A Riverine Infrastructure Database (RIDB) for Rapid Assessment of Asset Vulnerability and Incorporating Resiliency into Agency Practices

Final Report | October 2024

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16. Abstract

During flood events, it can be difficult to find relevant hydrologic and hydraulic information for assessing the vulnerability of infrastructure. In many cases, the information is not available or can be very time-consuming to obtain and evaluate. Without good information regarding the hydraulic relationship between infrastructure and flood discharges, it is difficult to be proactive with regard to the protection of lives, property, and infrastructure.

The Riverine Infrastructure Database (RIDB) is an effort the Iowa DOT started around 2008, after widespread flooding in the central and eastern parts of Iowa, to begin the collection of data to support rapid assessment of infrastructure during flooding events. The Iowa DOT provided the research team two sources of data including a spatial database and file database to support the effort to create the RIDB as a relational database in a geographical information system (GIS) environment. Using the provided data, Python scripts were developed to extract relevant data from the file database for over 270 sites including a site summary, feature summary, frequency curves, and one or more rating curves to further the development of the RIDB. The RIDB developed from the data is made up of multiple interconnected layers and tables that represent the stream network and infrastructure in Iowa and that help to identify locations where flooding may have impacts.

An architecture was developed for the RIDB system, including the core process developed to continuously monitor flooding impacts. Using stream flows provided by the IFC's HLM, the system has the ability to utilize the rating curves for each infrastructure feature to quickly determine whether the stream flows will result in features or controls being overtopped or whether the flow will be over the critical discharge level that may result in scour.

The RIDB developed as part of this project shows how maintaining a database of hydraulic and infrastructure data can support an agency in assessing the vulnerability of infrastructure during high-stress flooding events. The RIDB can also support scenario planning to allow the Iowa DOT to directly input stream flows or stage values to assess potential impacts across the network. The RIDB also supports additional resiliency analysis, as the flood frequency curves can be used to determine what severity of flooding events will impact infrastructure.

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INTRODUCTION

During flood events, it can be difficult to find relevant hydrologic and hydraulic information for assessing the vulnerability of infrastructure. In many cases, the information is not available or can be very time-consuming to obtain and evaluate. Without good information regarding the hydraulic relationship between infrastructure and flood discharges, it is difficult to be proactive with regard to the protection of lives, property, and infrastructure. Too often, departments of transportation (DOTs) and other infrastructure owners are reactive instead of proactive regarding flood events, resulting in unnecessary damages and risks to public safety.

In 2008, extreme flood events occurred along many large stream basins in the central and eastern parts of Iowa that impacted I-80 and many other primary routes. During these flood events, it was critical to assess and predict which highway locations had the potential for overtopping from floodwaters so that safe detour routes could be identified for the traveling public. The effort to evaluate the vulnerability of the roadway to flooding required significant Iowa DOT staff time and resources to reconcile the datums of various projects and correlate hydraulic estimates to determine accurate stage versus discharge relationships (rating curves) at specific bridge/highway locations.

The Iowa DOT was fortunate that a bridge replacement project was under construction on I-80 over the Cedar River at the time of the 2008 floods. Since the Iowa DOT had design information regarding the low roadway and detailed hydraulic data (a rating curve), the Interstate was closed before floodwaters impacted the traveling public. Traffic was proactively detoured along other primary routes, preventing significant traffic delays and diversion of traffic into the local roadway system. This event was the impetus for the development of an innovative Riverine Infrastructure Database (RIDB).

Purpose

The Iowa DOT owns approximately 2,100 bridges over streams and rivers on the primary highway system. Many of these highway bridge and roadway sites are vulnerable to flood damage and overtopping during flood events. An innovative and proactive approach to assessing the vulnerability and risk of transportation projects and systems will be accomplished by the development of the RIDB. The relational database incorporates hydraulic (flow and flood elevations) and infrastructure (low road and bridge beam elevations) data that can be utilized to provide rapid assessment of riverine locations when the potential for roadway overtopping or bridge inundation could occur.

The Iowa DOT has been collecting Global Positioning System (GPS) survey information of bridge/roadway locations along with hydraulic and historic flood information over the years. The collection of these data provides a repository of information that can be used to quickly ascertain the vulnerability of highway infrastructure and potentially other assets. The Iowa DOT has completed a mapping of Iowa’s stream network in a geographical information system (GIS) environment for site identification and flood forecasting/scenario assessments.

The overall goal of the Iowa DOT is to populate every site on the primary highway system in Iowa that has a drainage area of 10+ mi^2 with accurate hydraulic and infrastructure information into the RIDB.

Goals and Objective

The goal of the research project was to develop the RIDB into a relational database by incorporating hydraulic (flow and flood elevations) and infrastructure (low road and bridge beam elevations) data that can be used for rapid assessment of riverine locations. Through this research effort, the data collected by the Iowa DOT for the RIDB was integrated into the Iowa DOT's enterprise GIS environment, accessible for internal and public use. The system uses a series of relational databases and representational state transfer (REST) services to provide access to critical infrastructure flood data. As part of the RIDB system, various applications were developed that allow for easier use of the RIDB including flood frequency and near real-time flooding impacts.

The following describes the primary objectives of the project:

- Create a relational database of the RIDB in an enterprise GIS system
- Enable rapid assessment through the integration of flow data from the Iowa Flood Center (IFC) Hillslope Link Model (HLM)
- Provide field data collection capabilities to allow Iowa DOT staff to collect photos and data during flooding events, such as high-water marks

Report Summary

This final report documents the research effort in the development of the RIDB and various systems utilizing the RIDB. The report first provides a summary of the data extraction efforts that were used to convert the spatial and file databases maintained by the Iowa DOT into a relational database that could be deployed in an enterprise GIS system. The report then provides an overview of the RIDB, providing a summary of the layers/tables, an entity relationship diagram of the RIDB, and a detailed summary of all fields in the RIDB. The final section of the report summarizes the various systems that have been developed utilizing the RIDB including the rapid assessment of features using the IFC HLM and the field data collection application for flooding events.

RIDB INITIAL DEVELOPMENT

Initial RIDB Data from the Iowa DOT

The RIDB is an effort that the Iowa DOT started around 2008, after the Cedar River flooding, to begin the collection of data to support rapid assessment of features during flooding events. As part of these efforts, the Iowa DOT developed guidelines for the creation of data for the RIDB. The initial content served as the foundation for this research effort and the basis for the relational data structures. This section describes the processes used to extract the data for the RIDB from the existing information collected by the Iowa DOT.

Additional details about the structure of the RIDB are provided in the RIDB Overview chapter, but the RIDB at its core is based on sites located along the stream network that may be impacted by flooding. These sites have multiple features that may lead them to be overtopped or significantly impacted by a flooding event. An example of a site and its corresponding features are shown in Figure 1. Each of the sites include the stream it may be impacted by and the corresponding river mile, which allows for hydraulic loading and comparisons across sites along the stream network.

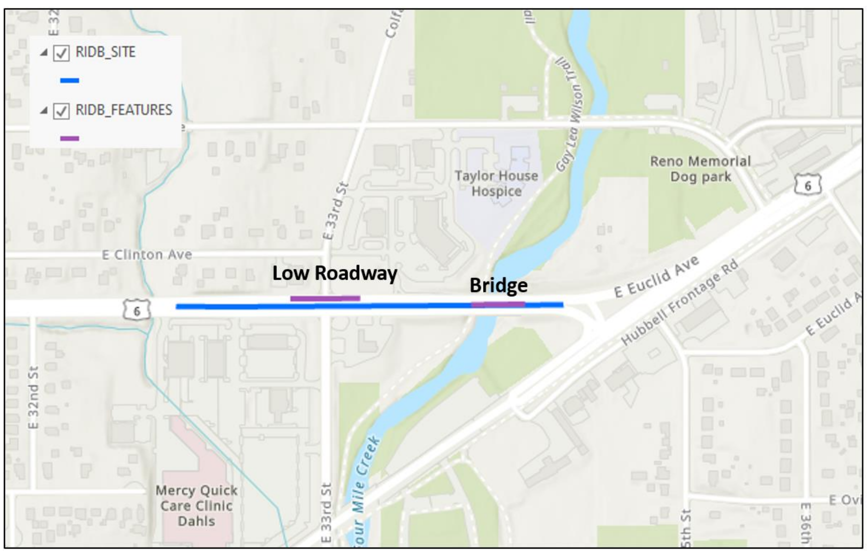

Figure 1. Summary of site and feature relationship

As part of the effort by the Iowa DOT, flood frequency and rating curves were developed for the sites and associated features to support the rapid assessment capabilities of the RIDB. Figure 2 provides a general overview of the relationships between the sites, features, flood frequency (FQ), and rating curves (QH). As part of the Iowa DOT's effort to classify each site, the agency developed a frequency curve that applies to both the site and its features. Rating curves were also developed that relate the flow and elevation/stage. Each site can have multiple rating curves, and each feature has been assigned a rating curve that can be used in the assessment of impact.

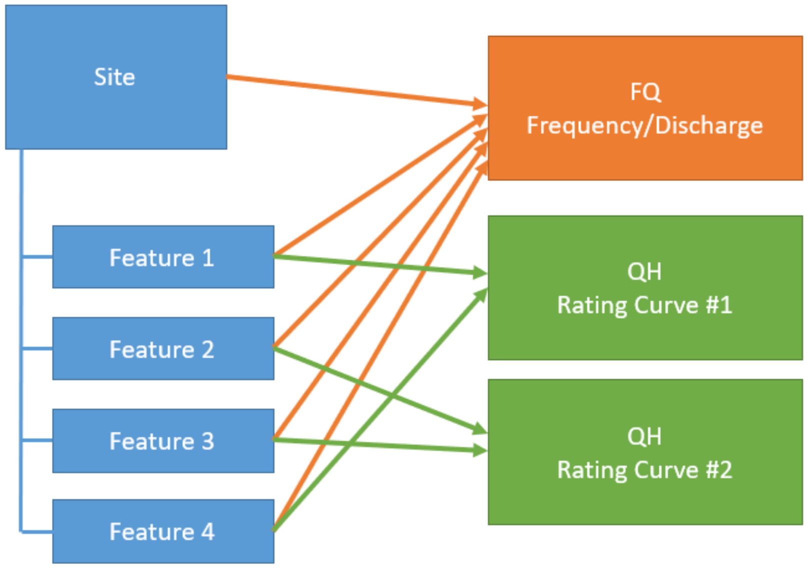

Figure 2. Overview of site/features and hydraulic components

Processing Iowa DOT Data

The Iowa DOT provided two sources of data including a spatial database and file database. The spatial database contained five layers including the stream network, sites, structures, controls, and low roads. The file database contained a folder for each site developed by the Iowa DOT. The contents of the folders varied slightly based on the level of analysis and the time the site overview was developed. The primary contents of the folder included text files for the site summary, the frequency curve, and one or more rating curves. The site summary file included detailed information about the site along with details about all features associated with the site.

The stream network provided by the Iowa DOT was primarily left unchanged through this project with only slight adjustments to the field names for consistency and, more significantly, the conversion of the network to a polyline with M values. Each polyline in the stream network included the begin and end river miles, and in the original network a user would need to calculate the distance along the polyline to identify a site. By enabling the use of M values, the stream network stores the river miles within the polyline, and users can select any point along the line to determine the river mile. This functionality opens up additional linear referencing capabilities within the GIS. Additionally, the original stream network included a field indicating if a stream was digitized in the reverse direction, and, as part of this project, those streams were corrected to reduce the complexity of the network.

The remainder of the initial development of the RIDB focused on extracting the site summary, frequency curve, and rating curves data to be related to the spatial layers or populate the database. Over 270 site summaries were provided by the Iowa DOT, so several Python scripts were developed to read the corresponding files and then extract the needed data into comprehensive comma separated values (CSV) files.

Each site summary text file includes data for both the site layer and the feature layer. Each file was structured to be human legible but formatted in a way that each attribute was easily identifiable systematically (Figure 3). A Python script was created to iterate through all site summary files in the file database and extract the pre-identified fields that would correspond to the given site. The data were populated into a CSV file that was then joined to the site spatial layer.

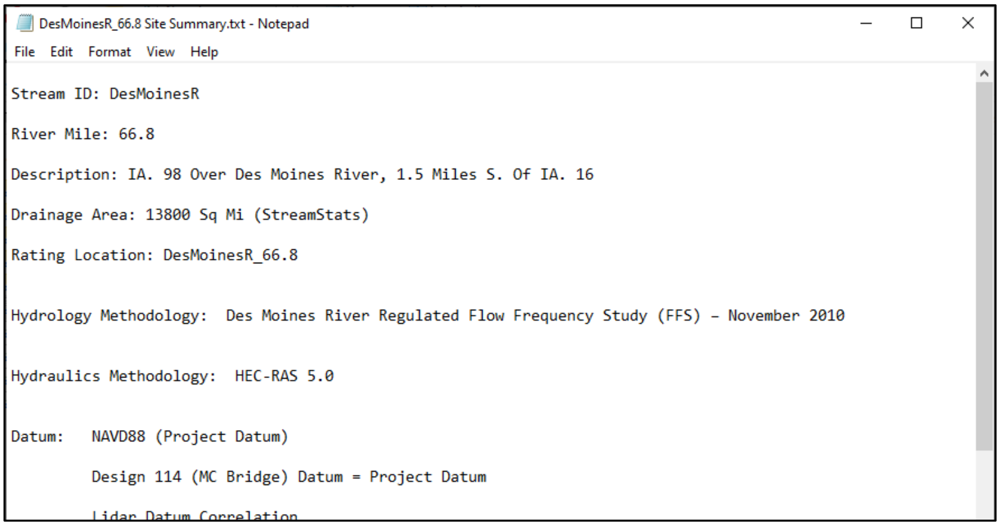

Figure 3. Example site summary file

The features (structures, culverts, low roads, etc.) in each of the site summary files had additional complexity, as each site could have one or more features. A Python script was created that would iterate through each of the site summary files and extract all features. The process was repeated for all site summary files to create a comprehensive CSV file for all features. For the features, multiple spatial layers existed that contained the locations of the features. Through coordination with the Iowa DOT, it was determined that the structure and low road spatial layers could be combined into a new layer named Features. The Features layer contains all features impacted by flooding including bridges, culverts, low roads, points of interest, and other future features not currently identified. The data from the CSV file were joined with the final spatial layer of the RIDB. The features extracted from the site summaries also include control locations. Those records were joined with the control spatial layer.

