travel enhancing safety for all along the highways.	- Map(s) of rest areas with available truck parking spaces - Potential Private Partnership to add data to smartphone-based applications or TxDOT website to disseminate real-time parking availabilities.
Comparative Travel Times (CTT)	Presenting comparative travel time to a set destination to road users on access-controlled highways based on real time traffic data.	- Travel time data – INRIX - Relay travel time information to road users (CTT)

Strategy	Explanation	Components/System Requirements
Traffic Management Center (TMC) Upgrades	Upgrade TMC video wall, workstations, hardware, etc. to improve real-time awareness and management of system from the TMC. Develop stakeholder agreements such as the City of Amarillo, DPS, Police, 911 Dispatch, and local media to share streaming video for incident response and disseminating traveller information.	- TMC upgrades • Video wall • Workstations • Hardware • Video Analytics - TxDOT One Call Center to allow monitoring of video by TxDOT maintenance.
Traffic Incident Management (TIM)	A planned multidisciplinary process to detect, respond to, and clear traffic incidents. This reduces the amount of traffic due to first responders, clears the travel lanes, enhances the safety of the traveling public, and restores the flow of traffic to decrease the likelihood of secondary collisions. TIM requires high collaboration and communication between state and local transportation departments, TMCs, fire and rescue services, law enforcement agencies, and others who play a primary role in traffic incidents to improve the transportation system.	Field detection using CCTV and speed maps Information Dissemination using DMS TIM Training Agency Coordination
Traffic Signal Operation	Establish communication to signalized intersections and utilize the traffic signal system software to monitor the operation of signalized intersections. Allow the traffic signal shop to view operation remotely and respond to complaints for hardware and timing issues.	-CCTV cameras at critical signalized intersections -Cellular, spread spectrum or ethernet radio connection between signal controller and TMC • Provides agencies the ability to monitor and correct deficiencies in traffic signal operations • Enhance safety by timely addressing congestion issues • Automated Traffic Signal Performance Measures (ATSPMs) along critical corridors

Strategy	Explanation	Components/System Requirements
Information Dissemination	Providing up-to-date travel conditions to road users via the ITS infrastructure. This strategy encompasses many of the previously defined strategies and may include implementing performance measures to ensure information is accurately, timely, and efficiently shared with the public in order to influence their decisions, such as the selections of mode, route, departure time, driving behavior, and trip deferral.	- DMS messaging - TxDOT website - Construction project websites - Social Media - Third-party applications
Work Zone Management	Managing traffic during construction to minimize traffic delays, maintain motorist and worker safety, complete the construction project on time, and maintain residential and business access. This strategy includes creating a Transportation Management Plan (TMP) utilizing the current vehicular patterns to analyze the corridor for optimal construction times. This reduces road closures and construction operations during peak periods which reduces traffic congestion. This strategy is low-cost but requires a high level of collaboration between governmental and local agencies.	- Temporary ITS trailers may be installed near work zones to collect data and monitor traffic and safety around the work zone. - Queue management/detection may be implemented with the inclusion of sensors and cameras. - Travel time information provided to the public through different communication methods (Smart Work Zone).

Table 7 presents other strategies that TxDOT considered but did not select for implementation within the next 10 years in the study area.

Table 7: Additional TSMO Strategies

Strategy	Explanation	Components/System Requirements

Wrong-Way Driver Detection	Wrong-Way Driver Detection is a safety improvement for exit ramps to identify wrong-way drivers and to activate a warning signal notifying the driver of the wrong-way violation. This system can be tied to DMS to warn oncoming motorists.	Wrong-Way Driver Detection system
		• Automated Ramp Detection System
		  ○ Radar detection
		  ○ CCTV verification
		  ○ Automated message to TMC
		• DMS
		  ○ Use upstream signs to disseminate oncoming vehicle notice (may be automated)
		Intersection wrong-way detection via CCTV video analytics (emerging technology requiring further research)

Bluetooth Detection System (BDS)	A traffic detection system that detects any Bluetooth devices inside vehicles for the purposes of calculating travel times, assisting route selection, and origin-destination analysis.	- Bluetooth detector(s) in the field • Usually, multiple detectors are used in the system - Server (hardware & software) in corresponding traffic agency
Over-height Vehicle Detection System (OHVD)	OHVD detects vehicles that won't clear the structures they are approaching, and notifies drivers via appropriate signs equipped with LED-enhanced alerts or audio alerts.	- Infrared detection system with static signs and activated beacons

Table 8 identifies safety prioritization methodology for identifying projects to be considered as high priority projects to be considered for implementation.

