Report P4A Flood Transportation Geodatabase

Prepared for Project 0-7095-01 Flood Assessment System for TxDOT (FAST)

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1. Introduction

Task 4 in the FAST project agreement describes the development of a Flood Transportation Geodatabase to support the FAST road and bridge flooding services. This geodatabase comprises the following layers:

- Road Elevation Model
- Stream hydrography
- Road inundation
- Bridges
- Culverts
- Low water crossings
- Administrative boundaries

The Flood Transportation Geodatabase is a foundation for dynamic Flood Map Services, as shown in Figure 1. The flood transportation geodatabase layers are all static, that is, they do not change with time during the period of a particular flood. Constructing the geodatabase begins with foundational data on 2D roads and bridges, which have to be geospatially integrated. By adding information derived from Lidar measurement, 3D road and bridge information is produced. All this is checked using a formal quality control and error detection process.

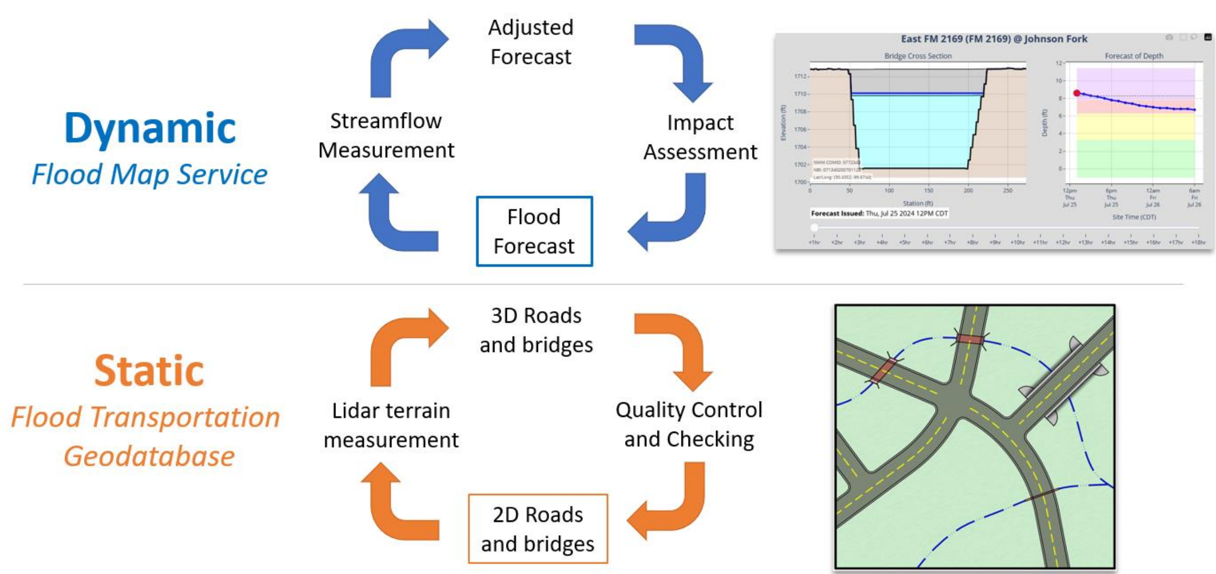

Figure 1. The Flood transportation geodatabase is a static foundation for dynamic flood map services.

The flood conditions themselves are dynamic and change with time during a flood event. Dynamic flood map services begin with a flood forecast and streamflow measurement, combine these using data assimilation to produce an adjusted forecast, and then an impact assessment creates bridge warning and flooded road maps.

2. Flood Transportation Geodatabase Components

The Flood Transportation Geodatabase itself contains two kinds of information, as shown in Figures 2 and 3. First, in Figure 2, are shown road lines and polygons, a road elevation model, bridges, culverts low water crossings, and streamlines. Second, in Figure 3, are shown the flood inundation map layers that are used to determine flood impact on the road and bridge system.

