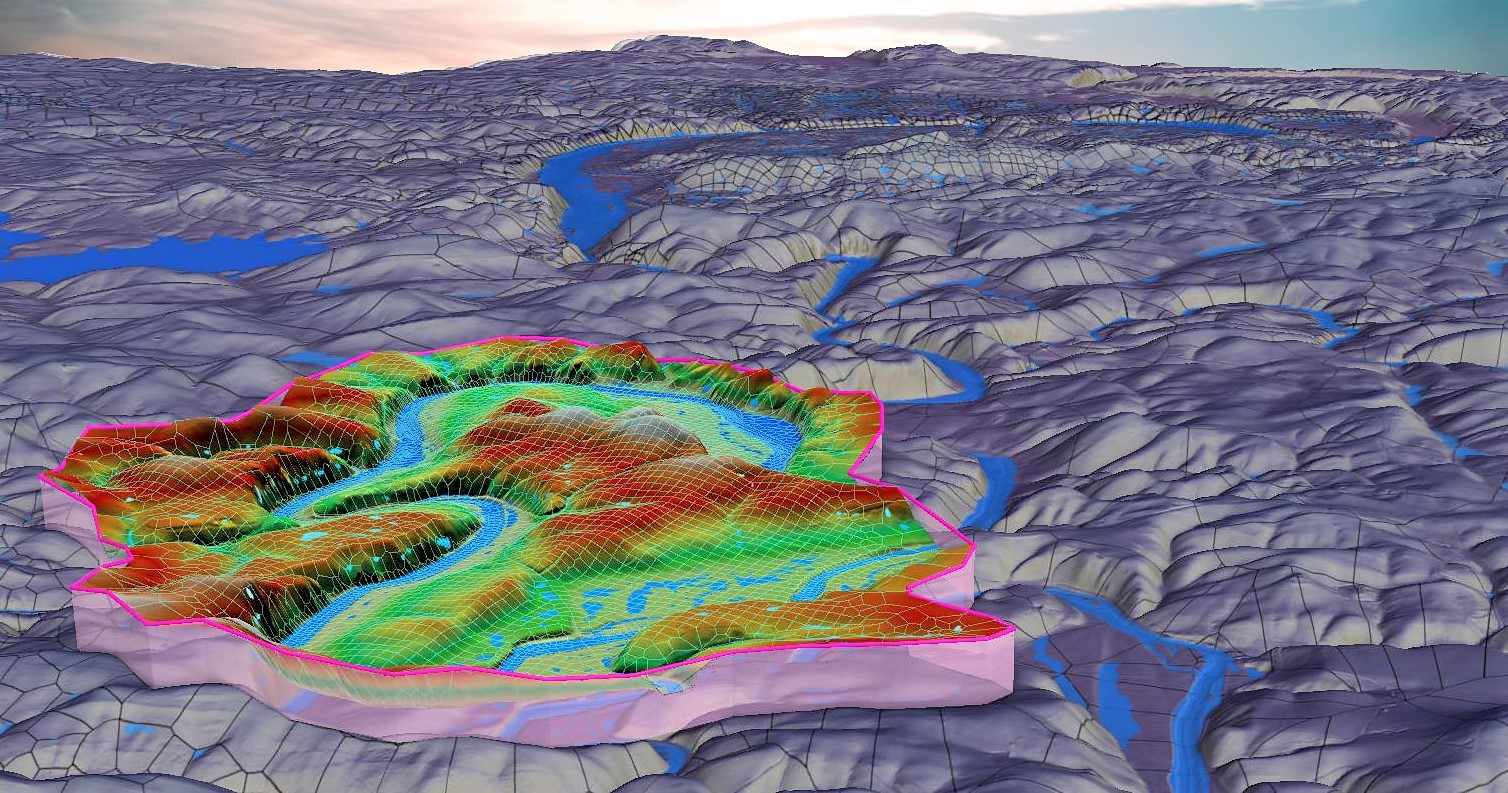
|  |
| --- |
|  |
| HEC-RAS— [«MODEL\_UNIT\_NAME»]  DRAFT REPORT  «Date»  U.S. Department of Homeland Security Seal: Federal Emergency Management Agency |



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Executive Summary

[Update]

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* 1. Basin Overview

[brief description of the basin form hydrology and hydraulics point of view including major features]

Example: The Elk Middle is an approximately 600-square mile subbasin of the Kanawha River Basin, located in West Virginia. The primary waterway within the basin is the Elk River, which receives flows from Sutton Dam, located at the upstream boundary of the subbasin. The downstream terminus of the Elk Middle subbasin is the United States Geological Survey (USGS) stream gaging station at Queen Shoals, West Virginia. This model unit is primarily located in HUC 8 NAME NUMBER. Karst geology is common in the Kanawha River watershed; however, the extent of the Karst features are located to the south and east of the Elk Middle subbasin. Figure 1 shows the Elk Middle subbasin in relation to the Kanawha basin. Figure 2 depicts the Elk Middle subbasin gage locations. «Section01\_GageSummary\_Txt» Additionally, the United States Corps of Engineers (USACE) Huntington District (LRH) maintains records of pool elevation behind Sutton Dam. Webster Springs, West Virginia, with a population of approximately 725, is the largest population center within this modeling domain (U.S. Census Bureau, 2020). River Analysis System (HEC-RAS) modeling for a limited portion in/near Webster Springs, West Virginia exists within this modeling domain.

[include overview figure showing location of modeling unit relative to the HUC4 pilot project study area]

Figure 1. «figure\_pilot\_study\_area»

Figure 2. «figure\_dem»

[include figure showing digital elevation model of the studied area]

* 1. Modeling Team & Metadata

The modeling team included personnel from the U.S. Army Corps of Engineers (USACE) and the PTS contracting group. The team developed models based on common techniques to ensure consistent results. The initial model development began in July 2022 and the final products were uploaded in November 2022.