Table 8 Safety Prioritization Methodology

Safety Priority Ranking	Category	Explanation
1	Roadway Monitoring and Traffic Detectors (e.g., CCTV cameras).	Improves real-time situational awareness in reducing incident detection, verification, response and clearance times.
2	Traffic Signal Operations	Traffic signal operations improvements are strategies to improve driver awareness of roadway conditions and operations to help reduce incidents.
3	Information Dissemination, TMC Operational Improvements, and Emergency Response Routing	Information dissemination will improve driver awareness to help prevent incidents. TMC improvements are intended to improve TMC operations, both through capital improvements and staffing improvements. More active and improved monitoring will lead to more efficient roadways which can be expected to reduce incidents. Emergency response routing and priority systems enables emergency vehicles to reduce response times, incident clearance times and the potential of secondary incidents.
4	Road Weather Information Systems	Monitors weather conditions and disseminates information to motoring public for safer operations during inclement weather conditions.
5	Travel Time Estimation and Prediction	Utilizing INRIX data, this provides the motoring public with comparative travel time information allowing for potential route adjustments decreasing congestion and potentially decreasing incidents.

Project Selection

Table 9 shows a summary of the devices recommended for installation in the Amarillo District for the next 10 years. For some equipment, such as "Additional Hardware (routers, firewalls), software integrations," there are zero new physical devices recommended to be implemented, but new computer programs, contracts, studies, and planning may be required to implement the project listed. Associated capital and design/study cost estimates are also listed. Over the next 10 years, the Amarillo ITS Master Implementation Plan includes 221 new devices with an estimated capital cost of about $17.5 million and $2.75 million in design and study costs.

Table 9: Summary of Proposed Future ITS Deployments, Amarillo District 2022-2031

Equipment	Number of Devices	Estimated Capital Cost	Estimated Design Cost
CCTV wireless	41	$2,084,450	$312,668
CCTV Replacement	20	$247,500	$37,125
Comparative Travel Time Sign	2	$220,875	$33,131
DMS wireless	68	$12,720,605	$1,908,091
DMS Replacement	13	$1,554,381	$233,157
High Water Detection Systems	2	$353,318	$52,998
Weather Station	7	$386,750	$58,013
Traffic Signal Communications	68	$816,580	$122,487
TOTAL	221	$17,567,897	$2,757,669

Table 10 displays the unit cost table used to estimate costs for the ITS equipment installations for each project in Appendix C. The breakdown of each unit cost is available in Appendix D.

Table 10: ITS Equipment Unit Costs

TSMO Strategy	ITS Equipment	Unit Cost	Unit
Traffic Signal Operations	Radios, Battery Backups	$12,000	EA
Roadway Monitoring	CCTV Wireless	$50,840.23	EA
Information Dissemination	DMS Wireless	$187,067.71	EA
Information Dissemination	Comparative Travel Time Sign	$110,437.50	EA
RWIS	Road Weather Information System	$55,250	EA
HWDS	High Water Detection System	$37,500	EA
Work Zone Management	Radar Speed Feedback Sign	$7,395	EA

Priority Projects

Projects were identified as top-priority projects for the Amarillo District. These were selected based on an examination of high-priority corridors and strategies that may have the greatest impact on congestion and safety.

Table 11 through **Table 19** and the corresponding figures show a breakdown of these priority projects, advantages and disadvantages of each, and a cost estimate that includes estimated capital and design/study cost. The total estimated capital cost of priority projects is about $8.86 million and the total estimated design and study cost is about $1.05 million. Most of these projects have a proposed timeframe of 2022 or 2025 to denote their urgency.

Table 20 is a summary of ITS devices to be deployed with recommended implementation priorities by fiscal year. Detailed information about each device, including location data, is provided in the KMZ file.