The flood frequency and rating curves were stored as independent CSV files in each site folder by the Iowa DOT. A single flood frequency CSV file existed for each site that included two fields: the frequency in years and the discharge in cubic feet per second. A Python script was developed to extract all flood frequency files from each site and then combine them into a comprehensive CSV file, which allows for easier query of the data for any site.

For the rating curves, multiple CSV files may exist for a single site, as each feature may have its own rating curve or share a rating curve among features (see the example in Figure 2). To add to the complexity, some rating curves may be a single curve, while others may be a three-dimensional (3D) rating curve that is tailwater dependent. For the single curves, each file contained two fields, including the discharge in cubic feet per second and the elevation in feet. For the 3D rating curves, each file contained seven fields that made up the three curves and were typically labeled floor, shift A, and shift B. All three curves used the same discharge value in cubic feet per second but contained different elevations in feet and tailwater values representing the discharge or stage value. To allow for easier use of the data in the RIDB, each curve was extracted independently to include the discharge, elevation, and tailwater value. An additional field was then added to identify whether the curve was the floor, shift A, or shift B. The type of curve was also identified as part of the data extraction with all rating curves for all sites processed and combined into a single comprehensive CSV file.

Upon the extraction of all data from the Iowa DOT, an extensive data quality check was completed. This included verifying that all attributes were successfully populated into the database and random checks on sites to ensure they were complete. Due to some inconsistencies in the format of the files or file names, some data had to be manually populated into the layers and tables. Additional quality checks were used to verify the completeness of the data. For example, if a feature had a rating curve, then that rating curve must exist in the database. Additional details about quality checks completed are described in the Data Quality Checks section.

Through coordination with the Iowa DOT, various additional fields were added or removed throughout the development of the RIDB to reduce redundant fields or enhance the functionality of the RIDB. Most new attributes were not populated but are anticipated to be populated by the Iowa DOT as the content of the database is further developed through future efforts.

All of the layers and tables created from the Iowa DOT data were imported into a file geodatabase, which allows for uploading the data into an enterprise GIS system hosted by the Iowa DOT. The structure and relationships within the GIS system are described in additional detail in the RIDB Overview chapter.

RIDB OVERVIEW

The RIDB is made up of multiple layers and tables that represent the stream network and infrastructure in Iowa. The layers and tables are interconnected to be able to identify the locations where flooding may have impacts across the stream network in Iowa and the corresponding infrastructure at each identified site. Each infrastructure feature has a corresponding frequency-discharge (frequency curve) and discharge-stage (rating curve) relationship that was developed in the database that can allow for rapid assessment of potential roadway overtopping, bridge inundation, or other flood-related impacts.

The Iowa DOT utilizes Esri's ArcGIS Online for maintaining and hosting the RIDB. The file geodatabase created from the Iowa DOT's initial data was uploaded and stored in Esri's ArcGIS Online as a hosted feature layer. The hosted feature layer can be accessed publicly using the following REST Service link:

- RIDB REST Service: https://services.arcgis.com/8lRhdTsQyJpO52F1/arcgis/rest/services/RIDB_Public/FeatureServer

Three additional maps are also provided as follows, which are the public-facing views of the RIDB for exploring the overall database, the near real-time flooding impacts, and the flooding frequency:

- RIDB Map: https://experience.arcgis.com/experience/23255ae7d8ac40519f044262bec2a8ba/
- RIDB Flooding Impact (Near Real-Time): https://experience.arcgis.com/experience/23c55237dbf34bb3990889d5cb305031/
- RIDB Flood Frequency: https://experience.arcgis.com/experience/506ffdf2ef53457aa4952da067249ae8/

The applications will be described in additional detail in the RIDB Processes section.

The RIDB consists of six spatial layers and six tables. The layers and tables can be categorized into three areas: stream network, infrastructure, and reference. The stream network category includes two spatial layers and two tables. The primary layer for the stream network is RIDB_STREAM that represents the Iowa stream network and is used as the reference for all other tables associated with the stream network. The infrastructure category includes three spatial layers and four tables with the primary layer being RIDB_SITE that represents locations that may be impacted by a stream. The reference category only has a single spatial layer, which allows for archiving historical flood information collected in the field through notes or images. A description of each spatial layer and table is provided below.

Stream Tables and Layers

- **RIDB_STREAM** – This layer represents the Iowa stream network and is the basis for locating and relating all infrastructure and stream network layers.

- **RIDB_STREAMMAPPING** – This table is used to identify which streams connect to other streams across the network.
- **RIDB_STREAMVELOCITY** – This table is used to identify the low and high velocity of the stream to identify arrival times of gauge flow rates.
- **RIDB_GAUGE** – This table is a placeholder for gauge information that can be inputted into the RIDB.

<u>Infrastructure Tables and Layers</u>

- **RIDB_SITE** – This layer represents a linear feature of a site that may be impacted by a stream at a roadway crossing or location adjacent to a stream. The site represents the extent along the roadway of features that may be impacted. Each site can contain multiple features that may be impacted. The site is located along the stream network based on the Stream ID and river mile. Each site has a corresponding frequency curve (frequency-discharge relationship) that can be used for all features.
- **RIDB_FEATURES** – This layer represents the individual features that correspond to a site that may be impacted. Features can include bridges, culverts, low roadways, buildings, and other structures. Each feature has a corresponding rating curve (discharge-stage relationship) and critical elevation/discharge to determine if the feature is impacted.
- **RIDB_CONTROL** – This layer represents any control locations such as dikes and levees that can control which features are impacted. Each control can be related to multiple features. Similar to features, each control has a corresponding rating curve (discharge-stage relationship) and critical elevation/discharge.
- **RIDB_FQ** – This table contains the frequency curve (frequency-discharge relationship) developed for each site. Each frequency curve developed contains multiple records in the database of the frequency and corresponding discharge, which can be used to create a frequency-discharge curve. Each frequency curve developed can be related to multiple sites.
- **RIDB_QH** – This table contains the rating curve (discharge-stage relationship) developed for each site. Each rating curve developed contains multiple records in the database of the discharge and corresponding height/stage, which can be used to create a rating curve. This table also contains 3D rating curves that are further separated by the label field with a corresponding tailwater value, which may be either a discharge or flow value.
- **RIDB_SITEIMPACT** – This table is used to indicate the peak flow and arrival time for a given site.
- **RIDB_FEATUREIMPACT** – This table is used to indicate the flow at each feature to determine whether the flow will result in an individual feature being impacted based on its corresponding critical elevation/discharge. This table also includes the low and high arrival times of the impacts.

<u>Reference Layer</u>

- **RIDB_FIELDNOTES** – This layer represents an archive of field notes that can be inputted into the database, including attributes that may be collected from the field, and provides the ability to attach photos of the flooding, which can be used for future reference.

Figure 4 provides an overview of the primary layers that make up the RIDB including the five spatial layers and four tables. The remaining RIDB_FIELDNOTES layer, RIDB_SITEIMPACT table, and RIDB_FEATUREIMPACT table are not currently included, as they are more dynamic and support other functions of the RIDB. The overview includes both the stream and infrastructure tables/layers and how each of the layers and tables are related. As described above, the stream network is the primary layer that can be used to locate other layers along the stream network. Along with the stream network are the stream velocity and stream mapping databases, which provide additional attributes about the stream network. The gauge layer is a placeholder for additional gauge data that can be added in the future for hydraulic loading/analysis and is located along the stream network.

For the infrastructure layer, each location that may be impacted by a stream corresponds to a site that can be located along the stream network. Each site can contain multiple features and/or controls including low roadways, bridges, dikes, levees, etc. During the development of the site summaries, the frequency-discharge relationship (FQ) was developed typically for return periods of 2-, 5-, 10-, 25-, 50-, 100-, and 500-year flood events. The relationship was developed at the site level but applies to all features/controls that are associated with the site. Additionally, for each feature, a discharge-stage relationship (QH) was developed, which generally encompasses 5- to 500-year flood events. The same discharge-stage relationship may be used for multiple features.

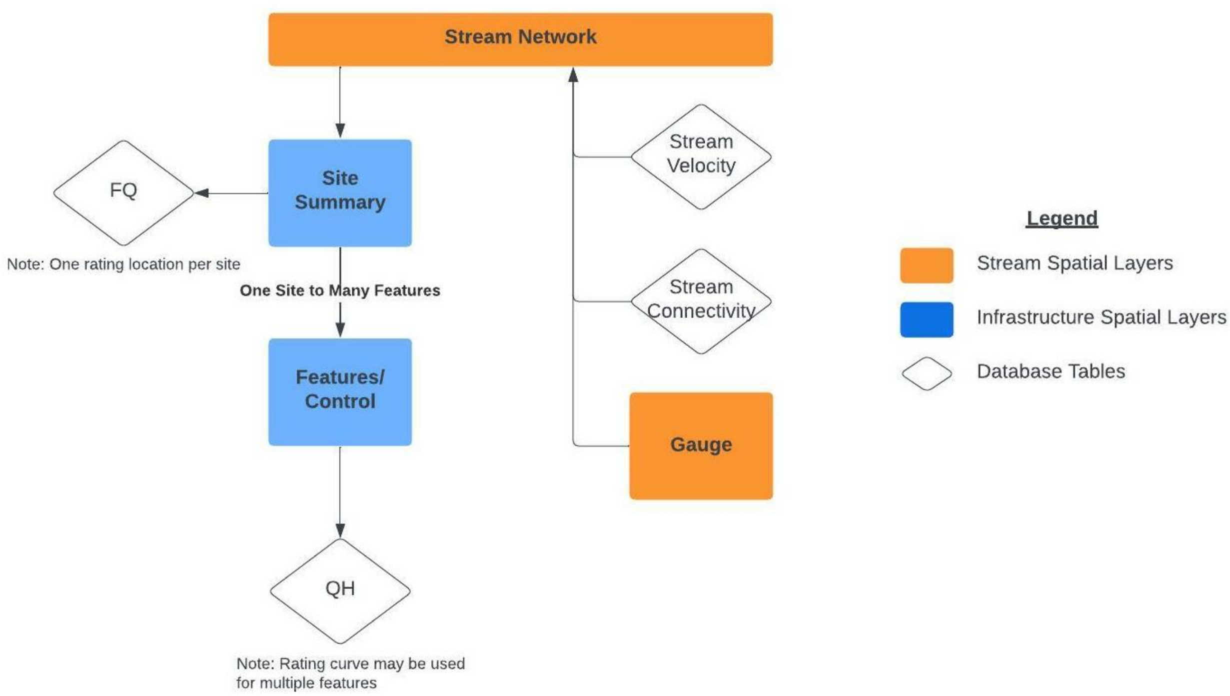

Figure 4. Overview of layer/table relationship in RIDB

For the stream network, Figure 5 provides an entity relationship diagram to show all of the attributes in each table along with how each of the spatial layers and tables are related to each other. For example, the Stream Mapping table can be joined with the Stream layer based on the Stream ID, while other layers require a combination of Stream ID and additional river mile attributes.

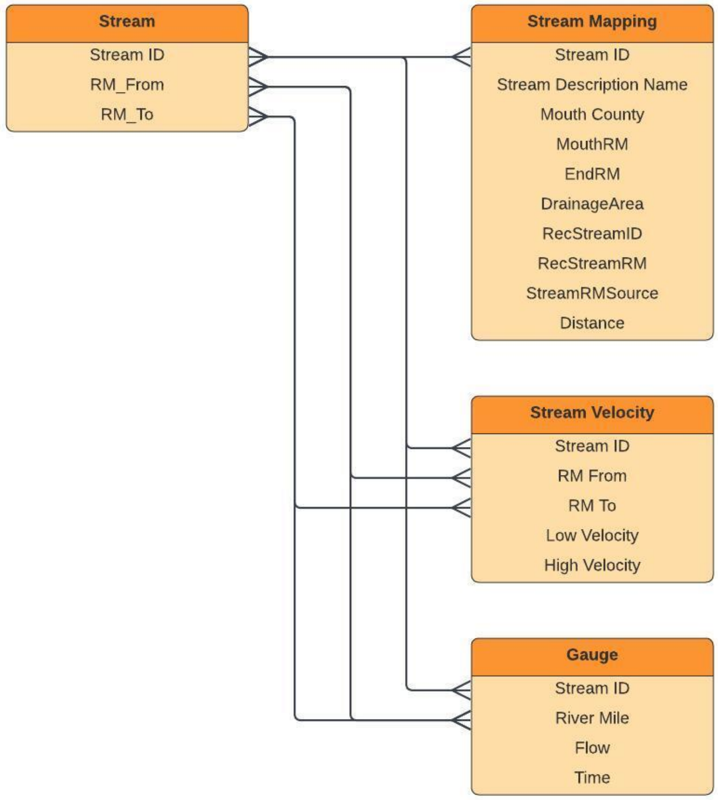

Figure 5. Entity relationship diagram of stream tables

For the infrastructure network, Figure 6 provides an entity relationship diagram to show all of the attributes in each table along with how each of the spatial layers and tables are related to each other. Site represents the primary layer that interconnects the various attributes for the impact analysis. Each site has a unique Site ID that can be used to identify the corresponding features and controls that are associated with the site.

