Report P4D Flood Forecast System Operation

Project 0-7095 Evaluate Improved Streamflow Measurement at TxDOT Bridges

30 June 2023

Prepared by Attila Bibok and Matt Ables, KISTERS North
America, and David Maidment, University of Texas at Austin

Introduction

This is the last of four progress reviews for Task 4, Flood Forecast System Operation. The schedule of these reports is shown in Table 1.

Report	Due Date	Months from Project Initiation
P4A	April 2021	8
P4B	January 2022	17
P4C	July 2022	23
P4D	June 2023	34

Table 1. Schedule of P4 reports

Flood Assessment System for TxDOT (FAST)

The Flood Assessment System for TxDOT (FAST), developed in this project, comprises six real-time map services, as shown in Figure 1. Three of these services come from NOAA and USGS (Precipitation, Flood Inundation and Streamflow Measurement), and three are internally generated by TxDOT to support assessment of flooding on the road transportation system (Bridge Warnings, Flooded Roads, and Flood Impact). The Bridge Warning system is now operational on about 600 bridges in and around the Austin District. The other two services will be similarly developed and supported at a later time.

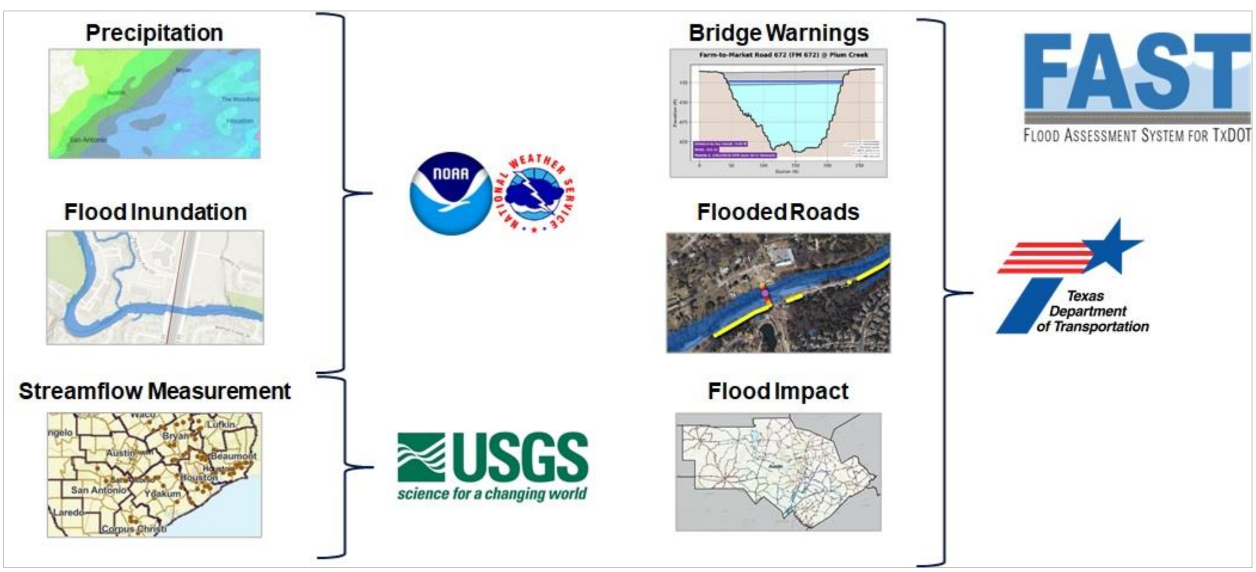

Figure 1. The Flood Assessment System for TxDOT (FAST)

Functions of Datasphere

The underlying technical infrastructure that supports the FAST system is a set of software and data functions called Datasphere, which resides on the Eastern United States facility of Amazon Web Services. It is maintained there by the KISTERS firm, whose parent company KISTERS AG https://www.kisters.de/en/ is based in Aachen, Germany, and KISTERS North America, based in Sacramento, California. Datasphere contains two kinds of information: observations and rasters. Observations are time series records of measured data at gauges, such as precipitation, water level and streamflow. Raster data are arrays of information distributed over space and time, such as a sequence of precipitation maps or flood forecasts defined for each reach of a stream network. These are called "Time Series Value Layers" in Datasphere. Data from the TxDOT Flood Data Network developed in this project are stored as observations data. Information from the National Water Model is stored as raster data. Note that use of the term "raster" in this context is different from the use of this term in GIS where it refers exclusively to data stored one value per cell in a dense cell mesh, such as a Digital Elevation Model or a photographic image.