Table 11: Priority Projects - CCTV

Project	Description	Advantages	Disadvantages	Est. Let. Date	Est. Capital Cost	Est. Design/Study Cost
Replace 11 end of life CCTV cameras. Install 18 new CCTV cameras at the following locations. IH 40 (2 EA) IH 27 (3 EA) US 87 (4 EA) SL 335 (8 EA) US 54 (1 EA)	Install additional CCTV coverage along corridor to improve roadway monitoring in order to identify and/ or confirm congestion and incidents for faster response and clearance times.	CCTV increases roadway monitoring capacity of the TMC. Roadway monitoring can lead to faster response times, more accurate and reliable information sharing to the public and third-parties, and performance measurement.	CCTV installations may be difficult to maintain and may not be reliable at night or in foggy or snowy conditions.	2022-2025	$1,051,250	$105,125

Table 12: Priority Projects - DMS

Project	Description	Advantages	Disadvantages	Est. Let. Date	Est. Capital Cost	Est. Design/ Study Cost
Replace 5 end of life DMS. Install 30 new DMS at the following locations. IH 40 (2 EA) IH 27 (10 EA) SL 335 (12 EA) US 87 (5 EA) US 54 (1 EA)	Install Dynamic Message Signs at interchange approaches for routing guidance.	Provides information to the traveling public for easier routing at interchanges. Information can help drivers to make safer decisions and/or faster routing decisions and alert them to closures and other hazards at interchanges.	Must be continually updated. Too much information to drivers may be distracting. Sign must be placed at a distance where merging conflicts influenced by signs may be minimized.	2022-2025	$6,209,870	$620,987

Table 13: Priority Projects – Road Weather Information System

Project(s)	Description	Advantages	Disadvantages	Est. Let. Date	Est. Capital Cost	Est. Design/ Study Cost
Install Road Weather Information System at the following locations: US 87 (2 EA) US 287 (1 EA) IH 40 (1 EA) See Figure 10	Install weather station locations to monitor weather conditions along roadway corridors. Information can be used to inform public of adverse conditions via the information dissemination strategy and can be used to proactively deploy maintenance as conditions develop.	Decentralized weather stations can provide weather information in a more targeted manner; e.g., by monitoring conditions along the whole interstate rather than just from one location can give the traveling public a more specific picture of road conditions, and indicate the speed of a storm front and the rate at which roadway conditions are deteriorating.	Additional operation and maintenance cost	2022	$221,000	$22,100

Table 14: Priority Projects – High Water Detection System

Project(s)	Description	Advantages	Disadvantages	Est. Let. Date	Est. Capital Cost	Est. Design/ Study Cost
Install High Water Detection Systems along IH 40. (2 EA) See Figure 12	Install high water detection systems to monitor rain and rising water conditions at locations historically known for flooding and causing water to cover the roadway. Information can be used to inform public of adverse conditions via the information dissemination strategy and can be used to proactively deploy maintenance	High Water Detection Systems can provide information to maintenance and notify the public of low areas prone to flooding and provide warning when roadways are unsafe to travel.	Additional operation and maintenance cost	2022	$100,000	$10,000

Table 15: Priority Projects – Comparative Travel Time Signs

Project(s)	Description	Advantages	Disadvantages	Est. Let. Date	Est. Capital Cost	Est. Design/ Study Cost
Install Comparative Travel Time Signs on US 87 and IH 27 approaching LP 335. IH 27 (1 EA) US 87 (1 EA) See Figure 15	Static signs with small DMS insert panels installed to display Travel Time estimates approaching the loop to encourage drivers to utilize the loop and avoid downtown Amarillo.	Concise display limits driver distraction while disseminating real time travel time information to the public. Smaller DMS panel is less capital intensive and costs less to maintain than large DMS board. Cost decreases if able to install on existing signs/ bridges.	Additional operation and maintenance cost	FY 2023	$220,875	$22,087

Table 16: Priority Projects – TMC Upgrades

Project	Description	Advantages	Disadvantages	Est. Let. Date	Est. Capital Cost	Est. Design/ Study Cost
TMC Upgrades Non-Corridor Specific Strategy (System Wide)	TMC upgrades and improvements, include updating the TMC room with video wall, work stations, hardware, communications equipment, video analytics, etc. Software upgrades include additional programming to integrate incident data into third party application, e.g., Waze and real time performance measurement software. Performance metrics will be displayed on upgraded TMC video wall. May include ATSPM information from traffic signals, and performance metrics from other ITS devices.	Implementing these improvements creates a state-of-the-art TMC that is a good place for staff to work and enables system operability with other technologies; e.g., incident detection, work zone monitoring, signal operation, and other intelligent transportation systems such as wrong-way detection and communications systems. Traffic management becomes central to operations of the road network in Amarillo. Emergency response routing may be improved, leading to better incident clearance times. Providing information to the traveling public can enable them to choose alternate routes and be updated on incident clearance progress. Software upgrades will help to elevate the TMC as the centralized source of information to streamline data collection, communications, and public messaging. Continuous monitoring of traffic on a 24/ 7 basis enables better responses to incidents that occur outside of normal operating hours and may lead to quicker incident clearance times in night-time or weekend hours.	TMC improvements have a high upfront cost. Many stakeholders and third-parties introduce the problem of system compatibility with all applications. Public adoption or consumption of data is not easy to measure. Operability is required with technologies that may be phased out in the future (e.g., Bluetooth). Uncertainty about technology changes – the investment may be partially obsolete after 10 years.	2022		$250,000