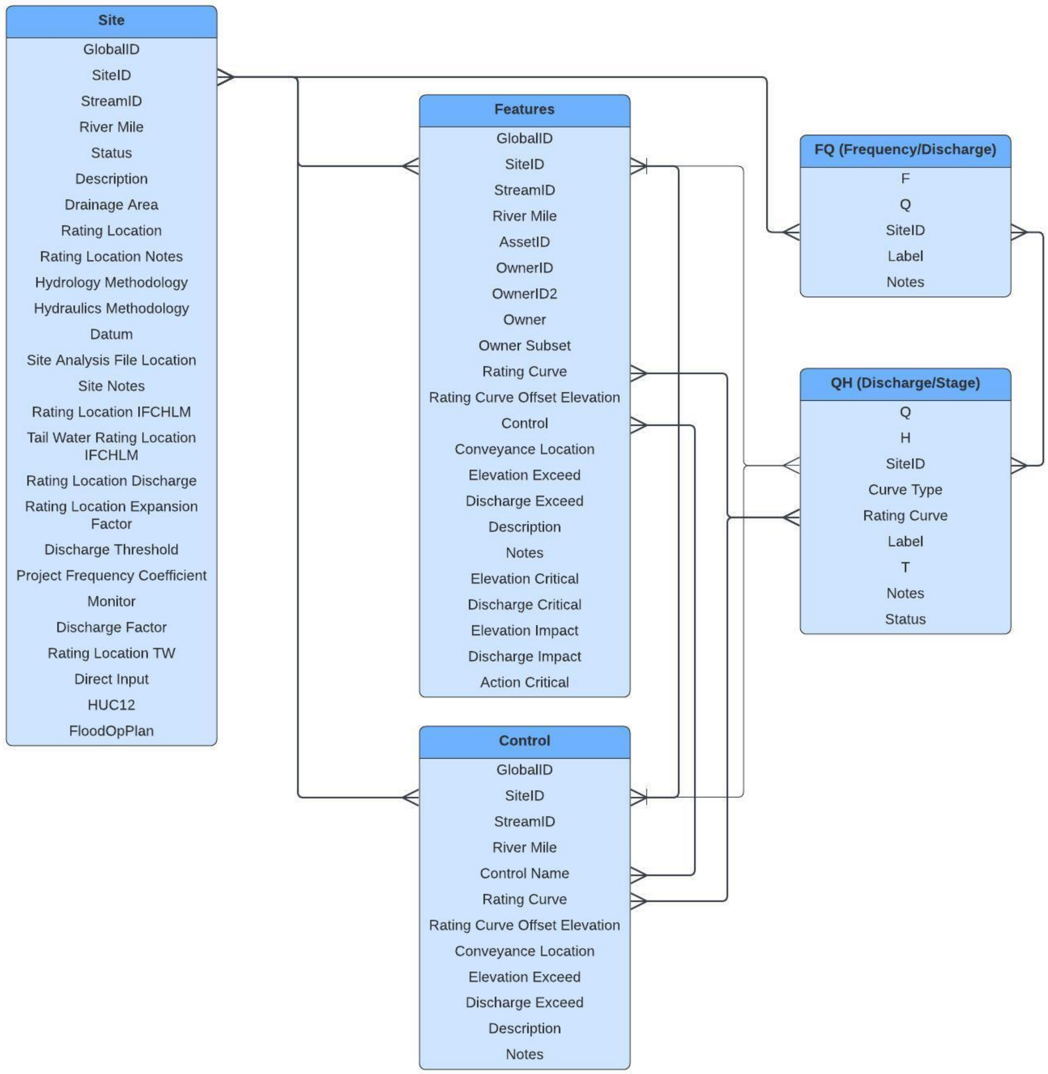

Figure 6. Entity relationship diagram of infrastructure tables

As shown in Figure 4, the site summary also includes the relationship with the frequency-discharge (FQ) table based on a unique identifier. The features and controls each have a corresponding discharge-stage relationship (QH) and can be linked based on a unique Rating Curve identifier. In addition to the rating curve for a feature, a feature may also be associated to a control, which may determine if the feature is impacted. In these situations, all attributes for the control can be applied to the feature to determine if it will be impacted.

Stream Layer Description

The following sections describe each of the spatial layers and tables included in the RIDB that are associated with streams along with their corresponding attributes.

RIDB_STREAM

Description: This layer represents the mapping of Iowa's stream network and is the basis for locating and relating all infrastructure and stream network layers. The stream layer is a polyline with M values, which allows for identifying the location along any polyline using the M value or otherwise referred to as the river mile within the RIDB. This allows for the layer to utilize a linear referencing tool to locate features along the network to provide an exact river mile of its location. The Stream ID and river mile are used throughout the RIDB to spatially locate and reference locations along the stream network.

Layer Type: Polyline M layer

Field Descriptions: Field descriptions are listed by the alias used in the database followed by the field name in the database in parentheses.

- **GlobalID (GlobalID)** – This value is a unique identifier for the given record within the layer.
- **StreamID (StreamID)** – The unique identifier for each stream in the stream network. The short name contains no spaces and consists of the stream name and for common stream names will be appended with the county name where the mouth is located. The Stream ID is used to locate and relate features across the stream network.
- **RM_From (RM_From)** – RM_From and RM_To represent the distances the given section of a stream is from the mouth of the river. The mouth of the river will begin at river mile zero (in most cases) and then continue to increase until the farthest point upstream. RM_From represents the begin of the polyline farthest downstream, while RM_To represents the end of the polyline farthest upstream. The stream network has linear referencing capabilities due to being a polyline with M values, which allows for an M value to be provided in the GIS software based on these two fields.
- **RM_To** (**RM_To)** – See RM_From.

RIDB_STREAMMAPPING

Description: This table is used to identify which streams connect to other streams across the network. The layer identifies which Stream ID it is associated with and then provides the stream that it connects to based on the receiving Stream ID and the corresponding river mile where the streams connect.

Layer Type: Table

Field Descriptions: Field descriptions are listed by the alias used in the database followed by the field name in the database in parentheses.

- **GlobalID (GlobalID)** – This value is a unique identifier for the given record within the table.

- **StreamID (StreamID)** – This represents the unique identifier of the stream that connects to another stream. This is the primary field that can be used to link with the RIDB_STREAM layer.
- **Stream Description Name (StreamDesName)** – This field provides an expanded description of the stream name for the given Stream ID.
- **Mouth County (MouthCounty)** – This field provides the county that the mouth of the given Stream ID is located.
- **MouthRM (MouthRM)** – This field represents the river mile at the mouth of the given stream.
- **EndRM (EndRM)** – This field represents the river mile at the end or furthest upstream mapping of the given stream.
- **Drainage Area (DrainageArea)** – This field represents the drainage area for the given Stream ID in square miles.
- **RecStreamID (RecStreamID)** – This field represents the receiving Stream ID that the given Stream ID is connected to. Multiple receiving Stream IDs may be identified for a given Stream ID to ensure that all downstream receiving streams are identified for hydraulic loading. If only the first receiving Stream ID is needed, then this table can be filtered by Distance = 0, which indicates there are 0 mi between the mouth of the given stream and the connecting point in the receiving stream.
- **RecStreamRM (RecStreamRM)** – This field represents the river mile on the receiving Stream ID where the given Stream ID connects. This allows for locating exactly where along the receiving Stream ID that the mouth of the given Stream ID is located.
- **StreamRMSource (StreamRMSource)** – This field provides a description of source of the Stream ID that connects with the receiving Stream ID.
- **Distance (Distance)** – As noted in the RecStreamID, this table includes a reference of all downstream Stream IDs that the given Stream ID connects with to identify all downstream streams that may be impacted by the given Stream ID. Because the connection point may be farther downstream of another stream from the mouth of the given stream, the distance field is included as part of the table. Thus, this field represents the distance along another stream from the mouth of the given Stream ID to the connection point of the receiving Stream ID. If only the first receiving Stream ID is needed, then this table can be filtered by Distance = 0, which indicates there are 0 mi between the mouth of the given stream and the connecting point in the receiving stream.

RIDB_STREAMVELOCITY

Description: This table is used to identify the low and high velocity of the stream to identify arrival times of gauge flow rates.

Layer Type: Table

Field Descriptions: Field descriptions are listed by the alias used in the database followed by the field name in the database in parentheses.

- **GlobalID (GlobalID)** – This value is a unique identifier for the given record within the table.

- **StreamID (StreamID)** – This represents the unique identifier of the stream and is the one of the fields that can be used to link with the RIDB_STREAM layer. To allow for dynamically identifying the velocity of the stream, the river miles are provided as part of this table, which allow for changing the velocity of given sections of the stream based on the river mile.
- **RM From (RM_From)** – This is the downstream river mile along the stream network that the corresponding velocity values are associated with. This field along with StreamID and RM_To can be used for associating with other layers that are part of the stream network.
- **RM To (RM_To)** – This is the upstream river mile along the stream network that the corresponding velocity values are associated with. This field along with StreamID and RM_From can be used for associating with other layers that are part of the stream network.
- **Low Velocity (LowVelocity)** – This value represents the low velocity for the identified section of the stream.
- **High Velocity (HighVelocity)** – This value represents the high velocity for the identified section of the stream.

RIDB_GAUGE

<u>*Description*</u>: This table is a placeholder for gauge information that can be inputted into the RIDB.

<u>*Layer Type*</u>: Point layer

<u>*Field Descriptions*</u>: Field descriptions are listed by the alias used in the database followed by the field name in the database in parentheses.

- **GlobalID (GlobalID)** – This value is a unique identifier for the given record within the layer.
- **Stream ID (StreamID)** – This represents the unique identifier of the stream that the gauge is located on and is the one of the fields that can be used to link with the RIDB_STREAM layer.
- **River Mile (RiverMile)** – This field represents the river mile along the given Stream ID where the gauge is located. This field can be used to identify the location along the stream of the gauge and can be used in coordination with the Stream ID to link to other databases.
- **Flow (Flow)** – This field represents the measured flow of the gauge.
- **Time (Time)** – This field represents the time of the measured flow of the gauge.

Infrastructure Layer Description

The following sections describe each of the spatial layers and tables included in the RIDB that are associated with site infrastructure along with their corresponding attributes.

RIDB_SITE

Description: This layer represents a linear feature representing a site that may be impacted by a stream at a roadway crossing or location adjacent to a stream. The site represents the extent along the roadway of features that may be impacted. Each site can contain multiple features that may be impacted. The site is located along the stream network based on the Stream ID and river mile. Each site has a corresponding frequency curve (frequency-discharge relationship) that can be used for all features.

Layer Type: Polyline layer

Field Descriptions: Field descriptions are listed by the alias used in the database followed by the field name in the database in parentheses.

- **GlobalID (GlobalID)** – This value is a unique identifier for the given record within the layer.
- **SiteID (SiteID)** – This is the unique identifier for the site that corresponds to multiple features in the RIDB_FEATURES and RIDB_CONTROL layers. The Site ID consists of the Stream ID and River Mile and is intended to provide a short name for the given site. The Site ID can also be used to identify the corresponding frequency curve in the RIDB_FQ table. The frequency curve in RIDB_FQ includes multiple records that can be used to build the frequency-discharge curve.
- **StreamID (StreamID)** – This represents the unique identifier of the stream that the site is located on. This can be used to identify where the site is located along the stream network in the RIDB_STREAM layer.
- **River Mile (RiverMile)** – This represents the distance from the stream mouth for the corresponding Stream ID where the feature is located. This can be used to identify where the site is located along the stream network in the RIDB_STREAM layer.
- **Status (Status)** – This field indicates the development status for the corresponding site. The coded values in Table 1 are used to identify the current status of the development for the site in the RIDB.

Table 1. Coded values for status

Coded value	Description
C_	RIDB dataset complete
P_	Partial dataset
P_S_	Partial dataset with survey
P_R_	Partial dataset with impact rating
P_SR	Partial dataset with survey/impact rating
NULL	No development work completed

- **Description (Description)** – This field provides a descriptive name for the site. The description used is typically the location of the site and its relation to another feature such as a road (e.g., IA 928 over Cedar Creek, 0.5 mi W of Wildwood).
- **Drainage Area (Drainage_Area)** – This field provides the drainage area of the site in square miles.
- **Rating Location (Rating_Location)** – This field has been deprecated but initially provided the identifier for the corresponding rating location or frequency curve for the frequency-discharge relationship in the RIDB_FQ table for the given site. SiteID should be used instead for future efforts.
- **Rating Location Notes (Rating_Location_Notes)** – This field includes any additional notes related to the rating location or frequency curve developed for the corresponding site.
- **Hydrology Methodology (Hydrology_Methodology)** – This field indicates the hydrology methodology used to for the development of the corresponding site.
- **Hydraulics Methodology (Hydraulics_Methodology)** – This field indicates the hydraulics methodology used to for the development of the corresponding site.
- **Datum (Datum)** – All data in the RIDB is based on North American Vertical Datum of 1988 (NAVD 88)/Iowa Real-Time Network (IaRTN) (2011) datum. This field indicates the datums used in the development of the site.
- **Site Analysis File Location (Site_Analysis_File_Location)** – This field is used to identify where additional site analysis files are located and may correspond to a specific Iowa DOT project number.
- **Site Notes (SiteNotes)** – This field includes any additional notes that were included as part of the site development.
- **Rating Location IFCHLM (RatingLocIFCHLM)** – This field contains the identifier, LinkID, used to relate to the IFC HLM network. The corresponding LinkID in the HLM network provides the flow values used for the analysis of overtopping and overdischarge.
- **Tailwater Rating Location IFCHLM (RatingLocIFCHLMTW)** – This field contains the identifier, LinkID, used to relate to the IFC HLM network for the tailwater flow. The corresponding LinkID in the HLM network provides the tailwater flow values used for the analysis of overtopping and overdischarge for tailwater-dependent features.
- **Rating Location Coefficient (RatingLocCoeff)** – This field indicates the coefficient that should be used with respect to the corresponding rating location for the site.
- **Discharge Threshold (DischargeThreshold)** – This field is used to indicate the discharge threshold to identify whether the site would be impacted.
- **Projected Frequency Coefficient (ProjectFQCoeff)** – This field indicates the projected frequency coefficient that should be used with respect to the corresponding rating location for the site.
- **Monitor (Monitor)** – This field is used to indicate whether the site should be monitored. If an analysis is completed and it is determined that the site would not be impacted by flooding, then the site would not need to be monitored. The corresponding coded values used for this field are shown in Table 2.

