Appendix A

1.0 Hydrologic Modeling Research, Review, and Limited Verification

1.1 Limited Review of Hydrologic Model

The hydrologic model for project area was created by the U.S. Army Corps of Engineers (USACE) in the Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS) version 4.1. The Truckee River Flood Management Authority (TRFMA) adapted the model for a downstream impact analysis. The 100-year peak flow was used as the basis of analysis and design. The times series outflow at Junction C11, which has the highest peak flow and volume, was used as the inflow boundary condition in the hydraulic model. A validation study was preformed to confirm the flow rate of the hydrologic model.

1.1.1 Existing Model Configuration

The existing hydrologic model configuration includes 11 subbasins. The minimum subbasin area is 0.14 square miles while the maximum subbasin area is 0.35 square miles. The total area is 98.29 square miles. In the model, all the basins use initial and constant loss method, user specified unit hydrograph, and recession baseflow method. The user specified unit hydrograph appears to vary for each basin and, specifically, the unit hydrograph for subbasin 11 and subbasin 16 are significantly lower than all other basins. The initial loss, constant rate and impervious parameters are constant for all basins. The five percent impervious area determined seems reasonable, but the model does not account for that five percent of area in losses. Furthermore, the constant rate loss of 0.1 in/hour is run through the simulation with no initial losses. The baseflow method parameters are held constant for all basins.

In the model, the Muskingum equation is assigned to the four reaches established. The loss method is ignored for reasons stated previously. The HEC-HMS manual defines the Muskingum equation, where X is the discharge weight factor and K is the travel time of the flood wave through the reach. The parameters assigned to the reaches include X as 0.35, minimum K as 0.550 hours, and maximum K as 0.806 hours.

When X equals zero, storage and outflow are considered highly correlated (greater attenuation), and when equal to 0.5, there is equal weight given to inflow and outflow (little to no attenuation). Channels with mild slopes and overbank flows are consider X equal to zero, while steeper streams with well-defined channels, that do not have flow going out of banks, are closer to X=0.5. Setting X in the middle of these two values is a reasonable assumption for the project area.

The four reaches determined in the model are as follows:

- Reach from basin to junction at two locations;
- Reach from C16 to C21; and
- Reach from C21 to C11.

The five junctions established in the model are as follows:

- Two basins and one reach to C30;
- Two basins and one reach to C25;

- Three basins to C16 which is immediately downstream of C30 and C25;
- One basin to C21; and
- Three basins to C11.

The Meteorologic Model in HEC-HMS uses a specified hyetograph for each basin using single record Hydrologic Engineering Center's Data Storage System (HEC-DSS) in increments of one hour. It appears to be a 24-hour storm with simulation time of three days. The specified hyetograph for each basin occurs to be the same shape and scaled for each basin.

1.1.2 Limited Hydrology Validation Study

A simplified hydrologic model was created for the watershed using WMS version 11.1. The model used a single outlet point near the project area, corresponding to a single basin for the full watershed. Other selections in the model are as follows:

- Loss Method: SCS CN = 75;
- Total Basin Area= 63,115.48 acres;
- Transform Method: SCS Dimensionless;
- 100-year, 24-hour precipitation depth = 3.12 in; and
- Type II, 24-hour distribution of rainfall.

Peak flow computed from the simplified model for the 100-year, 24-hour storm was equal to 8,980.27 cubic feet per second (cfs), approximately 103 cfs less than the peak flow computed in the provided hydrologic model. The limited basis of this validation study should be noted when comparing the volume of the storm. The validation model results showed a storm volume equal to approximately 5,500 acre-feet (AF), while the provided model results in approximately 7,900 AF.

The ten square mile cloudburst (high-intense 3 hour rainfall) centered upstream of the LVC outlet was modeled with a 1% chance event having a peak flow of 1,700 cfs. The cloudburst was used to model a depth area reduction map of the subbasins, and a HEC-1 Model subbasin map shown in Figure 1-1. The hydrology report states the 1% flow will stay within the channel and the depth reduction factors vary by subbasin. The highest value was .94 for #C25 and the lowest was .788 for #C11.