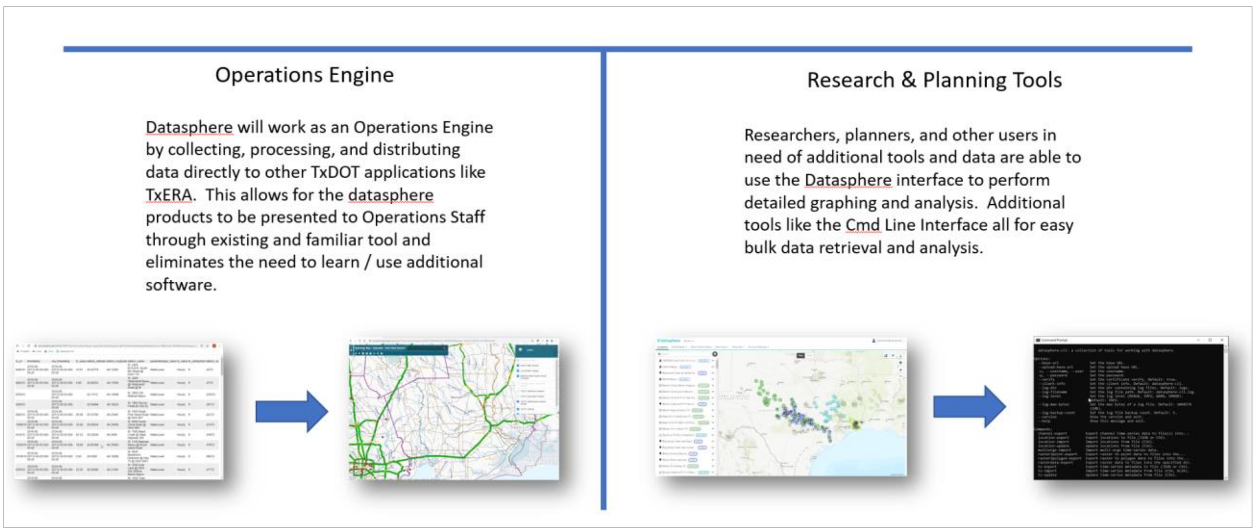

Figure 2. Datasphere supports real-time operations and retrospective research and planning analyses.

Two mechanisms of Datasphere operation are illustrated in Figure 2. The first mechanism is the "Operations Engine" which supports real-time flood information and is based on web services requests for data (see Figure 3) from the ArcGIS Online mapping environment, such as for the latest values of gauge readings – "give me the latest value from all the gauges over the whole spatial domain". This supports the creation of real-time flood maps in the Flood Assessment System for TxDOT (FAST). The second mechanism is the "Research and Planning Tools" which deal with extraction and analysis of historical information stored in Datasphere, such as past records of streamflow or water level or the retrospective flows of the National Water Model for the period 1979 to 2020, produced as part of the validation of the current National Water Model version 2.1. Such enquiries may include "give me the time series for this gauge" "give me all the time series from this observation network". These requests are made using Python programming to access the Datasphere's Command Line Interface (CLI).

Datasphere also supports a visual portal for querying and viewing observations and raster data. This set of functions is used for student research on such topics as forecast model error analysis.

Besides customizing Datasphere for use in FAST, the KISTERS firm provided additional services in support of the Streamflow project:

- Provided the RQ30 sensor and supporting gauge equipment to the USGS;
- Supported the USGS in logger and RQ30 configuration;
- Repaired and replaced gauge equipment as necessary;
- Designed and developed a telemetry process and web services for the USGS to download gauge data;
- Maintained alternative and backups of all original gauge telemetry data.