Table 2. Coded values for monitor

Coded value	Description
0	False – the site is not monitored
1	True – the site is monitored

- **Discharge Factor (DischargeFactor)** – This field applies to real-time feed discharge for testing against elevation thresholds, which can be used to establish a factor of safety. The default value is 1 (i.e., no adjustment).
- **Rating Location TW (Rating_Location_TW)** – This field includes the tailwater network location from the HLM/National Weather Service (NWS) models that is sampled for rating curve analysis and 3D curves.
- **DirectInput (DirectInput)** – This is a Boolean field used to indicate whether direct input data should be used instead of the HLM. If true, a direct input table is used instead of the HLM feed.
- **HUC12 (HUC12)** – This field is the HUC12 designation for subwatersheds at the site.
- **FloodOpPlan (FloodOpPlan)** – This field provides a link to a location containing a Flood Operations Plan, Scour Management Plan, etc., if one exists for the site.

RIDB_FEATURES

Description: This layer represents the individual features that correspond to a site that may be impacted. Features can include bridges, culverts, low roadways, buildings, and other structures. Each feature has a corresponding rating curve (discharge-stage relationship) and critical elevation/discharge to determine if the feature is impacted.

Layer Type: Polyline layer

Field Descriptions: Field descriptions are listed by the alias used in the database followed by the field name in the database in parentheses.

- **GlobalID (GlobalID)** – This value is a unique identifier for the given record within the layer.
- **Type (Type)** – This field indicates the type of feature that is represented by the data including bridges, culverts, low roadways, etc. Table 3 provides the coded value and descriptions for this field.

Table 3. Coded value for type

Coded value	Description
Bridge	Bridge
Culvert	Culvert
LowRoad	Low roadway
Bridgelet	Bridgelet
Facility	Building (Facility)
Utility	Building (Utility)
Other	Other

- **SiteID (SiteID)** – This is the unique identifier for the site that the feature is related to. This can be used to relate back to the RIDB_SITE layer for additional attributes including the Rating Location.
- **StreamID (Stream_ID)** – This represents the unique identifier of the stream that the feature is located on. This can be used to locate where the feature is located along the stream network in the RIDB_STREAM layer. This value should match the corresponding StreamID for the same Site ID in the RIDB_SITE layer.
- **River Mile (River_Mile)** – This represents the distance from the stream mouth for the corresponding Stream ID where the feature is located. This can be used to locate where the feature is located along the stream network in the RIDB_STREAM layer. This value should match the corresponding River Mile for the same Site ID in the RIDB_SITE layer.
- **AssetID (AssetID)** – This field provides a unique identifier for each feature. For features in the National Bridge Inventory (NBI), the Federal Highway Administration (FHWA) number is used in this field. For other features not in the NBI, a unique value based on an adjacent NBI structure was developed using the guidance below.

  For non-NBI features that are a bridge, bridgelet, or culvert, a three-digit prefix that starts with an 8 was added to the adjacent NBI structure FHWA number. A similar prefix was added for low roads, but the prefix starts with a 9. The second digit in the prefix will start at 0 and then increment by one for each additional structure/low road feature to ensure that each feature has a unique identifier. Examples for the main channel bridge that has an FHWA number of 59321 are given as follows:

  - Bridgelet → AssetID = 80059321
  - Culvert → AssetID = 81059321
  - Low road → AssetID = 90059321

- **OwnerID (OwnerID)** – This field provides the ability for the owner of the feature to include a unique identifier that relates back to their system. For Iowa DOT-owned features, this field is populated with the DOT Maintenance Number. To ensure that the values are unique in the Iowa DOT system, modifications to the maintenance number will be made to indicate the type of feature. The maintenance number is typically in the format "MMMM.MLXXX," with the M values indicating the location and distance, the L indicating the location code, and the

X providing an identifier. To create a unique identifier, the L value for location code will be modified for different features, as shown in the examples below for different features:

- Bridgelet / RCB → OwnerID = 9203.8B928 ‘B’ for location code
- Circular Culvert → OwnerID = 9203.8C928 ‘C’ for location code
- Low Road → OwnerID = 9203.8-928 ‘-‘ for location code
- Dual Roadway Bridgelet → OwnerID = 9203.8BL928 ‘L’ or ‘R’ follow location code
- Dual Roadway Low Road → OwnerID = 9203.8-L928 ‘L’ or ‘R’ follow location code

- **OwnerID2 (OwnerID2)** – This field provides a secondary ID for the owner of the feature to include a unique identifier that relates back to their system.
- **Owner (Owner)** – This field identifies the owner of the feature.
- **OwnerSubset (OwnerSubSet)** – This field allows for the owner to identify any subset owner information if needed. For example, the Iowa DOT utilizes this field to populate the district that the feature is located within.
- **Rating Curve (RatingCurve)** – This field provides the unique rating curve identifier that was developed for the corresponding feature. This field can be used to find the discharge-stage relationship data in the RIDB_QH table to build a rating curve.
- **Rating Curve Offset Elevation (OffsetElevRatingCurve)** – This field provides the offset elevation in feet that should be applied to the rating curve values that are obtained in the RIDB_QH table.
- **Control (Control)** – If a feature would be impacted only if a control feature is impacted, then this field is populated with the corresponding control unique identifier. This field can be used to link with the RIDB_CONTROL layer based on the ControlNam field in that table. All rating curves and the impact elevation for the control feature can be applied to the given feature to determine if it would be impacted.
- **Conveyance Location (Conveyance_Location)** – This field identifies the conveyance location for the given feature.
- **Elevation Exceed (ElevationExceed)** – This field represents the elevation that determines if the site will be impacted. The type of impact (low beam, slab, obvert, edge of the roadway) depends on the type of feature.
- **Discharge Exceed (DischargeExceed)** – This field represents the discharge that would impact the feature regardless of whether it would be impacted by the elevation (i.e., scouring).
- **Description (Description)** – This field allows for a description of the feature.
- **Notes (Notes)** – This field allows for notes about the feature including any information about the rating curve.
- **Elevation Critical (ElevationCritical)** – This is a Boolean field to indicate whether the elevation is critical and should be considered as part of the flood frequency layer.
- **Discharge Critical (DischargeCritical)** – This is a Boolean field to indicate whether the discharge is critical and should be considered as part of the flood frequency layer.
- **Elevation Impact (ElevationImpact)** – This field is used to describe the type of impact by the elevation being exceeded.

- **Discharge Impact (DischargeImpact)** – This field is used to describe the type of impact by the discharge being exceeded.
- **Action Critical (ActionCritical)** – This field is used to note what actions should be taken if a critical discharge or elevation is exceeded.

RIDB_CONTROL

Description: This layer represents any control locations such as dikes and levees that can control which features are impacted. Each control can be related to multiple features. Similar to features, each control has a corresponding rating curve (discharge-stage relationship) and critical elevation/discharge.

Layer Type: Polyline layer

Field Descriptions: Field descriptions are listed by the alias used in the database followed by the field name in the database in parentheses.

- **GlobalID (GlobalID)** – This value is a unique identifier for the given record within the layer.
- **SiteID (SiteID)** – This is the unique identifier for the site that the control feature is related to. This can be used to relate back to the RIDB_SITE layer for additional attributes including the Rating Location.
- **StreamID (StreamID)** – This represents the unique identifier of the stream that the control feature is located on. This can be used to identify where the control feature is located along the stream network in the RIDB_STREAM layer. This value should match the corresponding StreamID for the same Site ID in the RIDB_SITE layer.
- **River Mile (RiverMile)** – This represents the distance from the stream mouth for the corresponding Stream ID where the feature is located. This can be used to identify where the feature is located along the stream network in the RIDB_STREAM layer. This value should match the corresponding River Mile for the same Site ID in the RIDB_SITE layer.
- **Control Name (ControlNam)** – This field represents the unique identifier for the control feature. For features in the RIDB_FEATURE layer, which are only impacted if the control feature is impacted, then this unique identifier will be populated in the Control field. In these scenarios, all rating curves and impact elevations for the control will be applied to the feature to determine whether it would be impacted.
- **Rating Curve (RatingCurve)** – This field provides the unique rating curve identifier that was developed for the corresponding feature. This field can be used to find the discharge-stage relationship data in the RIDB_QH table to build a rating curve.
- **Rating Curve Offset Elevation (OffsetElevRatingCurve)** – This field provides the offset elevation in feet that should be applied to the rating curve values that are obtained in the RIDB_QH table.
- **Conveyance Location (Conveyance_Location)** – This field identifies the conveyance location for the given control.
- **Elevation Exceed (ElevationExceed)** – This field represents the elevation that determines whether the control would be impacted.

- **Discharge Exceed (DischargeExceed)** – This field represents the discharge that would impact the control regardless of whether it would be impacted by the elevation (i.e., scouring).
- **Description (Description)** – This field allows for a description of the control.
- **Notes (Notes)** – This field allows for notes about the control including any information about the rating curve.

RIDB_FQ

Description: This table contains the rating locations (frequency-discharge relationship) developed for each site. Each rating location developed contains multiple records in the database of the frequency and corresponding discharge that can be used to create a frequency-discharge curve. Each rating location typically contains 7 records for discharges ranging from a 2-year flood frequency up to a 500-year flood frequency. A frequency-discharge curve can be developed by plotting each of the points for a given rating location. Each rating location developed can be related to multiple sites. The rating curve should be used for any features related to a given site.

Layer Type: Table

Field Descriptions: Field descriptions are listed by the alias used in the database followed by the field name in the database in parentheses.

- **GlobalID (GlobalID)** – This value is a unique identifier for the given record within the table.
- **F (F_F)** – This field represents the frequency in years for the frequency-discharge relationship.
- **Q (Q)** – This field represents the discharge in cubic feet per second for the frequency-discharge relationship.
- **SiteID (SiteID)** – This field represents the unique identifier for the frequency-discharge relationship developed for a given site. Each point in the frequency-discharge relationship will have the same Site ID, which can be used to then create the frequency-discharge curve. This field is related back to the RIDB_SITE layer and provides the frequency-discharge relationship for all features and controls corresponding to that site.
- **Label (Label)** – This field provides any labels that are associated with the corresponding rating location/frequency-discharge relationship.
- **Notes (Notes)** – This field provides any notes about the corresponding rating location/frequency-discharge relationship.

RIDB_QH

Description: This table contains the rating curve (discharge-stage relationship) developed for each site. Each rating curve developed contains multiple records in the database of the discharge and corresponding height/stage, which can be used to create a rating curve. For each feature, a rating curve/discharge-stage relationship is available, which generally encompasses 5- to 500-

year flood events. The same discharge-stage relationship may be used for multiple features. This table also contains 3D rating curves and are further separated by the Label field.

Layer Type: Table

Field Descriptions: Field descriptions are listed by the alias used in the database followed by the field name in the database in parentheses.

- **GlobalID (GlobalID)** – This value is a unique identifier for the given record within the table.
- **Q (Q)** – The field represents the discharge in cubic feet per second for the rating curve/discharge-stage relationship.
- **H (H)** – This field represents the elevation in feet for the corresponding discharge for the rating curve/discharge-stage relationship.
- **SiteID (SiteID)** – This field indicates which frequency curve (or frequency-discharge relationship) in the RIDB_FQ table should be used in connection with this rating curve.
- **Curve Type (CurveType)** – This field indicates the type of rating curve that was developed as indicated by the coded values in Table 4. For Single, a single rating curve is developed, which includes multiple records to generate the rating curve/discharge-stage relationship. For TW Dependent (Q) and TW Dependent (S), these curves represent the TW Dependent (3D) curves, which also include the floor, shift A, and shift B curves as indicated by the Label field. For these curves, a combination of the Rating Curve and Label fields are critical to accurately display the rating curve. For TW Dependent (Q), the Q indicates that the T field below is a discharge and measured in cubic feet per second. For TW Dependent (S), the S indicates that the T field below is an elevation that is measured in feet.

Table 4. Coded values for curve type

Coded value	Description
Single	Single
TW Dependent (Q)	TW Dependent (Q)
TW Dependent (S)	TW Dependent (S)

- **Rating Curve (Rating_Curve)** – This field represents the unique identifier for the rating curve/discharge-stage relationship developed for a given feature or control. Each point in the discharge-stage relationship has the same Rating Curve, which can be used to then create the discharge-stage curve. For each feature, a rating curve/discharge-stage relationship is available, which generally encompasses 5- to 500-year flood events. This field is related back to the RIDB_FEATURES and RIDB_CONTROL layers and provides the discharge-stage relationship for each feature and/or control. For TW Dependent (3D) rating curves, the Rating Curve should be used in combination with the Label field to distinguish unique rating curves.
- **Label (Label)** – This field indicates the different curves that make up the TW Dependent (3D) curve, which includes the floor, shift A, and shift B. For single rating curves, this field will be null.

- **T (TQ)** – This field is used for the TW Dependent (3D) rating curves, and the corresponding value depends on the Curve Type. If the Curve Type is TW Dependent (Q), then this field represents the tailwater discharge and is measured in cubic feet per second. If the Curve Type is TW Dependent (S), then this field represents the tailwater elevation and is measured in feet.
- **Notes (Notes)** – This field allows for any additional notes about the given rating curve.
- **Status (Status)** – This field can be used when updating rating curves to identify whether a rating curve exists or is proposed.

RIDB_SITEIMPACT

Description: This table is used to indicate the peak flow and peak arrival times from the HLM or directly inputted flow/stage data.

Layer Type: Table

Field Descriptions: Field descriptions are listed by the alias used in the database followed by the field name in the database in parentheses.

- **GlobalID (GlobalID)** – This value is a unique identifier for the given record within the table.
- **SiteID (SiteID)** – This field identifies the Site ID in the RIDB_SITE layer that the gauge data have been associated with based on its location upstream of a given site.
- **StreamID (StreamID)** – This field represents the corresponding Stream ID for the given site.
- **RiverMile (RiverMile)** – This represents the distance from the stream mouth for the corresponding Stream ID where the site is located.
- **PeakFlow (PeakFlow)** – This field represents the peak flow for the corresponding HLM or direct input data.
- **PeakFlowTime (PeakFlowTime)** – This field represents the time of the peak flow from the HLM or direct input data.

RIDB_FEATUREIMPACT

Description: This table is used to indicate the impact the flow from the HLM or direct input will have on a feature. This includes summarizing whether the feature will be overtopped or over discharge based on the critical elevation/discharge. The table also summarizes the begin and end time of any critical impacts.