* Primary Modeler: [name, org]
* QC Reviewer: [name, org]
* [Calibrated Model Delivered: xxx; Model Comment Addressed: xxx]
* HEC–RAS Version: [version used]
* Vertical Datum: NAVD 88 - feet
* Projection of Model: Albers Equal Area per USACE FFRD Standard SOP

Table 1. Projection Details

|  |  |
| --- | --- |
| ID | Value |
| PROJCS | «table01\_projcs» |
| GEOGCS | «table01\_geogcs» |
| DATUM | «table01\_datum» |
| ELLIPSOID | «table01\_ellipsoid» |
| METHOD | «table01\_method» |
| AUTHORITY | «table01\_authority» |
| CODE | «table01\_code» |
| UNIT | «table01\_unit» |

* 1. Data Sources

d Several data sources were used to support the production of this model as tabulated and described in Table X.

Table 2. Model Production Data Sources

|  |  |
| --- | --- |
| **Data** | **Description / Use / Source / Citation** |
| Digital Elevation Model (DEM) | Ex: A DEM from the West Virginia light detection and ranging (LiDAR) dataset was preprocessed for the entire basin and delivered as a tiled 1-meter resolution grid. The mosaic dataset was sourced from The West Virginia GIS Technical center which references LiDAR Datasets with collection dates ranging from 2003-2018.    <https://www.mapwv.gov/floodtest/docs/WV_FloodTool_ElevationSource_Metadata.pdf> |
| Stream Gaging Data |  |
| National Hydrography Dataset (NHD) Stream Centerlines |  |
| Model Unit Boundary |  |
| Elevation Derived Hydrography (EDH) |  |
| HEC–HMS Model Outputs | Ex: HEC–HMS Model results were used as direct inputs to the HEC–RAS model. The HEC–HMS model relied on separate precipitation and temperature datasets described in a separate report. |
| National Levee Database (NLD) |  |
| National Inventory of Dams (NID) |  |
| Base Level Engineering (BLE) Model–Stream Centerlines |  |
| BLE Model-land use based on aerial image processing |  |
| National Land Cover Dataset (NLCD) |  |
| Corps Water Management System (CWMS) Model |  |
| National Flood Hazard Layer (NFHL) |  |
| Flood Insurance Study (FIS) |  |
| National Structure Inventory (NSI) |  |
| Aerial Photos | Ex: Publicly available aerial photos of the basin were referenced during model development |
| Etc |  |
| Etc |  |
| Etc |  |
| Etc |  |
|  | [add key data sources as needed] |

Figure 3. «figure\_basin\_datasets»

Table 3. USGS Stream Gage Summary

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Stream Gage | USGS ID | Priority | Drainage Area (sq-mi) | Period of Record (years) |
| «table03\_gage01\_name» | «table03\_gage01\_id» |  | «table03\_gage01\_area» | «table03\_gage01\_por» |
| «table03\_gage02\_name» | «table03\_gage02\_id» |  | «table03\_gage02\_area» | «table03\_gage02\_por» |
| «table03\_gage03\_name» | «table03\_gage03\_id» |  | «table03\_gage03\_area» | «table03\_gage03\_por» |
| «table03\_gage04\_name» | «table03\_gage04\_id» |  | «table03\_gage04\_area» | «table03\_gage04\_por» |
| «table03\_gage05\_name» | «table03\_gage05\_id» |  | «table03\_gage05\_area» | «table03\_gage05\_por» |
| «table03\_gage06\_name» | «table03\_gage06\_id» |  | «table03\_gage06\_area» | «table03\_gage06\_por» |
| «table03\_gage07\_name» | «table03\_gage07\_id» |  | «table03\_gage07\_area» | «table03\_gage07\_por» |
| «table03\_gage08\_name» | «table03\_gage08\_id» |  | «table03\_gage08\_area» | «table03\_gage08\_por» |
| «table03\_gage09\_name» | «table03\_gage09\_id» |  | «table03\_gage09\_area» | «table03\_gage09\_por» |
| «table03\_gage010\_name» | «table03\_gage010\_id» |  | «table03\_gage010\_area» | «table03\_gage010\_por» |

Figure 4. «figure\_stream\_gage\_summary»

* 1. Model Geometry Construction

[describe thought process and rational for approach to model construction – runtime target? number of cells?]

Example: The Elk Middle subbasin HEC–RAS model was built with a target of «Section04\_RunTime\_Time» run-times for a three to four week flood event. Experience has shown that a mesh with approximately «Section04\_CellCount\_Num» cells can achieve the desired run-time. Large grid cell resolution was intentionally used throughout the basin to allow for a finer resolution along the key channels and population centers. The model was built using judgement without strict criteria on how to select areas for refinement, as this is an early pilot project that will help inform future standards.

[add relevant figures to describe model geometry construction]

[describe model extent]

[describe background mesh resolution]

[describe any terrain modifications used]

[describe any use of breaklines («Section04\_Breaklines\_Num»), hydro connections («Section04\_HydroConn\_Num»), terrain modifications («Section04\_TerrainMod\_Num»), bridges («Section04\_Bridges\_Num»), or other geometry construction techniques used in model]

[describe treatment of sub-surface drainage systems: terrain mods, mesh refinement, culvert, pumpstations, etc]

[describe any modifications to the downstream boundary]

* + 1. Streams

[describe treatment of stream network - how and why. Include description of mesh refinement & how bathymetry was accounted for. Provide table of Key streams and Secondary Streams]

Table 4. Key Stream Modeling Techniques

|  |  |
| --- | --- |
| Key Stream Name | Treatment in Model |
|  |  |
|  |  |
|  |  |

Table 5. Secondary Stream Modeling Techniques

|  |  |
| --- | --- |
| Secondary Stream Name | Treatment in Model |
|  |  |
|  |  |
|  |  |

* + 1. Developed Areas

[describe any other areas that were refined: how and why – add map of “developed areas” when appropriate]

Figure 5. «figure\_nlcd»

* + 1. Dams

[Dams: Describe approach and List Dams that were accounted for in the model]