Table 17: Priority Projects – Traffic Incident Management

Project(s)	Description	Advantages	Disadvantages	Est. Let. Date	Est. Capital Cost	Est. Design/ Study Cost
Traffic Incident Management Non-Corridor Specific Strategy (System Wide)	Further study to refine and optimize Traffic Incident Management (TIM) program. Utilize performance metrics strategy to monitor performance of TIM program and adjust as needed. Identify potential training opportunities for emergency response personnel.	Streamline training process for staff involved in TIM. Performance tracking can help to adjust program where necessary, identify best practices and areas of improvement. Centralized standards for emergency response personnel can aid in incident clearance times, potentially limiting the secondary crash rate.	Accountability of using standards and performance measures across many stakeholders involved in TIM.	2022		

Table 18: Priority Projects – Traffic Signal Communication

Project	Description	Advantages	Disadvantages	Est. Let. Date	Est. Capital Cost	Est. Design/ Study Cost
Traffic Signal Communication	Install spread spectrum radios and /or cell modems to remotely communicate with traffic signal locations throughout the District. Install battery back-ups in traffic signal cabinets. Install CCTV cameras at high volume locations.	Remotely monitor traffic signal locations to determine equipment operation prior to dispatching signal techs. Maintain RYG operation during power spikes and outages. Reduce overtime and dispatching staff to restore operation and check complaints.	Additional operation and maintenance cost. Recurring monthly cost for cell modem installation.		$816,580	

Table 19: Priority Projects – Work Zone Management

Project(s)	Description	Advantages	Disadvantages	Est. Let. Date	Est. Capital Cost	Est. Design/ Study Cost
Work Zone Management Non-Corridor Specific Strategy (System Wide)	Implement work zone management practice into all construction projects. Train staff to utilize work zone equipment to optimize work zone operations and to provide real time construction zone data (speeds, volumes, etc.). Integrate work zone equipment into TMC for real time monitoring. Further study to determine benefits to TxDOT purchasing equipment and handling work zone management for maintenance work and other items that are not developed from a PS&E set.	A dedicated project for work zone management can also include purchasing work zone equipment and establishing institutional arrangements to manage traffic around work zones that would not come about in a normal PS&E project. Training for work zone management will improve and reduce the time for new employees to become familiar with and learn the processes that are required to manage work zones. By disseminating traveler information, the public can be better informed about construction impacts on travel times and the location of work zones to plan alternate routes and to be aware when workers are present to improve worker safety.	General work zone management practices may not work for every project. There may be unique circumstances or arrangements around a work zone that requires unique strategies or equipment.	2022	$240,644	$24,064

Table 20: Priority Projects – Summary of Proposed Devices with Implementation Priorities

Priority Projects – Summary of Proposed Devices													
I-40	Control-Section	CSJ	2022				2023			2024		2025	
			CCTV	DMS	RWIS	HWDS	CCTV	DMS	CTT	CCTV	DMS	CCTV	DMS
Coulter St. To Potter Co. Line East	0275-01					2							
10 Miles East Of New Mexico State Line To 0.23 Miles West Of FM 2858	0090-02				1								
US 385 in Vega to Potter Co. Line	0090-04	0904-00-181										1	1
0.2 Mile East of Adkisson Rd. to Bl 40-D	0090-05	0904-00-181										1	1
I-27													
Randall Co. Line North To SP 48 in Canyon	0168-09								1	2	5		4
Sundown Ln to US 60/IH 27 Split	0168-09	0904-00-181										1	1
US 287													
Oklahoma State Line to Sherman Co. Line	0066-01				1								
Loop 335													
FM 1541 To RANDALL CO. LINE NORTH	2635-02						1	2		2	2		
VARY	2635-03		2	4									
Bl 40-D To US 87	2635-04						3	4					
US 87													
New Mexico State Line To 8.6 Miles SE Of New Mexico State Line	0040-01				1								
South End of Dalhart To US 87/385 Split	0041-01	0904-00-181										2	2
Amarillo Creek To NE 12Th Street	0041-07								1				
0.863 Miles South Of FM 722 To Potter Co. Line South	0066-05	0904-00-181											1
US 385 To Moore Co. Line	0425-01	0425-01-021			1					1	1		
Hartley Co. Line To FM 2589	0425-02	0425-02-037					1	1					
US 54													
10.326 Miles NE of FM 767 to 0.788 Miles NE of FM 3139	0238-02	0904-41-010					1	1					
Total	**56**		**2**	**4**	**4**	**2**	**6**	**8**	**2**	**5**	**8**	**5**	**10**

Note: Detailed information about each device, including precise location data, is provided in the KMZ file.