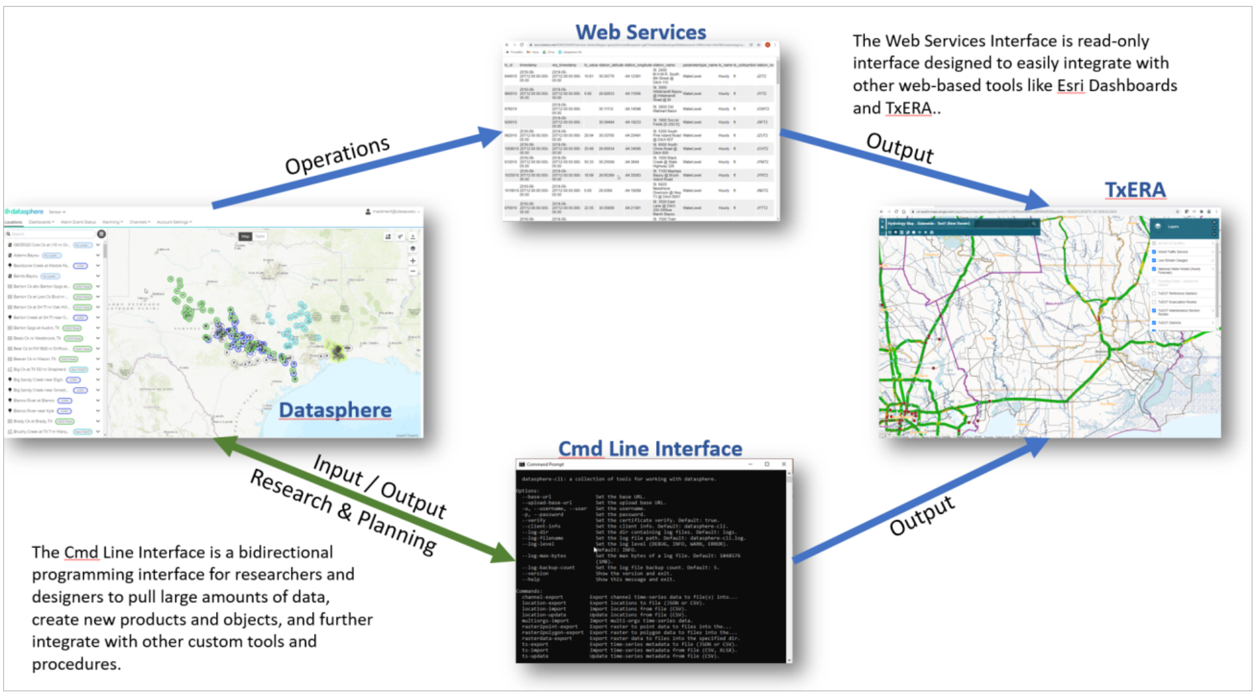

Figure 3. Mechanisms of operation of Datasphere

Flood Impact on Bridges

Flood impact on a bridge is depicted in FAST using a graphic of the elevation view of the bridge shown in Figure 4. The grey bar at the top is the bridge deck whose surface elevation is determined from LIDAR data and whose depth to low chord elevation is determined by an estimating formula based on the type and size of bridge. The stream cross-section is determined from a bare earth elevation model. The water level at the bridge is computed from the National Water Model short range forecast and comprises two values – the current level and the maximum level during the forecast period. These values are updated hourly. The forecast value is a discharge and the conversion to water surface elevation is given by a rating curve determined by the HAND method used for NWS flood inundation mapping with the stage height value measured from the bed of the channel cross-sections.

A map of the currently operational bridge warning services is shown in Figure 5, for about 600 locations in and near the Austin District. KISTERS also publishes the ESRI map service used to depict the bridge warning points, which in operation will be colored according to the level of risk at the bridge of the water hitting the low chord elevation of the bridge. There are about 30,000 bridges over water in Texas and when the FAST system is fully built out the KISTERS Datasphere will support forecast services for all those bridges whose streams have forecast discharge values in the National Water Model (about 25,000 bridges).