Table 6. Top 10 Dams within Modeling Unit

|  |  |  |  |
| --- | --- | --- | --- |
| NID | Name | Vertical Height (ft) | Description of Dam Model Technique and Collected Data |
| «table06\_dam01\_id» | «table06\_dam01\_name» | «table06\_dam01\_height» |  |
| «table06\_dam02\_id» | «table06\_dam02\_name» | «table06\_dam02\_height» |  |
| «table06\_dam03\_id» | «table06\_dam03\_name» | «table06\_dam03\_height» |  |
| «table06\_dam04\_id» | «table06\_dam04\_name» | «table06\_dam04\_height» |  |
| «table06\_dam05\_id» | «table06\_dam05\_name» | «table06\_dam05\_height» |  |
| «table06\_dam06\_id» | «table06\_dam06\_name» | «table06\_dam06\_height» |  |
| «table06\_dam07\_id» | «table06\_dam07\_name» | «table06\_dam07\_height» |  |
| «table06\_dam08\_id» | «table06\_dam08\_name» | «table06\_dam08\_height» |  |
| «table06\_dam09\_id» | «table06\_dam09\_name» | «table06\_dam09\_height» |  |
| «table06\_dam010\_id» | «table06\_dam010\_name» | «table06\_dam010\_height» |  |

* + 1. Levees

[Levees: Describe approach & table of levees in basin.]

Table 7.

|  |  |
| --- | --- |
| Levee System Name & NLD System ID# | Description of Alignment and Profile |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |

* + 1. Final Geometry

[include summary of final geometry]

Figure 6. «figure\_model\_mesh»

* 1. Boundary Conditions

[include that lists the boundary conditions used for all model scenarios used for calibration runs. Describe source and reasoning for application for upstream and downstream modeling technique]

Table 8. Boundary Conditions within Modeling Unit

|  |  |
| --- | --- |
| **Boundary Condition** | **Source** |
| Upstream Inflow 1 | [describe] |
| Upstream Inflow 2 | [describe] |
| Excess Rainfall / Runoff | [describe] |
| Baseflow | [describe] |
| Downstream Normal Depth | [describe] |

[show map of HMS subbasins overlaid on the RAS model extent, as well as locations of boundary conditions]

Figure 7. «figure\_hms\_subbasins»

* 1. Computational Options

Example: «Section06\_EquationSet\_Txt». Investigations were performed to quantify these differences and identify the locations/situations in which they occurred within this modeling domain. These investigations are detailed in Section 7.

Table 9. Two-Dimensional Computational Solver Tolerances and Settings

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Plan | **«plan01\_date»** | **«plan02\_date»** | **«plan03\_date»** | **«plan04\_date»** | **«plan05\_date»** | **«plan06\_date»** |
| Implicit Weighting Factor (theta) | «plan01\_iwf» | «plan02\_iwf» | «plan03\_iwf» | «plan04\_iwf» | «plan05\_iwf» | «plan06\_iwf» |
| Water Surface Tolerance (ft) | «plan01\_wst» | «plan02\_wst» | «plan03\_wst» | «plan04\_wst» | «plan05\_wst» | «plan06\_wst» |
| Volume Tolerance (ft) | «plan01\_volt» | «plan02\_volt» | «plan03\_volt» | «plan04\_volt» | «plan05\_volt» | «plan06\_volt» |
| Max Iterations | «plan01\_max\_iter» | «plan02\_max\_iter» | «plan03\_max\_iter» | «plan04\_max\_iter» | «plan05\_max\_iter» | «plan06\_max\_iter» |
| Fixed Time Step (sec) | «plan01\_fts» | «plan02\_fts» | «plan03\_fts» | «plan04\_fts» | «plan05\_fts» | «plan06\_fts» |
| 2D Equation Set | «plan01\_eqn» | «plan02\_eqn» | «plan03\_eqn» | «plan04\_eqn» | «plan05\_eqn» | «plan06\_eqn» |
| Hydrograph Output Interval (Base) | «plan01\_output\_interval» | «plan02\_output\_interval» | «plan03\_output\_interval» | «plan04\_output\_interval» | «plan05\_output\_interval» | «plan06\_output\_interval» |

* 1. Model Calibration & Validation

Example: The quality of the calibration was measured according to the future of flood risk data (FFRD) guidance, which calls for the comparison of statistical metrics that evaluate the fit of the modeled data to observed data over the entire hydrograph. Table 4 provides the summarized statistics. Calibration performance rating goals were set by the primary, secondary, and tertiary gage categories as follows:

* Primary Locations: Statistical comparisons of computed and observed flow/stage at all primary locations must be in the satisfactory or higher range.
* Secondary Locations: Statistical comparisons of computed and observed flow/stage at all secondary locations should be in the satisfactory or higher range.
* Tertiary Locations: Statistical comparisons of computed and observed flow/stage at all tertiary locations must be in the acceptable or higher range.

Table 10. Performance Ratings for Summary Statistics

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Performance Rating | R2 | NSE | RSR | PBIAS |
| Very Good | 0.65<R2≤1.00 | 0.65<𝑁𝑆𝐸≤1.00 | 0.00<𝑅𝑆𝑅≤0.60 | 𝑃𝐵𝐼𝐴𝑆< ±15 |
| Good | 0.55<R2≤0.65 | 0.55<𝑁𝑆𝐸≤0.65 | 0.60<𝑅𝑆𝑅≤0.70 | ±15≤𝑃𝐵𝐼𝐴𝑆<±20 |
| Satisfactory | 0.40<R2≤0.55 | 0.40<𝑁𝑆𝐸≤0.55 | 0.70<𝑅𝑆𝑅≤0.80 | ±20≤𝑃𝐵𝐼𝐴𝑆<±30 |
| Unsatisfactory | R2≤0.40 | 𝑁𝑆𝐸≤0.40 | 𝑅𝑆𝑅>0.80 | 𝑃𝐵𝐼𝐴𝑆≥±30 |

[describe and list the historical events used for calibration and validation of the RAS model. Include description of observed data availability. Primary Gages vs. Secondary gages for calibration]