Performance Measures

Performance measures are critical to the success of the TSMO program. Well defined performance metrics and accurately processed traffic data can enable transportation authorities to evaluate the performance of the transportation network, monitor and optimize the performance of the implemented ITS devices and technologies. The performance measurement dimensions of TSMO defined by FHWA are listed as below:

- Definition and criteria of each metric.
- How data is, or will be, acquired to track metrics.
- How data will be utilized.
- How data will be analyzed.

TxDOT Traffic Safety (TS) Division has developed dashboards to assist in monitoring the performance of ITS deployments. The Traffic Management System (TMS) Metrics Dashboards report the district and state-wide performance of the following items:

- District Asset Uptime - noting the percentage of devices that are reported to be online.
- District Average Incident Clearance Time – reported clearance times for collision and disabled vehicles.
- Level of Travel Time Reliability on Interstate Highways

Performance measures provide the benefit of allowing District staff to evaluate their procedures and refine them, increasing the performance and safety of their roadway network. They are also important tools for documentation of the District staff's response to incidents on roadways. This documentation is useful for training of future staff, performing lessons learned training sessions, and to illustrate the importance of the system to high level decision makers to help them make appropriate budget decisions.

As the amount of ITS devices within the Amarillo District increases over time, the responsibility for maintenance of those devices for uptime purposes also grows. This may require additional staff to perform field maintenance and provide a monthly report to TxDOT Traffic Safety Division (TSD) on which ITS devices are not functioning for various reasons, such as communications failures or construction projects. Additional training may also be needed for new maintenance staff as well as due to implementation of new ITS technologies.

The uptime metric reported by TxDOT TS is reliant on communication from the Amarillo District about the reasons for why some ITS devices may not be functioning. It should be noted that ITS devices down due to construction projects should not be counted within the overall uptime metric. It is important for the AMA District to communicate timely to TxDOT TS regarding the reasons of ITS devices that are not functioning.

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Appendix A: Existing Device Matrix

Existing ITS Device TxDOT Amarillo District							
	Existing			Existing Device To Be Replaced			
	Control Section	CCTV	DMS	Control Section	Year	CCTV	DMS
Coulter St. To Potter Co. Line East	0275-01	9	7	0275-01	2022-2023	8	1
					2026		3
					2028	1	
					2030		3
10 Miles East Of New Mexico State Line To 0.23 Miles West Of FM 2858	0090-02	1		0090-02	2028	1	
US 385 In Vega To Oldham Co. Line East	0090-04	1		0090-04	2028	1	
87							
Amarillo Creek To Potter Co. Line North	0041-05	1		0041-05	2028	1	
Amarillo Creek To NE 12Th Street	0041-07		2	0041-07	2022		2
0.863 Mile South of FM 722 To Moore Co. Line South	0066-05	1		0066-05	2028	1	
27							
Randall Co. Line North To Sundown Ln	0168-09	3	3	0168-09	2022	3	1
					2026		2
Potter Co. Line South To IH 40	0168-10	4		0168-10	2029	4	
BUSINESS 40							
IH 40 To RM 1061	0090-05		1	0090-05	2022		1
Total Existing CCTV		20					
Total Existing DMS			13				