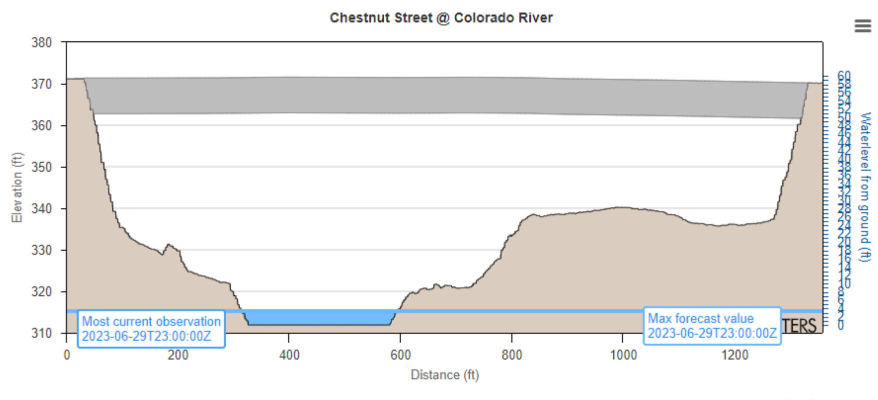

Figure 4. Bridge Warning Service for the Chestnut St bridge over the Colorado River, Bastrop, Texas

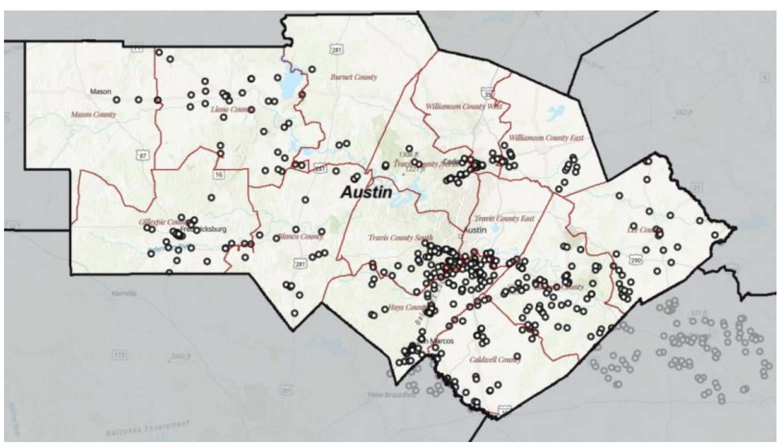

Figure 5. Location of currently operational bridge warning services.

Data Assimilation

Data Assimilation is a process that combines observations and NWS forecast information to produce updated forecast information. The outcomes of data assimilation are stored in a consistent format similar to that of the ingested NWM 2.1 outputs. This synchronization of data formats enables seamless visualization and comparison of the results obtained through data assimilation, the actual observed data, and the forecasts that have been adjusted using the results of the data assimilation.

To gain a clearer perspective on the dynamic interactions between Datasphere and the KISTERS model, an integration framework is shown in Figure 6.