Table 11. Gage Calibration Timesteps

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Gage | «plan01\_date» | | «plan02\_date» | | «plan03\_date» | | «plan04\_date» | | «plan05\_date» | | «plan06\_date» | |
|  | **Flow** | **Stage** | **Flow** | **Stage** | **Flow** | **Stage** | **Flow** | **Stage** | **Flow** | **Stage** | **Flow** | **Stage** |
| «table11\_gage01\_name» | «plan01\_gage01\_flow\_ts» | «plan01\_gage01\_stage\_ts» | «plan02\_gage01\_flow\_ts» | «plan02\_gage01\_stage\_ts» | «plan03\_gage01\_flow\_ts» | «plan03\_gage01\_stage\_ts» | «plan04\_gage01\_flow\_ts» | «plan04\_gage01\_stage\_ts» | «plan05\_gage01\_flow\_ts» | «plan05\_gage01\_stage\_ts» | «plan06\_gage01\_flow\_ts» | «plan06\_gage01\_stage\_ts» |
| «table11\_gage02\_name» | «plan01\_gage02\_flow\_ts» | «plan01\_gage02\_stage\_ts» | «plan02\_gage02\_flow\_ts» | «plan02\_gage02\_stage\_ts» | «plan03\_gage02\_flow\_ts» | «plan03\_gage02\_stage\_ts» | «plan04\_gage02\_flow\_ts» | «plan04\_gage02\_stage\_ts» | «plan05\_gage02\_flow\_ts» | «plan05\_gage02\_stage\_ts» | «plan06\_gage02\_flow\_ts» | «plan06\_gage02\_stage\_ts» |
| «table11\_gage03\_name» | «plan01\_gage03\_flow\_ts» | «plan01\_gage03\_stage\_ts» | «plan02\_gage03\_flow\_ts» | «plan02\_gage03\_stage\_ts» | «plan03\_gage03\_flow\_ts» | «plan03\_gage03\_stage\_ts» | «plan04\_gage03\_flow\_ts» | «plan04\_gage03\_stage\_ts» | «plan05\_gage03\_flow\_ts» | «plan05\_gage03\_stage\_ts» | «plan06\_gage03\_flow\_ts» | «plan06\_gage03\_stage\_ts» |
| «table11\_gage04\_name» | «plan01\_gage04\_flow\_ts» | «plan01\_gage04\_stage\_ts» | «plan02\_gage04\_flow\_ts» | «plan02\_gage04\_stage\_ts» | «plan03\_gage04\_flow\_ts» | «plan03\_gage04\_stage\_ts» | «plan04\_gage04\_flow\_ts» | «plan04\_gage04\_stage\_ts» | «plan05\_gage04\_flow\_ts» | «plan05\_gage04\_stage\_ts» | «plan06\_gage04\_flow\_ts» | «plan06\_gage04\_stage\_ts» |
| «table11\_gage05\_name» | «plan01\_gage05\_flow\_ts» | «plan01\_gage05\_stage\_ts» | «plan02\_gage05\_flow\_ts» | «plan02\_gage05\_stage\_ts» | «plan03\_gage05\_flow\_ts» | «plan03\_gage05\_stage\_ts» | «plan04\_gage05\_flow\_ts» | «plan04\_gage05\_stage\_ts» | «plan05\_gage05\_flow\_ts» | «plan05\_gage05\_stage\_ts» | «plan06\_gage05\_flow\_ts» | «plan06\_gage05\_stage\_ts» |
| \*At dam | | | | | | | | | | | | |

[describe how the model performed in relation to the metrics. Explain any difficulties achieving the metrics]

[describe modeled vs. observed stage discharge relationships, dam pool/release, etc.]

[describe approach to calibration. Include description of what parameters were adjusted? Roughness values? Equation set? Mesh refinement? Terrain modifications?]

Table 12. Assigned Roughness within Modeling Unit

|  |  |  |
| --- | --- | --- |
| Land Class Type | Base | Override |
|  |  |  |
|  |  |  |
|  |  |  |

[describe approach to calibration for any operable features in basin, dams, pumps, etc as needed]

[describe any other considerations or calibration data that was used – e.g. High Water Marks, Aerial Photos during flood events, etc]

[add any relevant tables or figures that help describe the calibration efforts]

Appendix A shows a full inventory of calibration results and statistical metrics.

* 1. Discussion

[add any relevant modeling information that does not fit well within other sections of the report. Delete section if not necessary.]

Appendix A – Results

Table 13. Plan #1 Calibration Results – Statistical Metrics «plan01\_date»