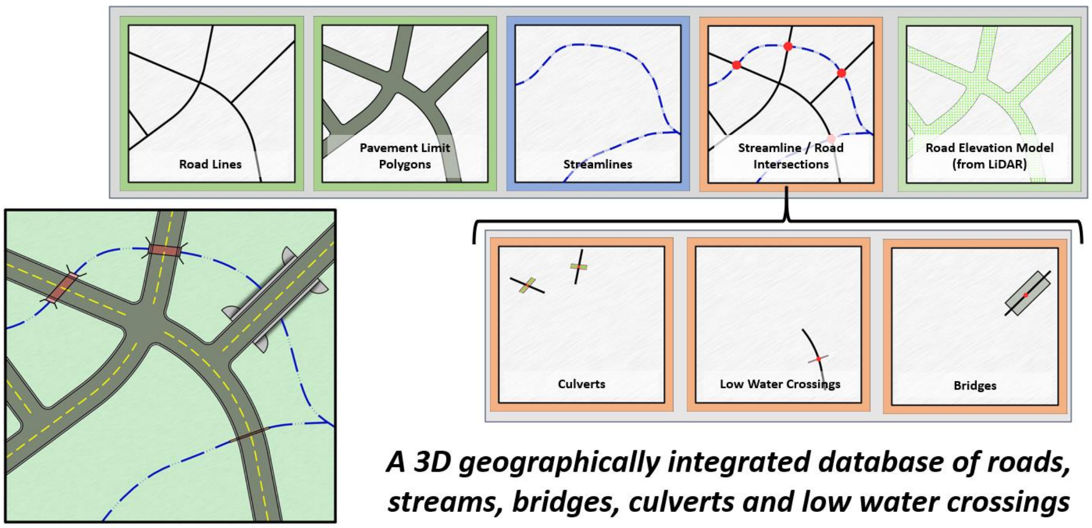

Figure 2.The Flood Transportation Geodatabase integrates a 3D representation of roads, streams, bridges, culverts and low water crossings.

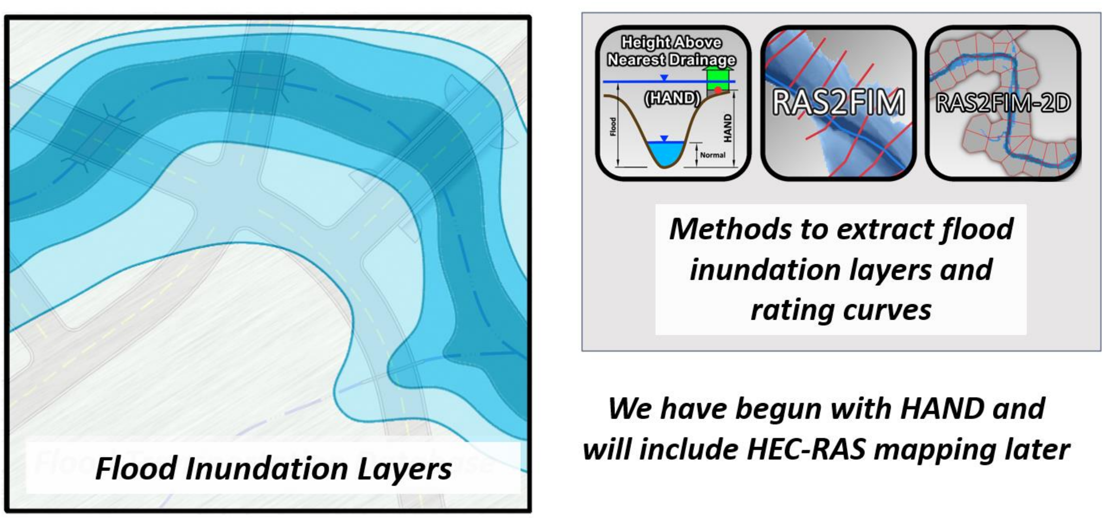

Figure 3. Flood inundation map layers in the Flood Transportation Geodatabase.