Layer Type: Table

Field Descriptions: Field descriptions are listed by the alias used in the database followed by the field name in the database in parentheses.

- **GlobalID (GlobalID)** – This value is a unique identifier for the given record within the table.

- **SiteID (SiteID)** – This field identifies the Site ID in the RIDB_SITE layer for the feature being analyzed with the gauge data.
- **StreamID (StreamID)** – This field represents the corresponding Stream ID for the given feature.
- **RiverMile (RiverMile)** – This represents the distance from the stream mouth for the corresponding Stream ID where the feature is located.
- **AssetID (AssetID)** – This field identifies the Asset ID in the RIDB_FEATURES layer that is being analyzed for impact.
- **OwnerID (OwnerID)** – This field identifies the Owner ID in the RIDB_FEATURES layer that is being analyzed for impact.
- **OwnerID2 (OwnerID2)** – This field identifies the secondary Owner ID, if applicable, in the RIDB_FEATURES layer that is being analyzed for impact.
- **Flow (Flow)** – This field provides the peak flow based on the HLM or direct input at the feature and is used to determine the Elevation using the rating curve.
- **Elevation (Elevation)** – This field provides the peak elevation at the feature based on the corresponding Flow, which uses the Rating Curve for the feature to calculate the elevation.
- **Overtop (Overtop)** – This field identifies whether the feature will be overtopped (low beam, slab, obvert, edge of the roadway) based on the Elevation value being greater than the ElevationExceed plus the OffsetElevRatingCurve fields in the RIDB_FEATURES layer.
- **Over discharge (OverDischarge)** – This field identifies whether the feature will be over the critical discharge based on the Flow value being greater than the DischargeExceed field in the RIDB_FEATURES layer.
- **LowArrivalTime (LowArrivalTime)** – This field represents the earliest impact based on the HLM or direct input of when the floodwaters will exceed either the critical elevation or critical discharge. For features using the HLM, this is based on analyzing the hourly discharge values provided for the next five days.
- **HighArrivalTime (HighArrivalTime)** – This field represents the latest impact based on the HLM or direct input of when the floodwaters will exceed either the critical elevation or critical discharge. For features using the HLM, this is based on analyzing the hourly discharge values provided for the next five days.

Reference Layer Description

The following section describes the spatial layer included in the RIDB that is associated with the reference layer along with the corresponding attributes.

RIDB_FIELDNOTES

<u>*Description*</u>: This layer is used for the field collection of high-water or other relevant flooding information. The layer allows for high-water data to be collected to support future hydraulic analysis during floods to evaluate and adjust data to make decisions regarding impacts to infrastructure. A secondary use will be to efficiently document locations that experience riverine and pluvial (overland) flooding problems.

Layer Type: Table

Field Descriptions: Field descriptions are listed by the alias used in the database followed by the field name in the database in parentheses.

- **Location (Location)** – This field provides a description of the location (e.g., US 30 WB shoulder, Meadows Trailer Park). Ultimately, the Iowa DOT administrator will enter the relevant RIDB network location in this field (e.g., RaccoonR_14.0).
- **Weather (Weather)** – This field allows for providing the weather at the time of data collection. Table 5 provides the coded value and descriptions for this field.

Table 5. Coded values for weather

Coded value	Description
Clear	Clear
Rain	Rain
Other	Other (Describe in notes)

- **FloodSource (FloodSource)** – This field is used to indicate the source of the flooding and will typically be river, stream, tidal or coastal. If the site is not a stream crossing, and there is no apparent secondary cause for flooding, pluvial would be an appropriate choice. Table 6 provides the coded value and descriptions for this field.

Table 6. Coded values for flood source

Coded value	Description
1	River, stream, tidal or coastal
2	Heavy rainfall – pluvial
3	Drainage – site flat/low and poorly drained
4	Drainage system overwhelmed
5	Undersized blocked culverts
6	Backup from sewer system

- **FloodMech (FloodMech)** – This field provides a description of the flood mechanism. Blank is an acceptable value if typical riverine. If flooding is due to levee or dike overtopping or another feature in the floodplain, then this would be the field to note such.
- **FloodLevel (FloodLevel)** – This field is used to identify the high-water elevation from survey data (GPS, level loop from benchmark, etc.). Blank is an acceptable value if information is not available.
- **Notes (Notes)** – This field allows for any other relevant information to be submitted. Use this field to document offsets from landmarks addressed in the above section.
- **SiteVisitTime (SiteVisitTime)** – This field is used to provide the time the information was collected. This field allows for users to collect the data and then submit later.

- **Audited (Audited)** – This field is used only by the Iowa DOT administrator. This is a Boolean field that will be changed to True once a field note has been reviewed and processed.
- **SurveyReqd (SurveyReqd)** – This field is used by the Iowa DOT administrator. This is a Boolean field to indicate whether a field survey is required to obtain elevation data.
- **Photos and Files (Photos and Files)** – This file includes any photos and files that are submitted by the field staff. This field allows for multiple photos or files to be submitted.

RIDB SYSTEMS/ARCHITECTURE

The RIDB contains the core data that can be used for rapid assessment of features during flooding events. The RIDB is made available publicly for use in other systems but also for hydraulic analysis using the IFC HLM. This chapter describes the overall architecture of the RIDB system including what services are made available publicly and various processes that have been developed to support the RIDB system.

RIDB Overall Organization

The RIDB will be maintained by the Iowa DOT and is not intended for widespread editing of the layers/tables. Only a small group of staff at the Iowa DOT have the ability to add or edit attributes in the RIDB to maintain the integrity of the data. To support this effort, the authoritative RIDB database is maintained in an enterprise GIS database, with public views of the data created daily (Figure 7).

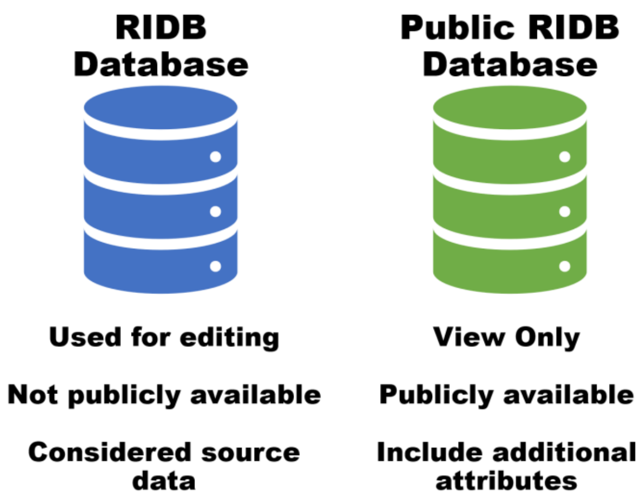

Figure 7. Comparison of RIDB databases

The authoritative RIDB is maintained in the Iowa DOT's enterprise portal GeoHub, while the public version is maintained in the Iowa DOT's ArcGIS Online. The authoritative RIDB only contains attributes relevant to hydraulic analysis and does not contain attributes that are maintained externally. For example, with bridges, an inventory of bridges exists within the Iowa DOT that contains roadway attributes. The process used to create the RIDB public view connects to additional data services for a comprehensive view of the data.

Figure 8 provides additional details about the overall architecture of the RIDB system. As noted above, the authoritative RIDB only contains the core data from the RIDB, and additional systems/services are used to create the public view. The blue cylinder represents the authoritative RIDB that is maintained in the Iowa DOT's enterprise portal GeoHub. The green cylinders represent the various services maintained that are then made available through various applications indicated by the purple items. Most services are made available through the Iowa

DOT's ArcGIS Online environment with the exception of the RIDB Field Collection, which is primary intended for Iowa DOT staff who use the enterprise portal GeoHub. The pink items represent the various processes that have been developed to create the public view of the RIDB, which are described in this section. The red cylinder is an external service used for the hydraulic analysis from the IFC.

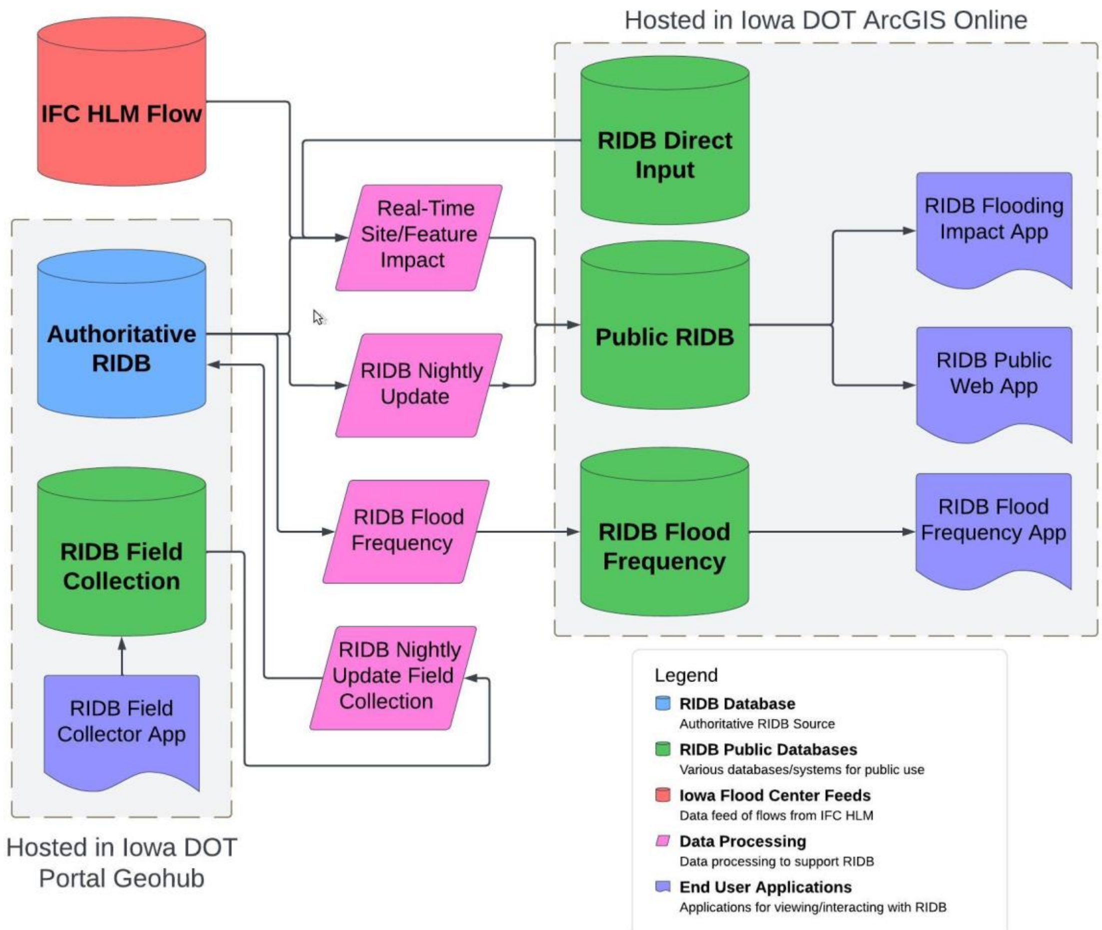

Figure 8. Overview of systems architecture for RIDB

A core supporting element of the RIDB for hydraulic analysis is the IFC HLM flow data. The IFC HLM provides flood forecasts for the entire stream network in Iowa. The RIDB has been integrated with the IFC HLM by associating each RIDB site to a given link along the HLM network. The IFC provides a JavaScript Object Notation (JSON) data feed of all links being monitored in the RIDB and contains hourly flow estimates for each link for 5 days (120 flow records). The JSON data feed from the IFC is updated each hour to allow for continuous monitoring.

RIDB Processes

The following sections describe all of the processes that have been developed as part of the RIDB system. Figure 9 provides an overview of the five process and the frequency that each process is run. The authoritative RIDB serves as the core for all of the processes, but additional data inputs are used depending on the outputs of the process.

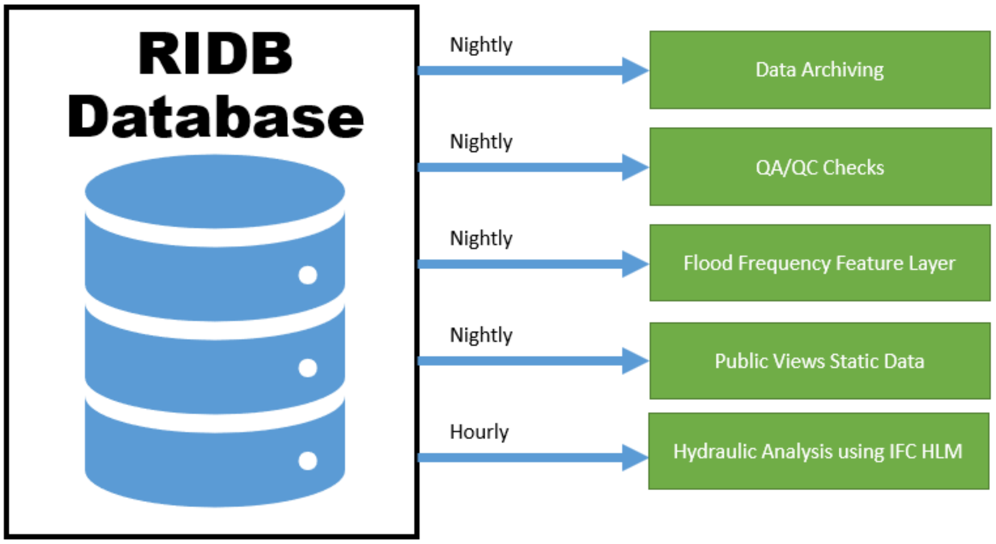

Figure 9. Summary of RIDB data processes

Data Archiving

The authoritative RIDB will only be accessible to a small group of Iowa DOT staff and is maintained in an enterprise GIS database, but errors may occur that may need reverting back to a previous RIDB version. To support this capability, the RIDB is archived nightly as a file geodatabase. The file geodatabase maintains the structure of the RIDB and can allow for data to be easily updated or replaced. The process is currently set up to maintain the last seven days of archives but can be modified to maintain the archives for a longer duration if needed.