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Gage ID | «plan01\_gage01» | | «plan01\_gage02» | | «plan01\_gage03» | | «plan01\_gage04» | |
| Metric | Flow |  | Flow |  | Flow |  | Flow |  |
| Nash Sutcliffe Efficiency | «plan01\_gage01\_flow\_nse» | «plan01\_gage01\_flow\_nse\_eval» | «plan01\_gage02\_flow\_nse» | «plan01\_gage02\_flow\_nse\_eval» | «plan01\_gage03\_flow\_nse» | «plan01\_gage03\_flow\_nse\_eval» | «plan01\_gage04\_flow\_nse» | «plan01\_gage04\_flow\_nse\_eval» |
| RMSE Standard Deviation Ratio | «plan01\_gage01\_flow\_rsr» | «plan01\_gage01\_flow\_rsr\_eval» | «plan01\_gage02\_flow\_rsr» | «plan01\_gage02\_flow\_rsr\_eval» | «plan01\_gage03\_flow\_rsr» | «plan01\_gage03\_flow\_rsr\_eval» | «plan01\_gage04\_flow\_rsr» | «plan01\_gage04\_flow\_rsr\_eval» |
| Percent Bias | «plan01\_gage01\_flow\_pbias» | «plan01\_gage01\_flow\_pbias\_eval» | «plan01\_gage02\_flow\_pbias» | «plan01\_gage02\_flow\_pbias\_eval» | «plan01\_gage03\_flow\_pbias» | «plan01\_gage03\_flow\_pbias\_eval» | «plan01\_gage04\_flow\_pbias» | «plan01\_gage04\_flow\_pbias\_eval» |
| Coefficient of Determination | «plan01\_gage01\_flow\_r2» | «plan01\_gage01\_flow\_r2\_eval» | «plan01\_gage02\_flow\_r2» | «plan01\_gage02\_flow\_r2\_eval» | «plan01\_gage03\_flow\_r2» | «plan01\_gage03\_flow\_r2\_eval» | «plan01\_gage04\_flow\_r2» | «plan01\_gage04\_flow\_r2\_eval» |
|  | Stage |  | Stage |  | Stage |  | Stage |  |
| Nash Sutcliffe Efficiency | «plan01\_gage01\_stage\_nse» | «plan01\_gage01\_stage\_nse\_eval» | «plan01\_gage02\_stage\_nse» | «plan01\_gage02\_stage\_nse\_eval» | «plan01\_gage03\_stage\_nse» | «plan01\_gage03\_stage\_nse\_eval» | «plan01\_gage04\_stage\_nse» | «plan01\_gage04\_stage\_nse\_eval» |
| RMSE Standard Deviation Ratio | «plan01\_gage01\_stage\_rsr» | «plan01\_gage01\_stage\_rsr\_eval» | «plan01\_gage02\_stage\_rsr» | «plan01\_gage02\_stage\_rsr\_eval» | «plan01\_gage03\_stage\_rsr» | «plan01\_gage03\_stage\_rsr\_eval» | «plan01\_gage04\_stage\_rsr» | «plan01\_gage04\_stage\_rsr\_eval» |
| Percent Bias | «plan01\_gage01\_stage\_pbias» | «plan01\_gage01\_stage\_pbias\_eval» | «plan01\_gage02\_stage\_pbias» | «plan01\_gage02\_stage\_pbias\_eval» | «plan01\_gage03\_stage\_pbias» | «plan01\_gage03\_stage\_pbias\_eval» | «plan01\_gage04\_stage\_pbias» | «plan01\_gage04\_stage\_pbias\_eval» |
| Coefficient of Determination | «plan01\_gage01\_stage\_r2» | «plan01\_gage01\_stage\_r2\_eval» | «plan01\_gage02\_stage\_r2» | «plan01\_gage02\_stage\_r2\_eval» | «plan01\_gage03\_stage\_r2» | «plan01\_gage03\_stage\_r2\_eval» | «plan01\_gage04\_stage\_r2» | «plan01\_gage04\_stage\_r2\_eval» |

«plan01\_figure\_gage\_Flow»

«plan01\_figure\_gage\_Stage»

«plan01\_figure\_wse\_errors»

«plan01\_figure\_wse\_ttp»

Table 14. Plan #2 Calibration Results – Statistical Metrics «plan02\_date»

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Gage ID | «plan02\_gage01» | | «plan02\_gage02» | | «plan02\_gage03» | | «plan02\_gage04» | |
| Metric | Flow |  | Flow |  | Flow |  | Flow |  |
| Nash Sutcliffe Efficiency | «plan02\_gage01\_flow\_nse» | «plan02\_gage01\_flow\_nse\_eval» | «plan02\_gage02\_flow\_nse» | «plan02\_gage02\_flow\_nse\_eval» | «plan02\_gage03\_flow\_nse» | «plan02\_gage03\_flow\_nse\_eval» | «plan02\_gage04\_flow\_nse» | «plan02\_gage04\_flow\_nse\_eval» |
| RMSE Standard Deviation Ratio | «plan02\_gage01\_flow\_rsr» | «plan02\_gage01\_flow\_rsr\_eval» | «plan02\_gage02\_flow\_rsr» | «plan02\_gage02\_flow\_rsr\_eval» | «plan02\_gage03\_flow\_rsr» | «plan02\_gage03\_flow\_rsr\_eval» | «plan02\_gage04\_flow\_rsr» | «plan02\_gage04\_flow\_rsr\_eval» |
| Percent Bias | «plan02\_gage01\_flow\_pbias» | «plan02\_gage01\_flow\_pbias\_eval» | «plan02\_gage02\_flow\_pbias» | «plan02\_gage02\_flow\_pbias\_eval» | «plan02\_gage03\_flow\_pbias» | «plan02\_gage03\_flow\_pbias\_eval» | «plan02\_gage04\_flow\_pbias» | «plan02\_gage04\_flow\_pbias\_eval» |
| Coefficient of Determination | «plan02\_gage01\_flow\_r2» | «plan02\_gage01\_flow\_r2\_eval» | «plan02\_gage02\_flow\_r2» | «plan02\_gage02\_flow\_r2\_eval» | «plan02\_gage03\_flow\_r2» | «plan02\_gage03\_flow\_r2\_eval» | «plan02\_gage04\_flow\_r2» | «plan02\_gage04\_flow\_r2\_eval» |
|  | Stage |  | Stage |  | Stage |  | Stage |  |
| Nash Sutcliffe Efficiency | «plan02\_gage01\_stage\_nse» | «plan02\_gage01\_stage\_nse\_eval» | «plan02\_gage02\_stage\_nse» | «plan02\_gage02\_stage\_nse\_eval» | «plan02\_gage03\_stage\_nse» | «plan02\_gage03\_stage\_nse\_eval» | «plan02\_gage04\_stage\_nse» | «plan02\_gage04\_stage\_nse\_eval» |
| RMSE Standard Deviation Ratio | «plan02\_gage01\_stage\_rsr» | «plan02\_gage01\_stage\_rsr\_eval» | «plan02\_gage02\_stage\_rsr» | «plan02\_gage02\_stage\_rsr\_eval» | «plan02\_gage03\_stage\_rsr» | «plan02\_gage03\_stage\_rsr\_eval» | «plan02\_gage04\_stage\_rsr» | «plan02\_gage04\_stage\_rsr\_eval» |
| Percent Bias | «plan02\_gage01\_stage\_pbias» | «plan02\_gage01\_stage\_pbias\_eval» | «plan02\_gage02\_stage\_pbias» | «plan02\_gage02\_stage\_pbias\_eval» | «plan02\_gage03\_stage\_pbias» | «plan02\_gage03\_stage\_pbias\_eval» | «plan02\_gage04\_stage\_pbias» | «plan02\_gage04\_stage\_pbias\_eval» |
| Coefficient of Determination | «plan02\_gage01\_stage\_r2» | «plan02\_gage01\_stage\_r2\_eval» | «plan02\_gage02\_stage\_r2» | «plan02\_gage02\_stage\_r2\_eval» | «plan02\_gage03\_stage\_r2» | «plan02\_gage03\_stage\_r2\_eval» | «plan02\_gage04\_stage\_r2» | «plan02\_gage04\_stage\_r2\_eval» |