Appendix B: Proposed Device Matrix

Proposed ITS Device TxDOT Amarillo District - 10-Year Plan												
								Proposed Installation Plan				
I-40	Control-Section	CSJ	CCTV	DMS	RWIS	CTT	HWDS	CCTV	DMS	RWIS	CTT	HWDS
Coulter St. To Potter Co. Line East	0275-01		1	11			2	2026	4 in 2026; 7 in 2027	-	-	2 in 2022
1.2 Miles East Of FM 2880 To Carson Co. Line East	0275-04		1	1				2029	2029	-	-	-
SH 70 To Gray Co. Line South	0275-08				1			-	-	2029	-	-
TX/NM State Limit To Deaf Smith Co. Line North	0090-01		1	1				2031	2031	-	-	-
10 Miles East Of New Mexico State Line To 0.23 Miles West Of FM 2858	0090-02				1			-	-	2022	-	-
0.23 Mile West of FM 2858 To US 385 in Vega	0090-03			1				-	2030	-	-	-
US 385 in Vega to Potter Co. Line	0090-04	0904-00-181	1	1				2025	2025	-	-	-
0.2 Mile East of Adkisson Rd. to Bl 40-D	0090-05	0904-00-181	1	1				2025	2025	-	-	-
0.2 Mile East of Adkisson Rd. to Bl 40-D	0090-05			1					2030			
I-27												
1.0 Mi South Of Rockwell Road To Randall Co. Line South	0067-17		1	1				2030	2030	-	-	-
Randall Co. Line North To SP 48 in Canyon	0168-09		2	9	1	1		2024	5 in 2024; 4 in 2025	2029	2023	-
Sundown Ln to US 60/IH 27 Split	0168-09	0904-00-181	1	1				2025	2025	-	-	-
US 287												
Oklahoma State Line to Sherman Co. Line	0066-01				1			-	-	2022	-	-
0.321 Miles South Of US 54 To Sherman Co. Line South	0066-03		1	1				2029	2029	-	-	-
US 87 To Moore Co. Line North	0066-04		1					2031	-	-	-	-
Loop 335												
VARY	2635-01		2	8				2028	2 in 2027; 6 in 2028	-	-	-
FM 1541 To RANDALL CO. LINE NORTH	2635-02		5	4				1 in 2023; 2 in 2024; 2 in 2031	2 in 2023; 2 in 2024	-	-	-
VARY	2635-03		2	4				2022	2022	-	-	-
Bl 40-D To US 87	2635-04		4	6				3 in 2023; 1 in 2031	4 in 2023; 1 in 2030; 1 in 2031	-	-	-
US 87												
New Mexico State Line To 8.6 Miles SE Of New Mexico State Line	0040-01		1	1	1			2029	2029	2022	-	-
South End of Dalhart To US 87/385 Split	0041-01	0904-00-181	2	2				2025	2025	-	-	-
Amarillo Creek To NE 12Th Street	0041-07		2	2	1	1		2029	2029	2029	2023	
FM 294 To Armstrong Co. Line East	0042-05		1	1				2031	2031	-	-	-
0.863 Miles South Of FM 722 To Potter Co. Line South	0066-05	0904-00-181		1				-	2025	-	-	-
US 385 To Moore Co. Line	0425-01	0425-01-021	1	1	1			2024	2024	2022	-	-
Hartley Co. Line To FM 2589	0425-02	0425-02-037	1	1				2023	2023	-	-	-

Continued on Next Page

Appendix B: Proposed Device Matrix – Continued

	Control-Section	CSJ	CCTV	DMS	RWIS	CTT	HWDS	Proposed Installation Plan				
								CCTV	DMS	RWIS	CTT	HWDS
IH 40 To RM 1061	0090-05		2	2				2030	2030	-	-	-
60												
Deaf Smith Co. Line South To US 385	0168-05		1	1				2031	2031	-	-	-
Roosevelt St. To Potter Co. Line East	0169-02		1					2028	-	-	-	-
US 83 North To Hemphill Co. Line North	0170-01		1	1				2031	2031	-	-	-
83												
CR K South of Perryton To Wolf Creek	0030-02		1	1				2029	2029	-	-	-
54												
10.326 Miles NE of FM 767 to 0.788 Miles NE of FM 3139	0238-02	0904-41-010	1	1				2023	2023	-	-	-
0.223 Miles Northeast of FM 2677 To TX/OK State Line	0238-06		1	1				2031	2031	-	-	-
385												
0.04 Mile South of Hwy 60 To Deaf Smith Co. Line South	0226-05		1	1				2031	2031	-	-	-
Total			**41**	**68**	**7**	**2**	**2**					