The first version of the Flood Transportation Geodatabase is based on flood inundation mapping using the Height Above Nearest Drainage (HAND) method. This method is the standard approach used by the US National Weather Service for its flood extent mapping. However, it has a simplifying assumption that the channel geometry and flood depth are uniform along each reach of the stream channel. There is a single rating curve that describes the relationship between the discharge and flood depth which is applied to all roads and structures impacted by flow in that stream reach.

A more realistic approach is to using engineering modeling, such as by 1-D and 2-D HEC-RAS to map the water surface elevation above geodetic datum for each indexed discharge value in a flood inundation map library, and then use these maps to define flood impact on the road and bridge system. A small number of HUC8 units in Texas have their National Weather Service flood inundation mapping created using 1-D HEC-RAS using a process called RAS2FIM developed in association with Project 0-7-095. A better result is achieved by using RAS2FIM-2D, which is presently being developed with support from the National Weather Service in association with this project.

3. Geodatabase Design

The Geodatabase design and quality control process comprises these five steps:

1. Data sources.

2. Database design.

3. Data ingest and assembly routines.

4. Quality control.

5. Product generation.

The original data inputs are obtained from authoritative sources. A listing of the sources and methods of identifying particular kinds of structures within these data is given in Appendix A. Once these data are assembled, they are built into a first draft geodatabase as illustrated in Figure 4. All the vector data layers (points, lines, polygons) are stored inside a Feature Dataset, which has a single projection. This facility ensures that some of the data are not inadvertently included with a mixture of coordinate systems.

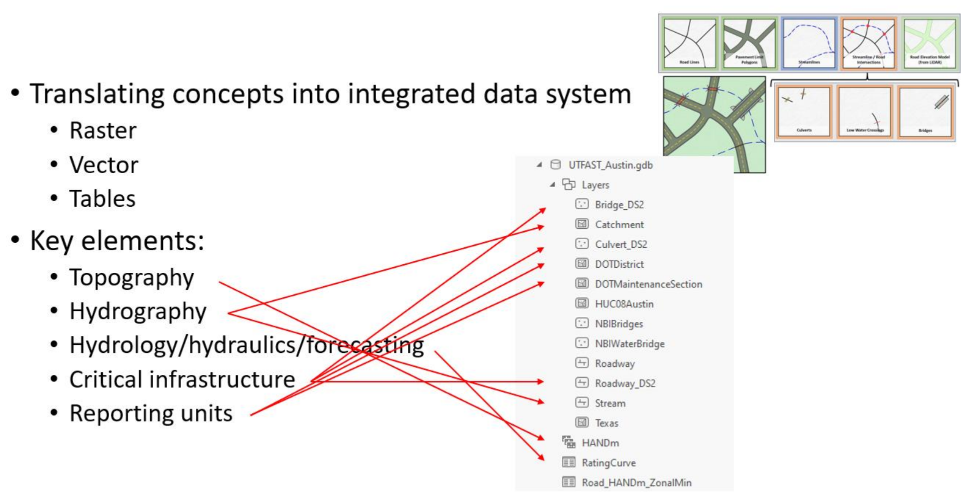

Figure 4. Draft geodatabase formed by ingesting data from data sources.

4. Quality Control

Once the draft geodatabase is assembled a Quality Control process is applied using the ArcGIS Data Reviewer. There are many rules that can be applied using the Data Reviewer interface shown in Figure 5. The first step in a "Feature on Feature" rule is to check what happens when a road line crosses a stream line. The rule searches within a defined radius to see if there is a bridge line present, and if so, if there is an NBI point describing that bridge line. As a final check, it looks at the attributes of the bridge line and of the NBI point to ensure that they have the same NBI Bridge ID. In the instance shown in Figure 6, there should be a bridge line present, but there is not, so this result is flagged as an error. Individual errors are examined using the Error Inspector component of the ArcGIS Data Reviewer.