«plan02\_figure\_gage\_Flow»

«plan02\_figure\_gage\_Stage»

«plan02\_figure\_wse\_errors»

«plan02\_figure\_wse\_ttp»

**Table 15.** Plan #3Calibration Results – Statistical Metrics «plan03\_date»

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Gage ID | «plan03\_gage01» | | «plan03\_gage02» | | «plan03\_gage03» | | «plan03\_gage04» | |
| Metric | Flow |  | Flow |  | Flow |  | Flow |  |
| Nash Sutcliffe Efficiency | «plan03\_gage01\_flow\_nse» | «plan03\_gage01\_flow\_nse\_eval» | «plan03\_gage02\_flow\_nse» | «plan03\_gage02\_flow\_nse\_eval» | «plan03\_gage03\_flow\_nse» | «plan03\_gage03\_flow\_nse\_eval» | «plan03\_gage04\_flow\_nse» | «plan03\_gage04\_flow\_nse\_eval» |
| RMSE Standard Deviation Ratio | «plan03\_gage01\_flow\_rsr» | «plan03\_gage01\_flow\_rsr\_eval» | «plan03\_gage02\_flow\_rsr» | «plan03\_gage02\_flow\_rsr\_eval» | «plan03\_gage03\_flow\_rsr» | «plan03\_gage03\_flow\_rsr\_eval» | «plan03\_gage04\_flow\_rsr» | «plan03\_gage04\_flow\_rsr\_eval» |
| Percent Bias | «plan03\_gage01\_flow\_pbias» | «plan03\_gage01\_flow\_pbias\_eval» | «plan03\_gage02\_flow\_pbias» | «plan03\_gage02\_flow\_pbias\_eval» | «plan03\_gage03\_flow\_pbias» | «plan03\_gage03\_flow\_pbias\_eval» | «plan03\_gage04\_flow\_pbias» | «plan03\_gage04\_flow\_pbias\_eval» |
| Coefficient of Determination | «plan03\_gage01\_flow\_r2» | «plan03\_gage01\_flow\_r2\_eval» | «plan03\_gage02\_flow\_r2» | «plan03\_gage02\_flow\_r2\_eval» | «plan03\_gage03\_flow\_r2» | «plan03\_gage03\_flow\_r2\_eval» | «plan03\_gage04\_flow\_r2» | «plan03\_gage04\_flow\_r2\_eval» |
|  | Stage |  | Stage |  | Stage |  | Stage |  |
| Nash Sutcliffe Efficiency | «plan03\_gage01\_stage\_nse» | «plan03\_gage01\_stage\_nse\_eval» | «plan03\_gage02\_stage\_nse» | «plan03\_gage02\_stage\_nse\_eval» | «plan03\_gage03\_stage\_nse» | «plan03\_gage03\_stage\_nse\_eval» | «plan03\_gage04\_stage\_nse» | «plan03\_gage04\_stage\_nse\_eval» |
| RMSE Standard Deviation Ratio | «plan03\_gage01\_stage\_rsr» | «plan03\_gage01\_stage\_rsr\_eval» | «plan03\_gage02\_stage\_rsr» | «plan03\_gage02\_stage\_rsr\_eval» | «plan03\_gage03\_stage\_rsr» | «plan03\_gage03\_stage\_rsr\_eval» | «plan03\_gage04\_stage\_rsr» | «plan03\_gage04\_stage\_rsr\_eval» |
| Percent Bias | «plan03\_gage01\_stage\_pbias» | «plan03\_gage01\_stage\_pbias\_eval» | «plan03\_gage02\_stage\_pbias» | «plan03\_gage02\_stage\_pbias\_eval» | «plan03\_gage03\_stage\_pbias» | «plan03\_gage03\_stage\_pbias\_eval» | «plan03\_gage04\_stage\_pbias» | «plan03\_gage04\_stage\_pbias\_eval» |
| Coefficient of Determination | «plan03\_gage01\_stage\_r2» | «plan03\_gage01\_stage\_r2\_eval» | «plan03\_gage02\_stage\_r2» | «plan03\_gage02\_stage\_r2\_eval» | «plan03\_gage03\_stage\_r2» | «plan03\_gage03\_stage\_r2\_eval» | «plan03\_gage04\_stage\_r2» | «plan03\_gage04\_stage\_r2\_eval» |

«plan03\_figure\_gage\_Flow»

«plan03\_figure\_gage\_Stage»

«plan03\_figure\_wse\_errors»

«plan03\_figure\_wse\_ttp»