Appendix C: Unit Cost Breakdown

Device	Components	Planning Level Cost (in 2020 dollars)	
		Capital	Maintenance Per Year
CCTV Wireless	60' CCTV Pole and Foundation, CCTV and Cabinet, Foundation, Service Pole, Radio	$50,840.23	$2,500.00
CCTV Replacement	CCTV and Pole Mount	$12,375.00	N/A
DMS Wireless	COSS and Foundation, DMS and Cabinet, Service Pole, Radio	$187,067.71	$4,500.00
DMS Replacement	COLOR DMS (POLE MNT CABINET)	$119,567.71	N/A
CTT	COSS and Foundation, SIGN, 2 DMS INSERTS and Cabinet, Service Pole, Radio	$110,437.50	$4,500.00
RWIS	Remote Processing Unit (RPU) and Cabinet, RPU to Network Server Data Communications, User Interface, Network Server to User Interface Data Communication, Passive Pavement Sensor, Subsurface Temperature Probe, Additional Sensors	$55,250.00	$1,000.00
HWDS	Stand Pipe, Wire line or wireless communications, Advanced warning signs with flashers, Central/Master software, Cellular communications, Internet-based communications	$37,500.00	$1,500.00
TSSC	Traffic Signal System Communication	$12,008.53	$500.00
Radio	ITS Radio, Single Band, 5 GHZ, Integrated Antenna, uni-directional	$4,425.00	$500.00
All capital costs include 25% contingency for mobilization and unknown conditions			
All costs are based on TxDOT statewide average bid item prices as of September 2020, unless otherwise noted			

CCTV - Wireless			
Item No.		Desc	Cost
416	6006	DRILL SHAFT (48 IN)	$4,200.00
628	6185	ELC SRV TY D 120/240 070(NS)SS(E)GC(O)	$7,000.00
6010	6002	CCTV FIELD EQUIPMENT (DIGITAL)	$9,000.00
6010	6004	CCTV MOUNT (POLE)	$900.00
6064	6038	ITS POLE (50 FT) (110 MPH) W/CABINET (TY 2) (CONF 1)	$14,572.18
6062	6018	ITS RADIO (SNGL) (5 GHZ)-I-U	$5,000.00
		Contingency (25%)	$10,168.05
		Total	$50,840.23

CCTV - Replacement			
Item No.		Desc	Cost
6010	6002	CCTV FIELD EQUIPMENT (DIGITAL)	$9,000.00
6010	6004	CCTV MOUNT (POLE)	$900.00
		Contingency (25%)	$2,475.00
		Total	$12,375.00

Dynamic Message Sign (DMS) - Wireless			
Item No.		Desc	Cost
416	6023	DRILL SHAFT (SIGN MTS) (54 IN)	$12,000.00
628	6185	ELC SRV TY D 120/240 070(NS)SS(E)GC(O)	$7,000.00
650	6042	INS OH SN SUP (40 FT BAL TEE)	$30,000.00
6062	6018	ITS RADIO (SNGL) (5 GHZ)-I-U	$5,000.00
6028	6001	INSTALL DMS (POLE MTD CABINET)	$25,069.17
		Force Acct State supplied DMS Full Matrix Amber Freeway	$70,585.00
		Contingency (25%)	$37,413.54
		Total	$187,067.71

Dynamic Message Sign (DMS) - Replacement			
Item No.		Desc	Cost
6028	6001	INSTALL DMS (POLE MTD CABINET)	$25,069.17
		Force Acct State supplied DMS Full Matrix Amber Freeway	$70,585.00
		Contingency (25%)	$23,913.54
		Total	$119,567.71

Item No.		Desc	Cost
416	6023	DRILL SHAFT (SIGN MTS) (54 IN)	$12,000.00
628	6185	ELC SRV TY D 120/240 070(NS)SS(E)GC(O)	$7,000.00
650	6042	INS OH SN SUP (40 FT BAL TEE)	$30,000.00
6062	6018	ITS RADIO (SNGL) (5 GHZ)-I-U	$5,000.00
6028	6001	INSTALL DMS (POLE MTD CABINET)	$25,069.17
		Force Acct State supplied DMS Full Matrix Amber Freeway	$70,585.00
		Contingency (25%)	$37,413.54
		Total	$187,067.71

Comparative Travel Time Sign (CTT)			
Item No.		Desc	Cost
416	6023	DRILL SHAFT (SIGN MTS) (54 IN)	$12,000.00
636	6003	ALUMINUM SIGNS (TY O)	$4,350.00
628	6185	ELC SRV TY D 120/240 070(NS)SS(E)GC(O)	$7,000.00
650	6042	INS OH SN SUP (40 FT BAL TEE)	$30,000.00
6062	6018	ITS RADIO (SNGL) (5 GHZ)-I-U	$5,000.00
6322	6001	DMS INSERTS (POLE MNT CABINET)	$30,000.00
		Contingency (25%)	$22,087.50
		Total	$110,437.50