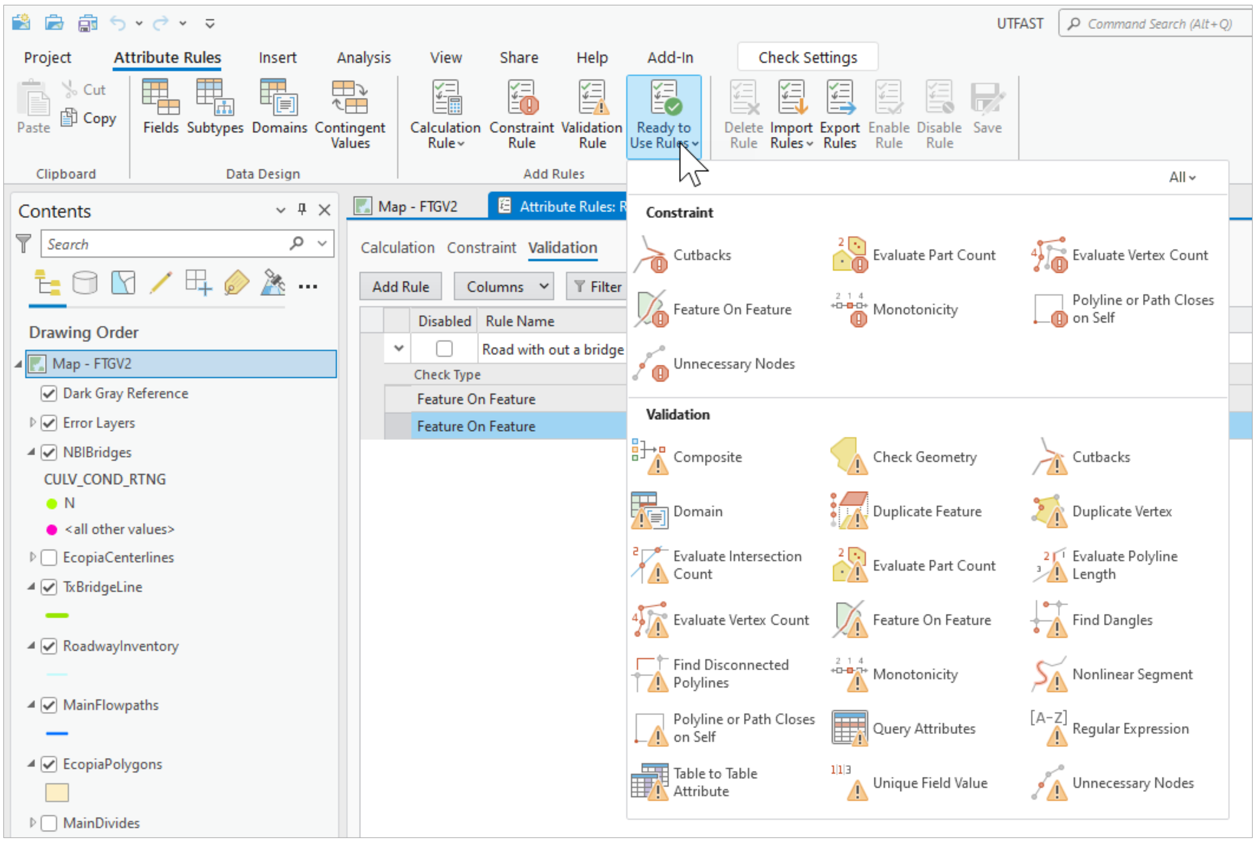

Figure 5. Rule options available in ArcGIS Data Reviewer.