**Table 16**. Plan #4Calibration Results – Statistical Metrics «plan04\_date»

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Gage ID | «plan04\_gage01» | | «plan04\_gage02» | | «plan04\_gage03» | | «plan04\_gage04» | |
| Metric | Flow |  | Flow |  | Flow |  | Flow |  |
| Nash Sutcliffe Efficiency | «plan04\_gage01\_flow\_nse» | «plan04\_gage01\_flow\_nse\_eval» | «plan04\_gage02\_flow\_nse» | «plan04\_gage02\_flow\_nse\_eval» | «plan04\_gage03\_flow\_nse» | «plan04\_gage03\_flow\_nse\_eval» | «plan04\_gage04\_flow\_nse» | «plan04\_gage04\_flow\_nse\_eval» |
| RMSE Standard Deviation Ratio | «plan04\_gage01\_flow\_rsr» | «plan04\_gage01\_flow\_rsr\_eval» | «plan04\_gage02\_flow\_rsr» | «plan04\_gage02\_flow\_rsr\_eval» | «plan04\_gage03\_flow\_rsr» | «plan04\_gage03\_flow\_rsr\_eval» | «plan04\_gage04\_flow\_rsr» | «plan04\_gage04\_flow\_rsr\_eval» |
| Percent Bias | «plan04\_gage01\_flow\_pbias» | «plan04\_gage01\_flow\_pbias\_eval» | «plan04\_gage02\_flow\_pbias» | «plan04\_gage02\_flow\_pbias\_eval» | «plan04\_gage03\_flow\_pbias» | «plan04\_gage03\_flow\_pbias\_eval» | «plan04\_gage04\_flow\_pbias» | «plan04\_gage04\_flow\_pbias\_eval» |
| Coefficient of Determination | «plan04\_gage01\_flow\_r2» | «plan04\_gage01\_flow\_r2\_eval» | «plan04\_gage02\_flow\_r2» | «plan04\_gage02\_flow\_r2\_eval» | «plan04\_gage03\_flow\_r2» | «plan04\_gage03\_flow\_r2\_eval» | «plan04\_gage04\_flow\_r2» | «plan04\_gage04\_flow\_r2\_eval» |
|  | Stage |  | Stage |  | Stage |  | Stage |  |
| Nash Sutcliffe Efficiency | «plan04\_gage01\_stage\_nse» | «plan04\_gage01\_stage\_nse\_eval» | «plan04\_gage02\_stage\_nse» | «plan04\_gage02\_stage\_nse\_eval» | «plan04\_gage03\_stage\_nse» | «plan04\_gage03\_stage\_nse\_eval» | «plan04\_gage04\_stage\_nse» | «plan04\_gage04\_stage\_nse\_eval» |
| RMSE Standard Deviation Ratio | «plan04\_gage01\_stage\_rsr» | «plan04\_gage01\_stage\_rsr\_eval» | «plan04\_gage02\_stage\_rsr» | «plan04\_gage02\_stage\_rsr\_eval» | «plan04\_gage03\_stage\_rsr» | «plan04\_gage03\_stage\_rsr\_eval» | «plan04\_gage04\_stage\_rsr» | «plan04\_gage04\_stage\_rsr\_eval» |
| Percent Bias | «plan04\_gage01\_stage\_pbias» | «plan04\_gage01\_stage\_pbias\_eval» | «plan04\_gage02\_stage\_pbias» | «plan04\_gage02\_stage\_pbias\_eval» | «plan04\_gage03\_stage\_pbias» | «plan04\_gage03\_stage\_pbias\_eval» | «plan04\_gage04\_stage\_pbias» | «plan04\_gage04\_stage\_pbias\_eval» |
| Coefficient of Determination | «plan04\_gage01\_stage\_r2» | «plan04\_gage01\_stage\_r2\_eval» | «plan04\_gage02\_stage\_r2» | «plan04\_gage02\_stage\_r2\_eval» | «plan04\_gage03\_stage\_r2» | «plan04\_gage03\_stage\_r2\_eval» | «plan04\_gage04\_stage\_r2» | «plan04\_gage04\_stage\_r2\_eval» |

«plan04\_figure\_gage\_Flow»

«plan04\_figure\_gage\_Stage»

«plan04\_figure\_wse\_errors»

«plan04\_figure\_wse\_ttp»

**Table 17**. Plan #5Calibration Results – Statistical Metrics «plan05\_date»

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Gage ID | «plan05\_gage01» | | «plan05\_gage02» | | «plan05\_gage03» | | «plan05\_gage04» | |
| Metric | Flow |  | Flow |  | Flow |  | Flow |  |
| Nash Sutcliffe Efficiency | «plan05\_gage01\_flow\_nse» | «plan05\_gage01\_flow\_nse\_eval» | «plan05\_gage02\_flow\_nse» | «plan05\_gage02\_flow\_nse\_eval» | «plan05\_gage03\_flow\_nse» | «plan05\_gage03\_flow\_nse\_eval» | «plan05\_gage04\_flow\_nse» | «plan05\_gage04\_flow\_nse\_eval» |
| RMSE Standard Deviation Ratio | «plan05\_gage01\_flow\_rsr» | «plan05\_gage01\_flow\_rsr\_eval» | «plan05\_gage02\_flow\_rsr» | «plan05\_gage02\_flow\_rsr\_eval» | «plan05\_gage03\_flow\_rsr» | «plan05\_gage03\_flow\_rsr\_eval» | «plan05\_gage04\_flow\_rsr» | «plan05\_gage04\_flow\_rsr\_eval» |
| Percent Bias | «plan05\_gage01\_flow\_pbias» | «plan05\_gage01\_flow\_pbias\_eval» | «plan05\_gage02\_flow\_pbias» | «plan05\_gage02\_flow\_pbias\_eval» | «plan05\_gage03\_flow\_pbias» | «plan05\_gage03\_flow\_pbias\_eval» | «plan05\_gage04\_flow\_pbias» | «plan05\_gage04\_flow\_pbias\_eval» |
| Coefficient of Determination | «plan05\_gage01\_flow\_r2» | «plan05\_gage01\_flow\_r2\_eval» | «plan05\_gage02\_flow\_r2» | «plan05\_gage02\_flow\_r2\_eval» | «plan05\_gage03\_flow\_r2» | «plan05\_gage03\_flow\_r2\_eval» | «plan05\_gage04\_flow\_r2» | «plan05\_gage04\_flow\_r2\_eval» |
|  | Stage |  | Stage |  | Stage |  | Stage |  |
| Nash Sutcliffe Efficiency | «plan05\_gage01\_stage\_nse» | «plan05\_gage01\_stage\_nse\_eval» | «plan05\_gage02\_stage\_nse» | «plan05\_gage02\_stage\_nse\_eval» | «plan05\_gage03\_stage\_nse» | «plan05\_gage03\_stage\_nse\_eval» | «plan05\_gage04\_stage\_nse» | «plan05\_gage04\_stage\_nse\_eval» |
| RMSE Standard Deviation Ratio | «plan05\_gage01\_stage\_rsr» | «plan05\_gage01\_stage\_rsr\_eval» | «plan05\_gage02\_stage\_rsr» | «plan05\_gage02\_stage\_rsr\_eval» | «plan05\_gage03\_stage\_rsr» | «plan05\_gage03\_stage\_rsr\_eval» | «plan05\_gage04\_stage\_rsr» | «plan05\_gage04\_stage\_rsr\_eval» |
| Percent Bias | «plan05\_gage01\_stage\_pbias» | «plan05\_gage01\_stage\_pbias\_eval» | «plan05\_gage02\_stage\_pbias» | «plan05\_gage02\_stage\_pbias\_eval» | «plan05\_gage03\_stage\_pbias» | «plan05\_gage03\_stage\_pbias\_eval» | «plan05\_gage04\_stage\_pbias» | «plan05\_gage04\_stage\_pbias\_eval» |
| Coefficient of Determination | «plan05\_gage01\_stage\_r2» | «plan05\_gage01\_stage\_r2\_eval» | «plan05\_gage02\_stage\_r2» | «plan05\_gage02\_stage\_r2\_eval» | «plan05\_gage03\_stage\_r2» | «plan05\_gage03\_stage\_r2\_eval» | «plan05\_gage04\_stage\_r2» | «plan05\_gage04\_stage\_r2\_eval» |