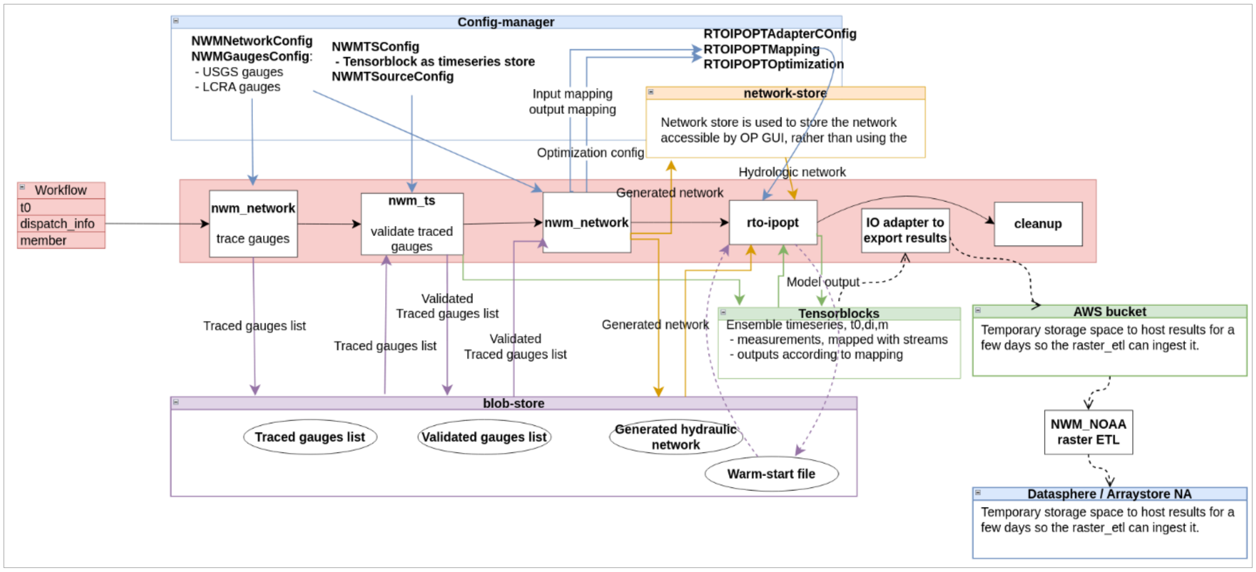

Figure 6. Solution Architecture Diagram showing the relation between the Model Integration Framework and Datasphere

The KISTERS model integration framework is designed to tackle a wide range of modeling tasks, operates on standardized procedures, ensuring reliability, reproducibility, and comparability of results. Leveraging the power of post-processing techniques and Extract, Transform, Load (ETL) adapters, Datasphere effectively assimilates and integrates the computed results into its system, enabling their convenient display in a manner that has already been demonstrated and validated. By employing these modeling and processing adapters, Datasphere efficiently incorporates, processes, and organizes the collected information. The historic and forecast storm and flood events can be stored, selected, and displayed (Figure 7).

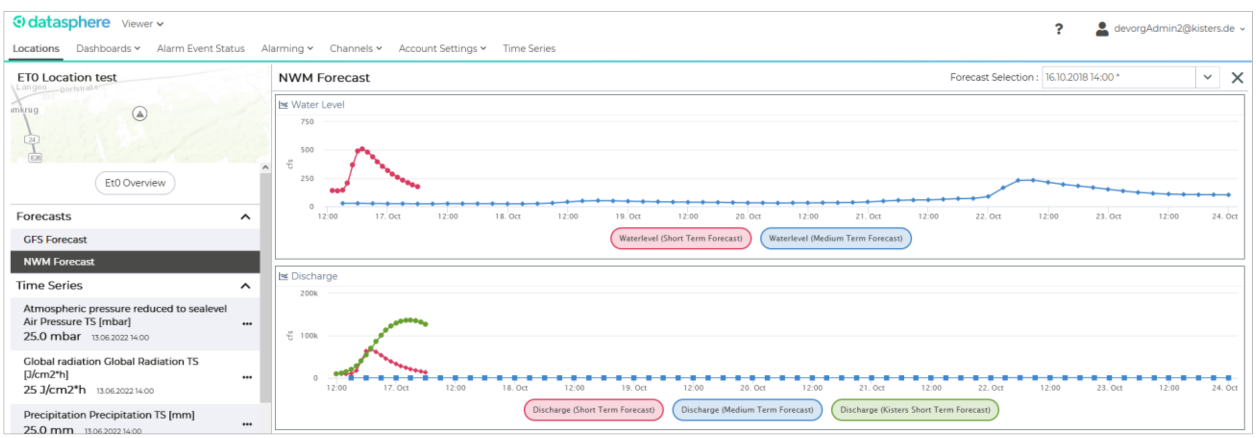

Figure 7. Displaying the NWM forecast and the adjusted forecasts in Datasphere.