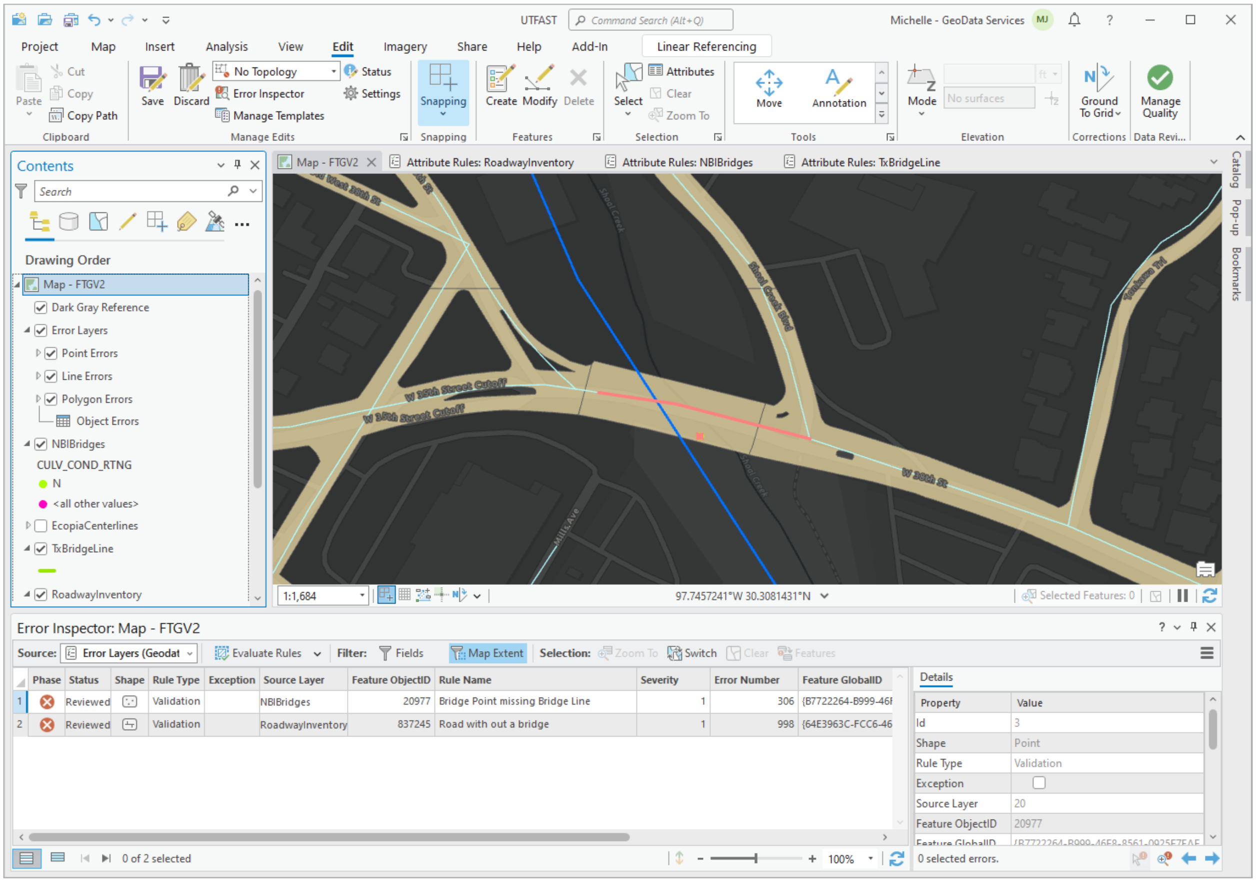

Figure 6. Application of a "Feature on Feature" rule in ArcGIS Data Reviewer.

The ESRI team (Dean Djokic as the Geodatabase Designer, and Michelle Johnson as the Quality Control reviewer), were authorized to begin working on this project in early July, so they have just completed the first steps on the work on assembling the source layers, and running some preliminary quality control checks. There will be many more cycles of this activity to follow. Dean and Michelle have each worked at ESRI for several decades and they are very experienced in successfully completing this type of task.

5. Conclusion

This report has described the concept of a Flood Transportation Geodatabase. There was no task in Project 0-7095 that preceded this project on this subject but it was found necessary to include such a task in the extension Project 0-7095-01 to ensure that the foundation upon which the flood map services for roads and bridges is constructed, is itself sound and of proper quality. If that is not the case, then, inevitably errors in the flood map services will follow.