Road Weather Information System (RWIS)			
Item No.		Desc	Cost
628	6011	ELC SVC TY A 120/240 060(NS)SS(E)TP(O)	$5,000.00
6147	6001	INSTALL OF ROAD WEATHER INFO SYSTEM	$39,200.00
		Contingency (25%)	$11,050.00
		Total	$55,250.00

High Water Detection System (HWDS)			
Item No.		Desc	Cost
628	6011	ELC SVC TY A 120/240 060(NS)SS(E)TP(O)	$5,000.00
6313	6001	HIGH WATER DETECTION SYSTEM	25,000.00
		Contingency (25%)	$7,500.00
		Total	$37,500.00

Traffic Signal System Communication (TSSC)			
Item No.		Desc	Cost
6058	6001	BBU SYSTEM (EXTERNAL BATT CABINET)	$6,752.09
6054	6001	Spread Spectrum Radio	$2,854.73
		Contingency (25%)	$2,401.71
		Total	$12,008.53

Smart Work Zones (SWZs)			
Item No.		Desc	Cost
6302	6001	TEMP Q-DETECT (TY1) (1 SYS)	$707.20
6158	6001	TMSP RADAR SPEED CONTROL MONITOR	$11,592.57
6348	6002	TEMP INCIDENT DETECT & SURVEIL SYS	$179,995.00
6344	6001	TEMP TRAVEL TIME (1 SYS)	$151.00
6307	6001	TEMP SPEED MONITOR (1 SYS)	$41.64
6309	6001	TEMP CON EQUIP ALERT (1 SYS)	$27.64
		Contingency (25%)	$48,128.76
		Total	$240,643.81

Appendix D: Summary by Fiscal Year 2022-2031

Fiscal Year ITS Expenditures 2022-2031																							
ITS Element	**Existing ITS Devices**	**Project Type**	**FY 22**		**FY 23**		**FY 24**		**FY 25**		**FY 26**		**FY 27**		**FY 28**		**FY 29**		**FY 30**		**FY 31**		**Category Total**
			New	Replace Existing	New	Replace Existing	New	Replace Existing	New	Replace Existing	New	Replace Existing	New	Replace Existing	New	Replace Existing	New	Replace Existing	New	Replace Existing	New	Replace Existing	
CCTV	20	Standalone ITS	2	11	2		1		5		1				3	5	6	4	3		10		**61**
		Roadway Construction Letting			4		4																
DMS	13	Standalone ITS	4		3	2	2	3	6		4	5	7		6		6		6	3	7		**81**
		Roadway Construction Letting			5		6		4				2										
Road Weather Information System		Standalone ITS	4														3						**7**
		Roadway Construction Letting																					
High Water Detection System		Standalone ITS	2																				**2**
		Roadway Construction Letting																					
Comparative Travel Time Sign		Standalone ITS			2																		**2**
		Roadway Construction Letting																					
Traffic Signal Sustem Communication		Standalone ITS	16		16		18		18														**68**
		Roadway Construction Letting																					
Stand Alone ITS Let FY			$1,474,212.70		$1,315,030.41		$999,832.24		$1,592,760.85		$1,396,949.64		$1,309,473.99		$1,336,801.95		$1,642,697.63		$1,633,630.09		$1,817,876.24		**$14,519,265.73**
ITS Roadway Construction Letting FY			$0.00		$1,138,699.46		$1,325,767.18		$748,270.85		$0.00		$374,135.43		$0.00		$0.00		$0.00		$0.00		**$3,586,872.91**
Estimated ITS Maintenance Budget	$108,500.00		$146,500.00		$214,500.00		$272,000.00		$338,500.00		$359,000.00		$399,500.00		$434,000.00		$479,000.00		$513,500.00		$570,000.00		**$3,726,500.00**
ITS System Software & TMC Hardware Upgrade		Maintenance Cost	$30,000.00		$30,000.00		$30,000.00		$30,000.00		$30,000.00		$30,000.00		$30,000.00		$30,000.00		$30,000.00		$30,000.00		**$300,000.00**
	Existing		**FY 22**		**FY 23**		**FY 24**		**FY 25**		**FY 26**		**FY 27**		**FY 28**		**FY 29**		**FY 30**		**FY 31**		
FY Total	**$108,500.00**		**$1,650,712.70**		**$2,698,229.88**		**$2,627,599.41**		**$2,709,531.70**		**$1,785,949.64**		**$2,113,109.41**		**$1,800,801.95**		**$2,151,697.63**		**$2,177,130.09**		**$2,417,876.24**		
Grand Total Estimated ITS Expenditures Through FY 2031			**$22,241,138.64**																				

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