Datasphere, with its extensive computational resources and advanced capabilities, plays a pivotal role in performing the conversion of stage from discharge. These calculations were executed utilizing synthetic rating curves developed for each individual bridge enlisted in the National Bridge Inventory for Texas. This comprehensive process ensures accurate and reliable stage predictions, enabling a deeper understanding of flood forecasts and their impact on bridges and infrastructure (Figure 8).

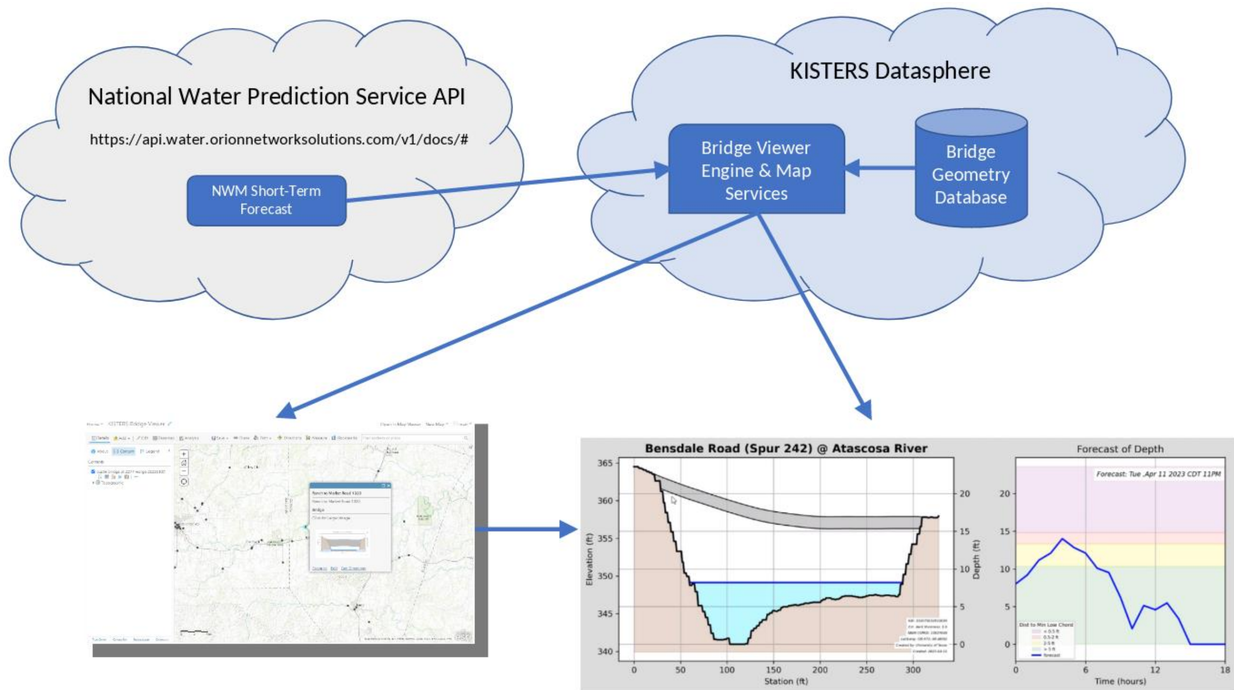

Figure 8. Relations between NWM short-range forecasts and bridge flooding visualization, and its integration with external tools

The functionality of Datasphere extends beyond its internal operations, offering external tools which provide seamless access to its services through REST APIs. This integration feature allows for smooth interaction with ESRI's map services. By bridging the gap between Datasphere and ESRI's tools, users can harness the power of both platforms, combining their respective strengths in time and space. This interoperability ensures that TxDOT can leverage the full potential of both Datasphere and ESRI's services, maximizing the efficiency of their workflows and gaining valuable insights into the intricate dynamics of water resources in Texas.

Conclusion

Through its robust computational infrastructure and its flexibility, Datasphere provides vital resources for the Flood Assessment System of TxDOT. Its ability to seamlessly integrate with external tools and services opens up new possibilities for data analysis, modeling, and decision-making, empowering users to make informed choices and drive meaningful advancements in flood forecasting and response.