The first version of the Flood Transportation Geodatabase is being built for the On-Systems roads in the Austin District during FY24. It is anticipated that the lessons learned will then be applied to extend the result to the state-wide On-System roads in FY25, and to the public road system in FY26.

Appendix A: Data Sources

This report describes the assembly of data to support the components of this geodatabase, and the procedure of database design and quality control checking to build a preliminary Flood Transportation Geodatabase for the Austin District.

Each of the Flood Transportation Geodatabase components has input information, in some cases comprising information from several sources.

Road Elevation Model

The Road Elevation Model is a geospatial representation of the paved road surface coupled with a set of LIDAR points that lie on that road surface. For the Austin District, a prototype Road Elevation Model was prepared in October 2023 as part of Project 0-7095, and is described at: https://www.caee.utexas.edu/prof/maidment/RoadElevationModel.htm The LIDAR point datasets for each Maintenance District are available at: https://web.corral.tacc.utexas.edu/nfiedata/road3d/austin_district/AustinMaintenanceSections_H_epsg6343_V_epsg5703/ and for each County at: https://web.corral.tacc.utexas.edu/nfiedata/road3d/austin_district/AustinCounties_H_epsg6343_V_epsg5703/ The polygons for the road surface used to derive these LIDAR point data collections were provided by the Ecopia corporation and are not publicly sharable.

Stream Hydrography

The reference stream hydrography is that developed for the National Water Model and is available from Michael Johnson of the National Water Center at: https://www.lynker-spatial.com/data?path=hydrofabric%2Fv20.1%2Fgpkg%2F

Road Inundation

The road inundation is being calculated using the TxDOT Roadway Inventory, a polyline (x,y,m) dataset accessible on the TxDOT Open Data Portal. https://gis-txdot.opendata.arcgis.com/ This consists of roads of two types: On-System roads that TxDOT owns and maintains, and Off-System roads that are owned and maintained by cities, counties and other entities. In FY24 (to August 2024) this FAST project is concerned with On-System roads in the Austin District, and in FY25 (September 2024 to August 2025) with On-System roads state-wide. Inclusion of Off-System roads in the public road system will be addressed in FY26 (September 2025 to August 2026). The TxDOT On-System roads are accessible through the TxDOT Open Data Portal at: https://gis-txdot.opendata.arcgis.com/datasets/46c6ad08e47e4117af4b12b9b2aa7e8d_0/explore

A data dictionary for the TxDOT Roadway Inventory can be found at: https://www.caee.utexas.edu/prof/maidment/StreamflowII/Documents/TxDOT_Roadway_Inventory_Specifications_2020.pdf

Bridges

During Project 0-7095, a bridge identification project was undertaken by Andy Carter using LIDAR point cloud data classified as bridges, along with LIDAR-based DEM's for the associated stream cross-section using a methodology called Tx-Bridge. This methodology was initially developed for use with extracting

USGS LIDAR point cloud data extracted through web calls, https://github.com/andycarter-pe/tx-bridge but was subsequently modified to run on LIDAR point cloud data stored at the Texas Advanced Computing Centre (TACC). The result is produced as a GeoJSON file whose attributes are described in Appendix A of Report TM5B of Project 0-7095 https://www.caee.utexas.edu/prof/maidment/StreamflowII/ReferenceDocs/0-7095-TM5B-Final.pdf

A Tx-Bridge GeoJSON file for bridges in the Austin-San Antonio area is at: https://utexas.app.box.com/s/ky79944hrieuyfo7et05b1eph4y4hvou

Bridges are also described by the National Bridge Inventory, a point data file that is accessible at the TxDOT Open Data portal https://gis-txdot.opendata.arcgis.com/datasets/83af0d2957ca4c2eb340e4bd04a1046f_0/explore This file contains about 55,000 bridges comprising, approximately:

- 25,000 span bridges over water
- 20,000 bridge-class culverts
- 10,000 bridges over roads, railroads or other features

The structures described in this inventory are 20 feet or more in length along the roadway centerline and their condition is required to be reported to the federal government. A span bridge is a bridge whose road is carried on a deck supported on piers well above the water surface of the stream or river flowing below. A bridge-class culvert is a set of pipes imbedded in the roadway itself and designed to operate if necessary in a submerged condition. Generally, bridge-class culverts are multiple box culverts built using reinforced concrete.