«plan05\_figure\_gage\_Flow»

«plan05\_figure\_gage\_Stage»

«plan05\_figure\_wse\_errors»

«plan05\_figure\_wse\_ttp»

Table 18. Plan #6 Calibration Results – Statistical Metrics «plan06\_date»

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Gage ID | «plan06\_gage01» | | «plan06\_gage02» | | «plan06\_gage03» | | «plan06\_gage04» | |
| Metric | Flow |  | Flow |  | Flow |  | Flow |  |
| Nash Sutcliffe Efficiency | «plan06\_gage01\_flow\_nse» | «plan06\_gage01\_flow\_nse\_eval» | «plan06\_gage02\_flow\_nse» | «plan06\_gage02\_flow\_nse\_eval» | «plan06\_gage03\_flow\_nse» | «plan06\_gage03\_flow\_nse\_eval» | «plan06\_gage04\_flow\_nse» | «plan06\_gage04\_flow\_nse\_eval» |
| RMSE Standard Deviation Ratio | «plan06\_gage01\_flow\_rsr» | «plan06\_gage01\_flow\_rsr\_eval» | «plan06\_gage02\_flow\_rsr» | «plan06\_gage02\_flow\_rsr\_eval» | «plan06\_gage03\_flow\_rsr» | «plan06\_gage03\_flow\_rsr\_eval» | «plan06\_gage04\_flow\_rsr» | «plan06\_gage04\_flow\_rsr\_eval» |
| Percent Bias | «plan06\_gage01\_flow\_pbias» | «plan06\_gage01\_flow\_pbias\_eval» | «plan06\_gage02\_flow\_pbias» | «plan06\_gage02\_flow\_pbias\_eval» | «plan06\_gage03\_flow\_pbias» | «plan06\_gage03\_flow\_pbias\_eval» | «plan06\_gage04\_flow\_pbias» | «plan06\_gage04\_flow\_pbias\_eval» |
| Coefficient of Determination | «plan06\_gage01\_flow\_r2» | «plan06\_gage01\_flow\_r2\_eval» | «plan06\_gage02\_flow\_r2» | «plan06\_gage02\_flow\_r2\_eval» | «plan06\_gage03\_flow\_r2» | «plan06\_gage03\_flow\_r2\_eval» | «plan06\_gage04\_flow\_r2» | «plan06\_gage04\_flow\_r2\_eval» |
|  | Stage |  | Stage |  | Stage |  | Stage |  |
| Nash Sutcliffe Efficiency | «plan06\_gage01\_stage\_nse» | «plan06\_gage01\_stage\_nse\_eval» | «plan06\_gage02\_stage\_nse» | «plan06\_gage02\_stage\_nse\_eval» | «plan06\_gage03\_stage\_nse» | «plan06\_gage03\_stage\_nse\_eval» | «plan06\_gage04\_stage\_nse» | «plan06\_gage04\_stage\_nse\_eval» |
| RMSE Standard Deviation Ratio | «plan06\_gage01\_stage\_rsr» | «plan06\_gage01\_stage\_rsr\_eval» | «plan06\_gage02\_stage\_rsr» | «plan06\_gage02\_stage\_rsr\_eval» | «plan06\_gage03\_stage\_rsr» | «plan06\_gage03\_stage\_rsr\_eval» | «plan06\_gage04\_stage\_rsr» | «plan06\_gage04\_stage\_rsr\_eval» |
| Percent Bias | «plan06\_gage01\_stage\_pbias» | «plan06\_gage01\_stage\_pbias\_eval» | «plan06\_gage02\_stage\_pbias» | «plan06\_gage02\_stage\_pbias\_eval» | «plan06\_gage03\_stage\_pbias» | «plan06\_gage03\_stage\_pbias\_eval» | «plan06\_gage04\_stage\_pbias» | «plan06\_gage04\_stage\_pbias\_eval» |
| Coefficient of Determination | «plan06\_gage01\_stage\_r2» | «plan06\_gage01\_stage\_r2\_eval» | «plan06\_gage02\_stage\_r2» | «plan06\_gage02\_stage\_r2\_eval» | «plan06\_gage03\_stage\_r2» | «plan06\_gage03\_stage\_r2\_eval» | «plan06\_gage04\_stage\_r2» | «plan06\_gage04\_stage\_r2\_eval» |

«plan06\_figure\_gage\_Flow»

«plan06\_figure\_gage\_Stage»

«plan06\_figure\_wse\_errors»

«plan06\_figure\_wse\_ttp»