Data Quality Checks

When initially extracting data from the Iowa DOT systems, various data quality issues were identified, which were generated from the data maintained by the Iowa DOT or in the Python scripts used to extract the data. For example, some inconsistencies in the Site ID existed based on a change in the naming conventions used by the Iowa DOT, resulting in features not being assigned to the site correctly. From the Python script, some data were not extracted, causing the data to be missing in the database. With these types of issues, there is a need to maintain the integrity of the RIDB through various data quality checks.

Multiple data quality checks were implemented for each layer/table within the RIDB and are summarized below. The data quality checks are run daily with a summary file of issues/errors developed for each layer. Any issues/errors would need to be resolved by the Iowa DOT to ensure the system operates as intended for the hydraulic analysis and accessibility to data. This process uses only the data within the authoritative RIDB.

Site Layer Quality Checks

- **Missing SiteID** – This process checks if any records have a null SiteID. This ensures all sites have a SiteID, which is used to relate to all other infrastructure layers/tables.
- **Unique SiteID** – This process checks if any duplicate SiteIDs exist to ensure each SiteID is unique to avoid features being associated incorrectly to a given site.
- **Missing Stream Attributes** – This process checks if any records have a null StreamID or RiverMile. This ensures all sites can be related back to the stream network.
- **Valid Stream Attributes** – This process checks that the StreamID and RiverMile are located within the stream network. Any invalid StreamID or a RiverMile outside the extents of the stream network are flagged as a potential data issue.
- **Rating_Location available** – If a Rating_Location is defined for a site, this checks to ensure a valid frequency curve is available in the RIDB_FQ table. A missing rating location can be a result of a typo in the SiteID field in the RIDB_SITE layer or RIDB_FQ table. The issue can also exist if no frequency curve was ever inputted into the RIDB_FQ for a given site.

Features Layer Quality Checks

- **Missing SiteID or AssetID** – This process checks if any records have a null SiteID or AssetID. These are the primary fields used to relate features to other infrastructure layers/tables.
- **Unique SiteID and AssetID combination** – This process checks that a unique combination of SiteID and AssetID exists. A feature can be related to multiple sites, which means multiple AssetID values may exist. This checks that each AssetID is only related to a SiteID once to avoid duplicate features associated to a site.
- **Missing Stream Attributes** – This process checks if any records have a null StreamID or RiverMile. This ensures all features can be related back to the stream network.
- **Valid Stream Attributes** – This process checks that the StreamID and RiverMile are located within the stream network. Any invalid StreamID or a RiverMile outside the extents of the stream network are flagged as a potential data issue.
- **Valid SiteID** – This process checks that the feature is related to a valid SiteID in the RIDB_SITE layer. If the SiteID in the RIDB_FEATURES layer does not relate to a SiteID in the RIDB_SITE layer, it is likely due to either a typo in either layer or a site does not exist for a feature, meaning it will not be analyzed.
- **RatingCurve available** – If a RatingCurve is defined for a feature, this checks to ensure a valid rating curve is available in the RIDB_QH table. A missing rating curve can be a result of a typo in the RatingCurve field in the RIDB_FEATURES layer or RIDB_QH table. The issue can also exist if no rating curve was ever inputted into the RIDB_QH for a given feature.

- **Control available** – If a Control is defined for a feature, this checks to ensure a corresponding ControlNam is available in the RIDB_CONTROL layer. A missing control can be a result of a typo in the Control or ControlNam fields in the RIDB_FEATURES or RIDB_CONTROL layers. The issue can also exist if no control is available in the RIDB_CONTROL layer.
- **Valid ElevationExceed** – If a feature has a RatingCurve, then the ElevationExceed cannot be null. A null ElevationExceed means that the site cannot be evaluated to determine if it would be overtopped.

Control Layer Quality Checks

- **Missing SiteID or ControlNam** – This process checks if any records have a null SiteID or AssetID. These are the primary fields used to relate controls to other infrastructure layers/tables.
- **Unique SiteID and ControlNam combination** – This process checks that a unique combination of SiteID and ControlNam exists. A control can be related to multiple sites, which means multiple ControlNam values may exist. This checks that each ControlNam is only related to a SiteID once to avoid duplicate controls associated to a site.
- **Missing Stream Attributes** – This process checks if any records have a null StreamID or RiverMile. This ensures all controls can be related back to the stream network.
- **Valid Stream Attributes** – This process checks that the StreamID and RiverMile are located within the stream network. Any invalid StreamID or a RiverMile outside the extents of the stream network are flagged as a potential data issue.
- **Valid SiteID** – This process checks that the feature is related to a valid SiteID in the RIDB_SITE layer. If the SiteID in the RIDB_CONTROL layer does not relate to a SiteID in the RIDB_SITE layer, it is likely due to either a typo in either layer or a site does not exist for a control, meaning it will not be analyzed.
- **RatingCurve available** – If a RatingCurve is defined for a control, this checks to ensure a valid rating curve is available in the RIDB_QH table. A missing rating curve can be a result of a typo in the RatingCurve field in the RIDB_CONTROL layer or RIDB_QH table. The issue can also exist if no rating curve was ever inputted into the RIDB_QH table for a given control.

Rating Curve (QH) Table Quality Checks

- **Missing SiteID, Rating Curve or CurveType** – This process checks if any records have a null SiteID, Rating_Curve, or CurveType. These are the primary fields used for the hydraulic analysis, and all three fields are required.
- **Duplicate Rating Curve** – This process counts the number of records for each combination of SiteID, Rating_Curve, and CurveType. If the count of records exceeds 10 records, then it is flagged as a possible duplicate curve. Most rating curves have fewer than 10 data points to make the curve. Anything with more than 10 records could be a result of 2 rating curves being inputted and that the system would incorrectly use for identifying if a feature/control is overtopped. Some exceptions are allowed for valid rating curves with 10 or more records.
- **Duplicate Rating Curve Values** – This process checks if there are duplicate records for the combination of SiteID, Rating_Curve, CurveType, Q (flow), H (elevation), and TQ (tailwater

flow). If any duplicate values exist, then multiple of the same records were inputted into the RIDB_QH table. This may impact how the system identifies if a feature/control is overtopped.

- **Unused Rating Curves** – This process checks if the SiteID and RatingCurve combination are present in the RIDB_FEATURES or RIDB_CONTROL layers. If the rating curve is not present in either layer, then it is flagged as an unused curve that could potentially be removed.
- **Missing Flow or Elevation** – This process checks if any records have a null H (elevation) or Q (flow). If these fields are null, then the outputs of the hydraulic analysis will discard these records.

Flood Frequency (FQ) Table Quality Checks

- **Missing SiteID** – This process checks if any records have a null SiteID. This ensures all rating location/frequency curves have a SiteID, which is used to relate to the RIDB_SITE layer.
- **Duplicate Frequency Curve** – This process counts the number of records for each combination of SiteID and Label. If the count of records exceeds 10 records, then it is flagged as a possible duplicate frequency curve. Most frequency curves have fewer than 10 data points to make the curve. Anything with more than 10 records could be a result of 2 frequency curves being inputted and that the system would incorrectly use for identifying if a feature/control is overtopped. Some exceptions are allowed for valid frequency curves with 10 or more records.
- **Duplicate Frequency Curve Values** – This process checks if there are duplicate records for the combination of SiteID, Label, F_F (frequency), and Q (flow). If any duplicate values exist, then multiple of the same records were inputted into the RIDB_FQ table. This may impact how the system utilizes the frequency curves.
- **Duplicate Frequency Values** – This process checks if there are duplicate frequency values with different flows by using the SiteID, Label, and F_F (frequency). If any duplicate values exist, then multiple flows exist for the same frequency in the RIDB_FQ table. This will result in ambiguity in determining the appropriate flow for a given frequency.
- **Unused Frequency Curves** – This process checks if the SiteID is present in the RIDB_SITE layer. If the frequency curve is not present in the layer, then it is flagged as an unused curve that could potentially be removed.
- **Missing Flow or Frequency** – This process checks if any records have a null F_F (frequency) or Q (flow). If these fields are null, then the outputs of the flood frequency will be invalid.

Stream Layer Quality Checks

- **Missing StreamID, RM_From or RM_To** – This process checks if any records have a null StreamID, RM_From, or RM_To. These are the primary fields used for the stream network to relate and display data.
- **Incorrect River Mile values** – This process checks if the RM_From is greater than RM_To. The system currently assumes the river mile from measure is always less than the to measure.

Stream Mapping Table Quality Checks

- **Invalid StreamID or RecStreamID** – This process checks if the StreamID and the RecStreamID from the RIDB_STREAMMAPPING table is present in the StreamID from the RIDB_STREAM layer. If the values are not present, then the stream mapping is referring to an invalid stream.
- **Valid Stream Attributes** – This process checks that the RecStreamID and RecStreamRM are located within the stream network. Any invalid RecStreamID or a RecStreamRM outside the extents of the stream network are flagged as a potential data issue.
- **Duplicate Stream Mapping** – This process checks if multiple StreamIDs exist. If multiple values exist, then it indicates the stream is connecting to multiple other streams that will impact the networking across the stream network. A stream can only connect to one other stream.

Stream Velocity Table Quality Checks

- **Invalid StreamID** – This process checks if the StreamID from the RIDB_STREAMVELOCITY table is present in the StreamID from the RIDB_STREAM layer. If the values are not present, then the stream velocity is referring to an invalid stream.
- **Valid Stream Attributes** – This process checks that the StreamID, RM_From, and RM_To are located within the stream network. Any invalid StreamID or an RM_From/RM_To outside the extents of the stream network are flagged as a potential data issue.

Flood Frequency

The frequency curves (RIDB_FQ) in the RIDB allow for understanding what types of flows are expected based on the magnitude of the flooding event. The frequency curves typically include return periods of 2-, 5-, 10-, 25-, 50-, 100-, and 500-year flood events. The frequency curves in combination with the RIDB_FEATURES can be used for resiliency analysis to determine what types of flooding events will result in features being overtopped.

The data for this analysis relies only on the RIDB, which can be used to create a layer showing which flooding events will impact each feature. The process described below runs daily, which updates a feature service in ArcGIS Online as shown in Figure 8 (RIDB Flood Frequency). These data are then used in an RIDB flood frequency application as shown in Figure 10. The application shows all features in the RIDB and then determines whether the feature will be overtopped based on the flood frequency in years that is selected.

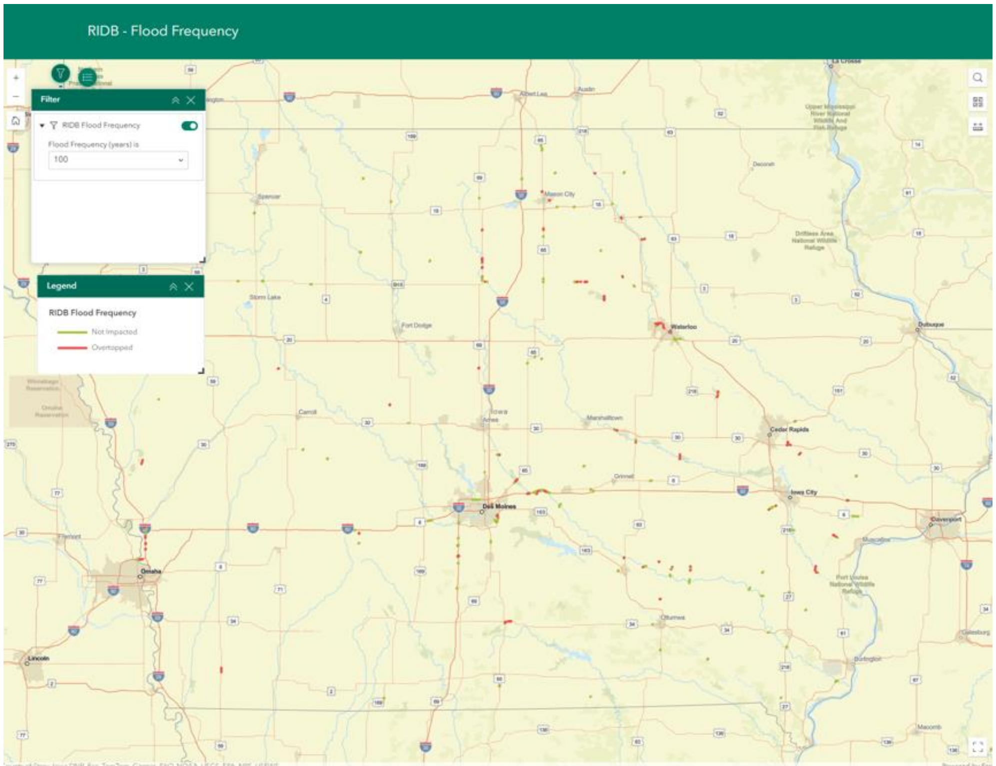

Figure 10. RIDB flood frequency application

To create the layer for the flood frequency application, the RIDB_SITE, RIDB_FEATURES, and RIDB_FQ layers are extracted from the authoritative RIDB. The RIDB_SITE layer is joined to the RIDB_FEATURES layer using the SiteID. This step was originally required when a frequency curve could be used across multiple sites but is no longer necessary now that the SiteID is used as the identifier for the frequency curves. The RIDB_FEATURES layer is then joined to the RIDB_FQ table based on the SiteID. This join results in a many-to-many relationship, as each feature is associated to all of the flood frequency values for the frequency curve. Since multiple features are typically associated to a given site, the frequency curve is used across all features as well.

Ultimately, the joined output allows for each frequency value and corresponding elevation to be associated to each feature. The elevation for a given frequency can then be compared to the ElevationExceed and OffsetElevRatingCurve to determine if the feature will be overtopped. If the frequency elevation is greater than the ElevationExceed plus the OffsetElevRatingCurve, then the feature for the given frequency will be coded as overtopped. Only features that have an indicator of CriticalElevation of true will be included in the outputted data. The resulting layers are published to ArcGIS Online for use in the application described above.