A Coding Guide for the National Bridge Inventory is accessible at: https://www.caee.utexas.edu/prof/maidment/StreamflowII/Documents/BridgeCodingGuide.pdf and a Data Dictionary which translates the Coding Guide into GIS data attributes is found at: https://www.caee.utexas.edu/prof/maidment/StreamflowII/Documents/Bridge_Data_Dictionary.pdf

A Bridge-Warning Service is included in the FAST project which signals if there is a likelihood that the bottom of the beams supporting the bridge deck are threatened by rising floodwaters.

In the National Bridge Inventory, bridges that are over water are distinguished from those that are not by means of the attribute Service Type Under Bridge. If this number is between 1 and 4, the structure is not over water, and if between 5 and 9, the structure is over water, as shown in Figure 1.

SRVC_TYPE_UNDER_BRDG
5
5
5
5
1
1
1
1

Figure 1. Service Type Under Bridge in the National Bridge Inventory

Bridge-Class Culverts

Span bridges are differentiated from Bridge-Class culverts in the National Bridge Inventory using the attribute Culvert Condition Rating. If this rating has the value "N" it means that the structure is a span bridge. If the rating is a number between 1 and 10, for example 6 in Figure 1, then the structure is a bridge-class culvert

CULV_COND_RTNG
N
N
6
6
N
N

Figure 1. Culvert Condition Rating in the National Bridge Inventory.

TxDOT maintains a more detailed description than in the National Bridge Inventory of the size of the boxes, and the length and material type of bridge class culverts in its AssetWise system.

Low Water Crossings

A low water crossing is a road that is designed to be inundated whenever high water occurs in the associated stream. There are often small culvert pipes beneath the road that convey the stream during normal flow conditions. There is no standard database of low water crossings, but the Austin District has commissioned a special study of its low water crossings, which can be seen at: https://www.caee.utexas.edu/prof/maidment/StreamflowII/Documents/Final%20Report%20WA%204%20Low%20Water%20Crossing%200227017.pdf which identified 153 low water crossing locations and classified 20 of these as being the highest priority. During Project 0-7095, a rapid field assessment procedure was developed and data collected for these 20 locations https://www.caee.utexas.edu/prof/maidment/StreamflowII/Documents/ProjectP6B2Project07095.pdf

Administrative Boundaries

TxDOT has two key sets of administrative boundaries: Districts and Maintenance Sections. There are 25 TxDOT Districts each comprising a collection of counties, and these are the primary coordinating point for flood emergency response. Texas has 254 counties, so on average a District covers about10 counties. Maintenance Sections are regions for which a particular group of Maintenance personnel is responsible for field operations during flood emergencies, including closing and opening roads. Maintenance Sections are led by a Maintenance Supervisor. The Maintenance Section boundaries are not always coincident with District boundaries.

The TxDOT District Boundaries can be obtained from the TxDOT Open Data Portal: https://gis-txdot.opendata.arcgis.com/datasets/c0f9e13775d04422bbd60926b00709ff_0/explore

The TxDOT Maintenance Section Boundaries can also be obtained from the TxDOT Open Data Portal: https://gis-txdot.opendata.arcgis.com/datasets/3209155fa26b470db63f56733dd17d36_0/explore?location=30.775999%2C-100.049436%2C5.78

Discussion with the TxDOT Project Management Team has indicated that the default projection for state-wide datasets is Geographic Coordinates with the NAD 1983 (2011) datum.