Public View Updates/Enhancements

To allow for public usage of the RIDB, a feature layer is updated daily to include the latest attributes within the authoritative RIDB. The feature layer allows for integrating the RIDB into other systems or to quickly explore the content of the RIDB. The process described below runs daily, which updates a feature service in ArcGIS Online as shown in Figure 8 (Public RIDB). These data are then used in an RIDB map application as shown in Figure 11. The RIDB Map application shows the primary layers of the RIDB and allows for filtering based on the SiteID. Filtering the map will show only the given site and corresponding features/controls. Additional links are provided to the frequency curves and rating curves by selecting a given record.

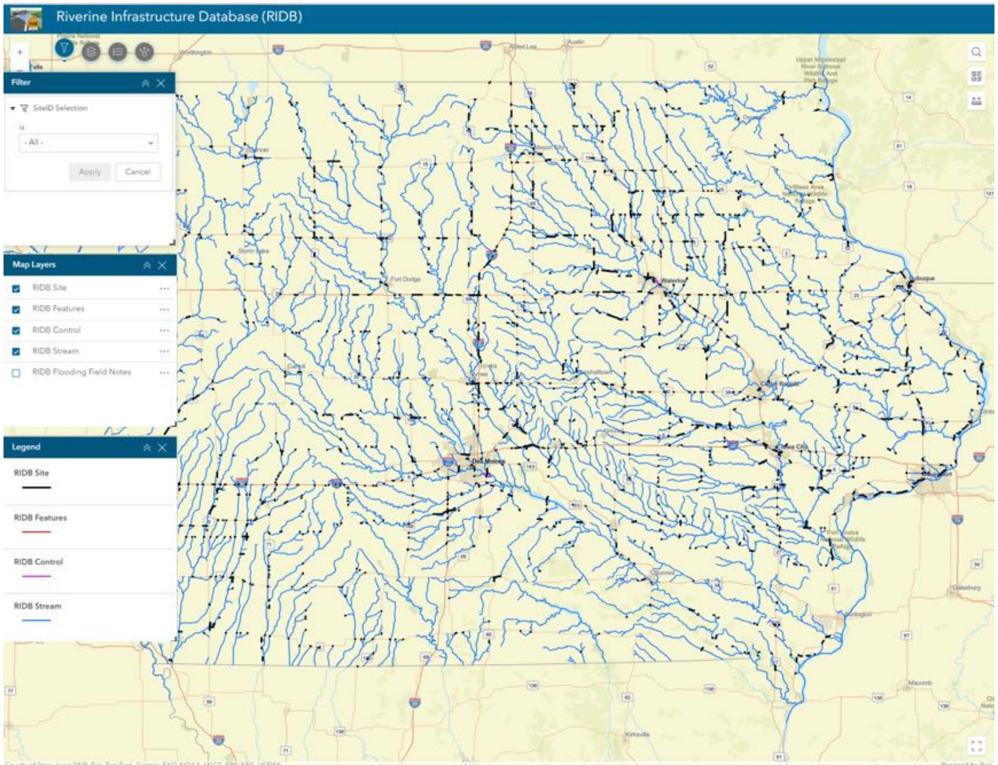

Figure 11. RIDB public map application

As noted previously, the authoritative RIDB is intended to only store attributes related to flooding, and other attributes maintained in other systems can be joined as part of this process. The first part of the nightly process is extracting the information about structures from the Iowa DOT Roadway Asset Management System (RAMS). The RAMS data for structures are joined to the RIDB_FEATURES layer based on the AssetID. The primary data of interest from the RAMS structure layer are the roadway information that can allow for the data in the RIDB to be integrated with other roadway attributes across the Iowa DOT. To support this, the RouteID, FromMeasure, and ToMeasure are retained from the RAMS structure data layer for use with the corresponding feature.

After extracting the data, any features not in the RAMS structure are missing attributes to locate them along the roadway network. To resolve this, the begin and end coordinates are conflated to the RAMS Iowa Linear Referencing System (LRS) to determine the begin and end measure values for the feature (similar to mile markers). The begin location is initially conflated to the network using a 50 m tolerance, which will return the corresponding dominant RouteID and measure value. The RouteID for the begin location is then used when conflating the end coordinates to get the end measure value. After the completion of this process, all features will have a corresponding RouteID, FromMeasure, and ToMeasure, which can be used to associate with any other roadway features associated to the RAMS network.

The process does not perform any additional data manipulation of the remaining layers and tables in the authoritative RIDB. All layers and tables are then published to the ArcGIS Online feature service including the RIDB_FEATURES, RIDB_SITE, RIDB_STREAM, RIDB_CONTROL, RIDB_FQ, RIDB_QH, RIDB_STREAMMAPPING, and RIDB_STREAMVELOCITY.

In addition to publishing the RIDB for public usage, the nightly process also archives any field notes that were collected publicly. The process and details of the nightly update are further discussed in the Field Notes Data Collection section below.

Hydraulic Analysis using IFC HLM

One of the primary benefits of the RIDB is the capability to continuously monitor the flooding impacts across the entire network. The system has the ability to quickly utilize the rating curves to determine whether the predicted stream flows will result in features or controls being overtopped or whether the flow will be over the critical discharge that may result in scour. The process described in this section to monitor the impacts is run hourly and creates an application that can be used to show any potential impacts.

The data for the hydraulic analysis relies on three primary inputs including the authoritative RIDB, the IFC HLM JSON data feed, and the Direct Input feature service as shown in Figure 8. This process ultimately updates components of the public RIDB, which are then used in the RIDB flooding impact application as shown in Figure 12. The application shows all sites and features in the RIDB that are indicated as being monitored. The sites will show the peak flow rate and the peak flow times. The Features layer will indicate whether the feature will be overtopped or over the discharge over the next five days. If the feature will be overtopped or over the discharge, a low arrival and high arrival time will be provided indicating the potential begin and end times of the impact. The application color codes the features based on their significance and list the most significantly impacted features along the left side.

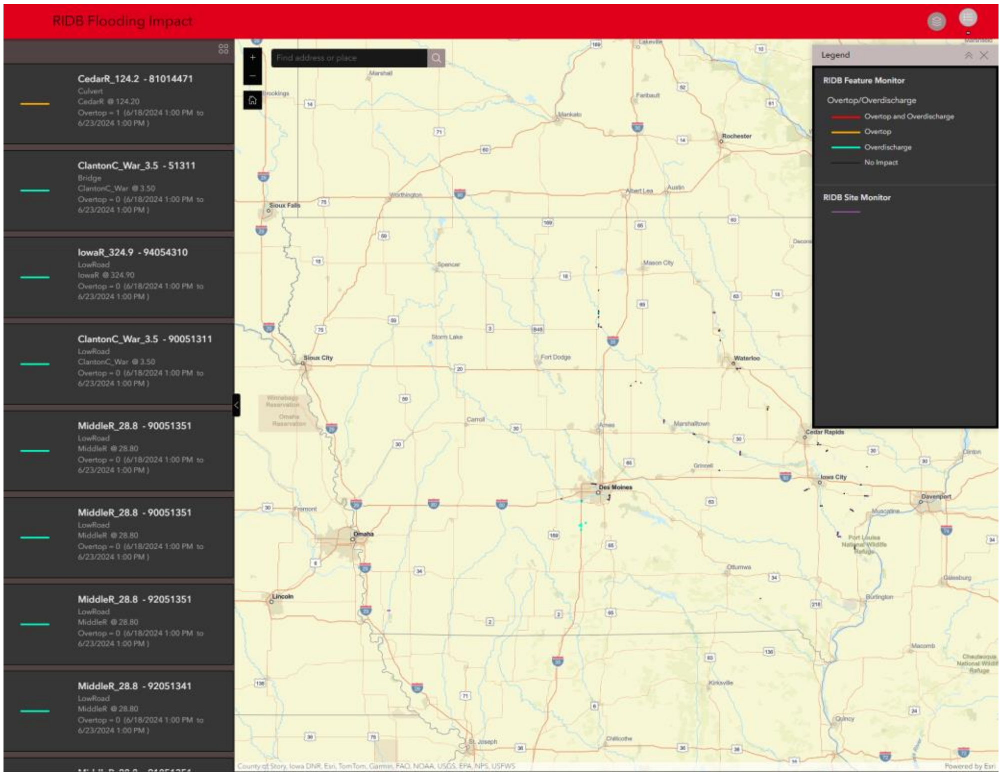

Figure 12. RIDB flooding impact application

The overall hydraulic analysis is summarized in Figure 13. Due to the complexity of the hydraulic analysis, this flow chart provides the organization of the components of the process listed along the right side. The remainder of this section describes in detail the various steps of the process to determine the peak flow for each site and identify any impacts for each feature.

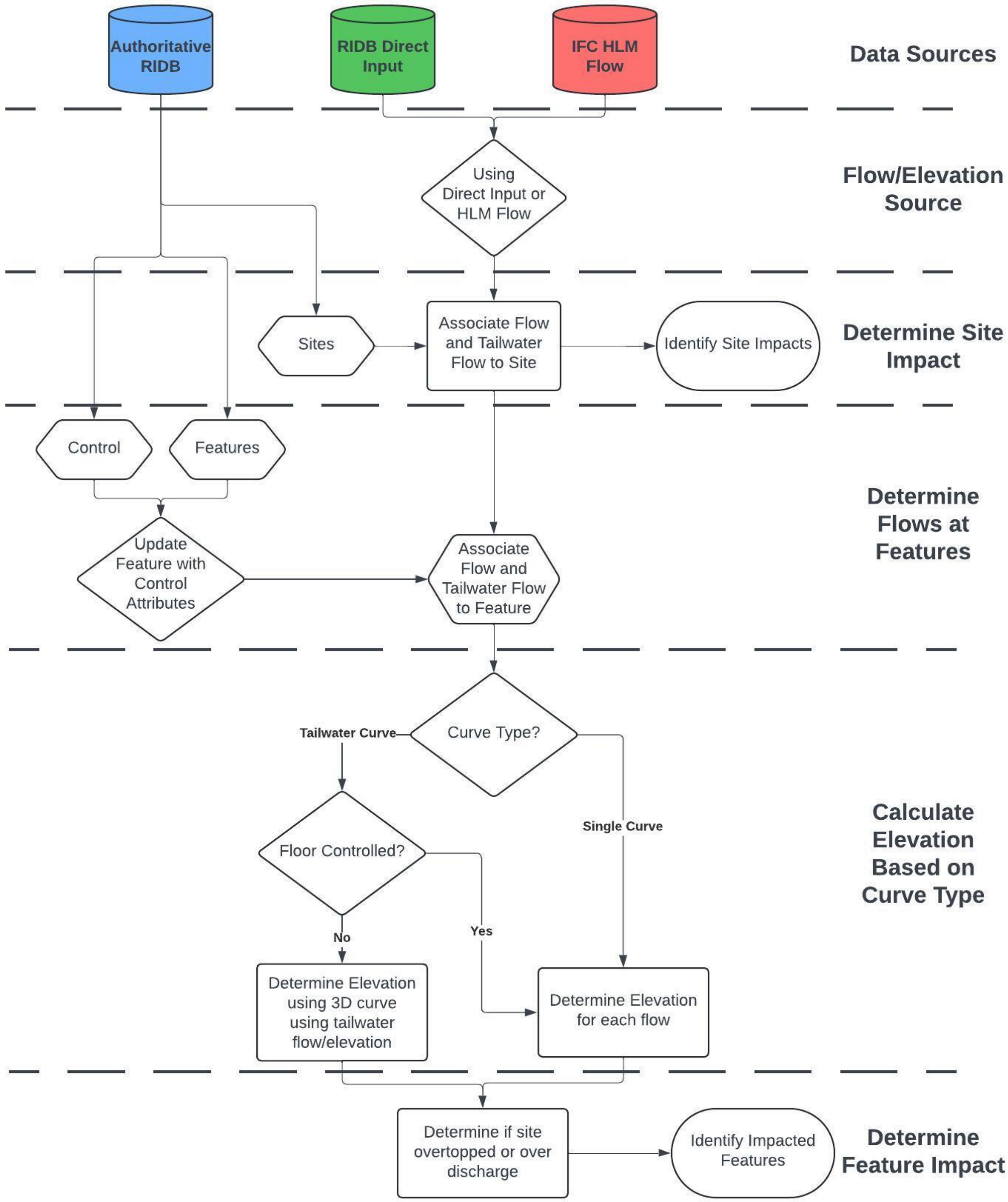

Figure 13. Hydraulic analysis flow chart

The first part of the hydraulic analysis process is to determine the flow rates for each site. The primary source of the data is provided through JSON feeds from the IFC using its HLM. The JSON feed contains a list of links across the state, with each link containing estimated flow rates for each hour for the next 5 days (120 readings total). The data in the JSON feed are updated each hour, allowing for continuous monitoring of the stream flows.

The HLM network is composed of LinkIDs that represent locations where the model estimates flow rates and is the primary method of associating with the RIDB. The RIDB includes two fields that are used to associate the sites in the RIDB to the HLM network. The primary field is named RatingLocIFCHLM that is populated based on the LinkID from the HLM network, which determines the stream flow for the site. Additionally, a field named RatingLocIFCHLMTW is populated based on the LinkID, which should be used for the stream flow at tailwater-dependent sites.

Through coordination with the IFC, the process has been automated so that any LinkIDs in either RatingLocIFCHLM or RatingLocIFCHLMTW show up in the JSON feed. This is accomplished by the IFC querying the public RIDB_SITE layer and then returning the sites, which are indicated as monitored. The LinkID for the given sites are available in the JSON feed for use in the hydraulic analysis.

In addition to the IFC HLM flows, the Iowa DOT wanted the capability to manually enter stream flows. This Direct Input capability provides two purposes. The first purpose of the Direct Input is to allow for entering tailwater-dependent stage values that are typically located near reservoirs. The stage-dependent sites cannot utilize the flows from the IFC HLM, and there are no current capabilities to get a forecast feed for the reservoir stage. Direct Input allows the Iowa DOT to extract the forecast stages and then manually utilize them with this process. The second purpose of the Direct Input is for overriding the IFC HLM or for planning scenarios with different flow rates to determine potential impacts. To accomplish this, an RIDB_DirectInput feature service was created (https://iowadot.maps.arcgis.com/home/item.html?id=f1f4dc446f3847f6a2f24c42856fe813) that allows the DOT to directly upload flow and stage values. The data are structured similar to the IFC HLM JSON feed with the following fields:

- **SiteID** – This is used to indicate which site the direct input values will apply to.
- **Rating_Location** – This is used to indicate the corresponding rating location the direct input values will apply to.
- **QH** – This value represents either the flow or elevation (stage) for the given time that will be used.
- **Time** – This value represents the time corresponding to the flow/elevation and should be provided in milliseconds.
- **Tailwater** – This field is used to indicate whether the flow should be used in the tailwater flow analysis.
- **StageFlow** – The QH field can represent either a flow or elevation. This field is used to explicitly identify the value of the QH field as opposed to relying on only the curve type in the RIDB. This field allows for validating that corresponding values are being compared appropriately (i.e., not comparing flow with elevation/stage values).

The first part of the process labeled Flow/Elevation Source in Figure 13 determines whether the HLM data or Direct Input data will be used. If direct input values exist for a given site, then the corresponding flows from the HLM will be ignored. The values are dependent on whether the direct inputs are for the primary flow or the tailwater flow. For example, if tailwater flow rates are directly inputted for a site only, then the system will still utilize the HLM flow rates for the primary flow. Similarly, if the primary flow rates are provided through direct input with no tailwater flow, then the tailwater flow from the HLM will be used. Direct input relies on the DOT to manually upload data into the system. To reduce the potential for human error, the system will discard any data before the current time. This ensures that if directly inputted data are not removed, the system will revert back to the HLM values when the direct input data time has passed the current time.

After determining which data source to use, the flow/stage is associated to each site labeled Determine Site Impact in Figure 13. For sites using the HLM, LinkID and RatingLocIFCHLM are used to join the flow with the site. For sites using Direct Input, the SiteID is used for values that are not identified as tailwater. After the primary flow is established, the tailwater flow will be determined for each site. For sites using the HLM, LinkID and RaingLocIFCHLMTW are used to join the tailwater flow using the timestamp for the primary flow. The process will be repeated for the Direct Input using the SiteID but only for values that are identified as tailwater. Upon completion of this step, each site will have a series of primary flow values along with tailwater flow values for the same time period. Using the flow for each site, the peak flow is determined along with the corresponding time. The attributes are then stored for publishing to ArcGIS Online to show site impacts with the peak flow and time.

The third step of the process in Figure 13 named Determine Flows at Features starts with extracting the RIDB_FEATURES and RIDB_CONTROL layers. Any features that have a control identified are updated with the attributes from the control layer. This allows users to determine whether the feature will be impacted only if the control is first impacted. For each feature, the corresponding flows for the given site associated with the feature are assigned. These data contain both the primary flow and tailwater flow for up to five days if using the HLM flow data.

The core of the hydraulic analysis is completed in the section named Calculate Elevation Based on Curve Type in Figure 13. For consistency throughout this section, flow refers to the values provided by the HLM or Direct Input. The values from the HLM or Direct Input may also be referred to as tailwater flow for some applications. The values from Direct Input may also include stage values that will be explicitly called out. For consistency, when referring to the rating curves, various labels (Q, TQ, TQ*, H, H*) are used that relate to the corresponding field names in the RIDB_QH table. The values indicated with asterisks refer to interpolated values determined from the rating curves (e.g., TQ* represents an interpolated value from the TQ field).

This hydraulic analysis part of the process depends on multiple factors including the rating curve type and the tailwater flows. For features with a single curve, the elevation (H) is calculated for each flow by interpolating between the curve elevation (H) and discharge (Q). For flows greater than the maximum discharge in the rating curve, the two highest discharge values are used to extrapolate the elevation.

For the features with tailwater dependent curves, there are multiple paths for analysis. The first path analyzes whether a site is tailwater stage-dependent. The data for tailwater stage-dependent sites can only be entered through direct input. If the data provided in the tailwater direct input has the value of Stage in the StageFlow field, then it is retained for additional analysis. If no Stage values are provided, then the process defaults back to the single curve process for determining the elevation (H) based on the flow values only.

The next check on the tailwater-dependent curves determines if the feature is floor controlled. Each of the flows/stages from the HLM and Direct Input are used to estimate the discharge tailwater value using the floor curve. At this point in the process, both the tailwater stage and discharge are handled the same. The discharge tailwater value is determined by interpolating between the discharge (Q) and discharge tailwater values (TQ). For flows greater than the maximum values in the rating curve, the two highest discharge values are used to extrapolate the discharge/stage tailwater value (TQ*). The discharge/stage tailwater value (TQ*) is then compared against the tailwater flow/stage values from the HLM and direct input. If the tailwater flow/stage value from the HLM and direct input is less than the discharge/stage tailwater value (TQ*), then the feature is floor controlled. If the feature is floor controlled, then the process defaults back to the single curve process for determining the elevation based on the flow values only.

For tailwater-dependent sites that are not floor controlled, the process utilizes the floor, shift A, and shift B curves to determine the elevation. For each flow value, the process interpolates between both the elevation (H) and tailwater values (TQ) for all three curves. This results in an array of three records with the elevation (H*) and tailwater values (TQ*) for the floor, shift A, and shift B curves. The tailwater flow/stage from the HLM or Direct Input is then used to interpolate between the values in the array for estimating the elevation. If the tailwater flow/stage from the HLM or Direct Input exceeds the tailwater value (TQ*) in the shift B curve, then the shift A and shift B curve values are used to extrapolate the elevation value.

After processing, all features have an elevation for all flow/stage values from the HLM or Direct Input data. The elevations are determined by the respective rating curves and also factor in any controls related to a feature. The final step of the process labeled Determine Feature Impact in Figure 13 is to determine if a feature will be overtopped or over the discharge rating. Overtopping is determined if the calculated elevation is greater than the ElevationExceed plus the OffsetElevRatingCurve fields. The process provides an indicator that a site is overtopped and whether the overtopping was based on tailwater-dependent data (i.e., not floor controlled). Overdischarge is determined if the flow values multiplied by the DischargeFactor field are greater than the DischargeExceed field, indicating scour may be an issue.

To create the final output, the results for each feature are aggregated to find the minimum time a site is overtopped or over discharge along with the maximum time. Upon completion of this step, each feature will have a field indicating if it is overtopped or over discharge and the minimum and the maximum impact time. The attributes are then stored for publishing to ArcGIS Online to show feature impacts as shown in the RIDB Flood Impact Application.

Field Notes Data Collection

Input from field staff is critical during major events to understanding the actual flooding conditions and in comparing these observations to model predictions. To support this effort, the RIDB has included a reference layer named RIDB_FIELDNOTES, which was described in the RIDB Overview chapter. Field notes provide the ability for data and images to be collected during flooding events that DOT staff can use for post-flooding analysis.

As opposed to the authoritative RIDB, field notes are intended by be collected by a large user group. The flow of data is collected in the field and then archived into the authoritative RIDB. To support this, a feature service in ArcGIS Online was developed as shown in Figure 8 (RIDB Field Collection). This feature service can be accessed by anyone in the Iowa DOT through the ArcGIS Field Maps application. The ArcGIS Field Maps mobile application is provided by Esri and already utilized by Iowa DOT staff for other field data collection efforts. Screenshots from the application are shown in Figure 14, which allows users to select a point on the map, take multiple photos or add attachments, and enter details about the flooding event. The map within the application also shows the sites, features, and controls within the RIDB, which can be selected as a point for entering data. The Iowa DOT has developed guidelines and reference materials that are accessible within the application.

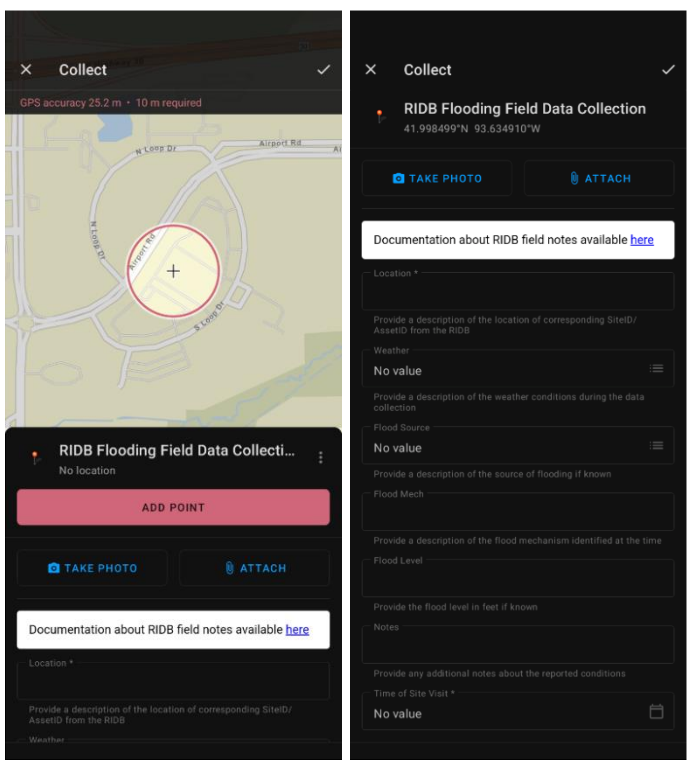

Figure 14. Screenshots from RIDB field notes collection application

To archive the field notes, the Public View Updates/Enhancements process is used to push any field notes into the authoritative RIDB. The process retains any images taken as well as all attributes entered by the user. The process runs daily and will update the authoritative RIDB based on any records entered during the previous 24 hours. Within the authoritative RIDB, two additional Boolean fields are available to Iowa DOT system users including whether the field note has been audited and whether a survey is required.

CONCLUSIONS

Flooding events can be difficult for engineers, as there can be widespread impacts and it can be difficult to quantify what infrastructure is most vulnerable. The process of completing a hydraulic analysis is often time-consuming and, in many cases, cannot be completed by the time a stream crests. The challenge is typically that relevant hydrologic and hydraulic information for assessing the vulnerability of infrastructure is not available or not easily accessible. Additionally, because of the time commitments, only a fraction of the system can be monitored, which often leaves agencies being reactive instead of proactive, resulting in unnecessary damages and risks to public safety.

The concept of the RIDB was developed by the Iowa DOT during the extreme flood events in 2008. Many large stream basins in the central and eastern parts of Iowa caused impacts to I-80 and many other primary routes. During these flood events, it was critical to assess and predict which highway locations had the potential for overtopping from floodwaters so that safe detour routes could be identified for the traveling public. The effort to evaluate the vulnerability of the roadway to flooding required significant DOT staff time and resources to reconcile the datums from various projects and correlate hydraulic estimates to determine accurate stage versus discharge relationships (rating curves) at specific bridge/highway locations.

The RIDB is an innovative and proactive approach to assessing the vulnerability and risk of transportation projects and systems. The relational database incorporates hydraulic (flow and flood elevations) and infrastructure (low road and bridge beam elevations) that can be utilized to provide the rapid assessment of riverine locations when the potential for roadway overtopping or bridge inundation could occur.

Through this project, the data collected by the Iowa DOT to support the RIDB were extracted and populated into an enterprise GIS database. The GIS database allowed for easier access to the various layers and tables within the RIDB. A simple map platform of the RIDB can be used to select sites and then quickly see all associated features and controls. Users can quickly access rating curves and frequency curves associated to the layers for any manual analysis of the data. On the hydraulic side, the stream network provides linear referencing capabilities to easily associate and reference attributes tied to the network. The RIDB now includes detailed documentation for each field along with entity relationship diagrams to show how each layer/table is related. The following are the services directory and map platforms of the RIDB for public usage:

- RIDB REST Service: https://services.arcgis.com/8lRhdTsQyJpO52F1/arcgis/rest/services/RIDB_Public/FeatureServer
- RIDB Map: https://experience.arcgis.com/experience/23255ae7d8ac40519f044262bec2a8ba/

In addition to establishing the RIDB GIS environment, the project provided additional systems to improve the accuracy and usability of the RIDB. This includes data archiving capabilities to allow the system to be reverted back to a previous state if needed. The system also performs a series of data quality checks to ensure the functionality of the RIDB. The RIDB has the capability to be used for planning or resiliency analysis based on frequency curves. To support the frequency analysis, the RIDB flood frequency application was developed to allow users to select a flood frequency event and see the impact for all features in the RIDB.

One of the primary benefits of the RIDB is the capability to continuously monitor the flooding impacts across the entire network. The RIDB system has the ability to quickly utilize the rating curves to determine whether predicted stream flows will result in features or controls being overtopped or whether the flow will be over the discharge level that may result in scour. The RIDB has been integrated with the IFC's HLM, which provides hourly flow values for the next five days. The data from IFC are updated each hour to allow for continuous monitoring of features. The system was developed to provide a map showing any flooding impacts, with the added capability to receive direct input of flow values from the Iowa DOT. Links for both the flooding impact and flood frequency applications are given as follows:

- RIDB Flooding Impact (Near Real-Time): https://experience.arcgis.com/experience/23c55237dbf34bb3990889d5cb305031/
- RIDB Flood Frequency: https://experience.arcgis.com/experience/506ffdf2ef53457aa4952da067249ae8/

Input from field staff is critical during major events to understanding the actual flooding conditions and in comparing these observations to model predictions. The RIDB supports the ability to collect information about flooding events from field staff. The field notes layer provides the ability for data and images to be collected during flooding events that Iowa DOT staff can use for post-flooding analysis. An application was developed that allows for field notes to be provided by field staff including multiple photos or attachments along with details about the flooding event. The application utilized the Esri Field Maps application, which allows for collecting the data using a mobile phone. The data are archived to the authoritative RIDB daily, which allows Iowa DOT staff to identify whether the note needs to be audited or the location surveyed.

The RIDB effort provides the foundation for planning and operational use of hydraulic data and infrastructure impacted during flooding events. With the framework established, additional future efforts can be completed related to flooding using the RIBD including the following:

- Develop an RIDB repository of historic flood information to refine rating curve information and impacts to the infrastructure, creating an asset management database system that will provide valuable data for future planning and design improvements.
- Promote/integrate vulnerability assessments into other stakeholders' practices (e.g., Iowa Department of Natural Resources, Iowa Homeland Security and Emergency Management, counties/cities) to reduce risks and damages associated with flooding on other assets and the general public.

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