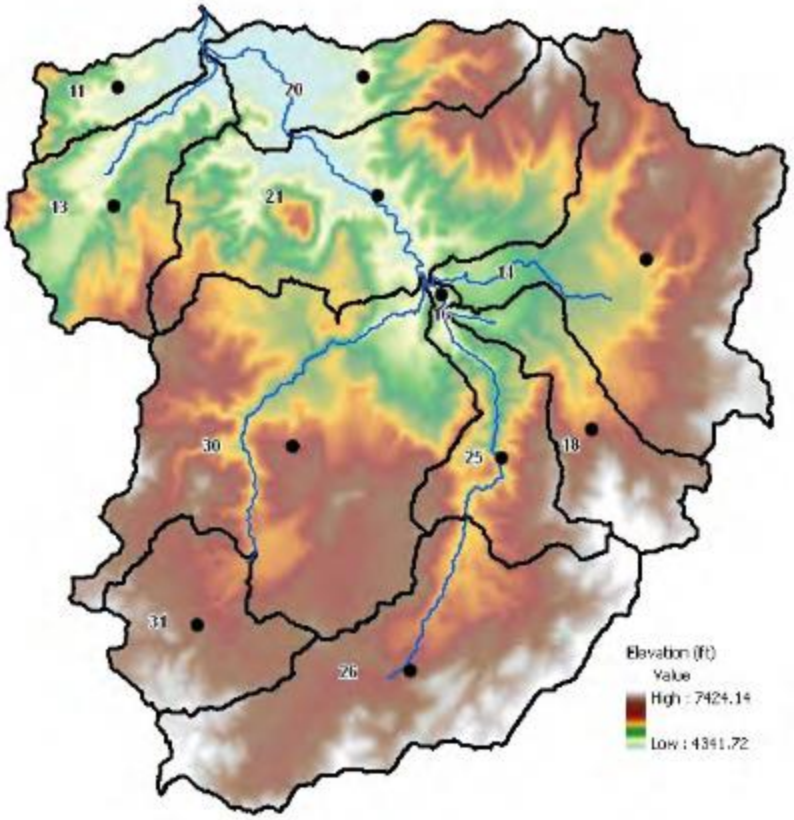

Figure 1-1- Long Valley Creek HEC-1 Model Subbasin Map

1.2 Long Valley Creek and Lockwood Hydrology Documentation Review

The hydrologic analyses for LVC and Lockwood were documented in a hydrologic analysis. The review of the HEC-2 model and analyses were used to supplement the updated model and compare findings.

1.2.1 Long Valley Creek Peak Flow Frequency Curve

The LVC peak flow frequency curve was generated by the USACE. Without daily or hourly flow records the graph is based off instantaneous peak stage during a storm. The peak flow values are from the United States Geological Survey Station #10350100. To fill in the gaps for the gage record, the precipitation gage at Virginia City was used. The rainfall levels were plotted, and a polynomial equation was used to approximate the peak flow of LVC. The positions were adjusted for the 1986 historic flood. The following are attributes in the HEC-2 model:

- Drainage Area= 82.6 sq. mi.
- R squared value of .8636
- The regression line is fitted through the upper values

- The peak flow is modeled at subbasin #C21 gage site

1.2.2 FIS Model Descriptions

J-U-B requested data and models relevant to the current FEMA Flood Information Study (FIS), and received several documents and files. **Table 1-1** summarizes the documents J-U-B has received.

Table 1-1 - FIS Data and Models Received

Study Title	Author	Date of Study
Hydrologic and Hydraulic Analyses by USACE	USACE	Date Unknown
Hydrologic Analysis for Rainbow Bend	Unknown	1986
Preliminary Flood Insurance Study	FEMA	March 1991?
Limited Map Maintenance Program Verification Documentation by Baker Engineers	Baker Engineers	11/1990 - 1/1991
Hydrology Update Report for Rainbow Bend	Summit Engineering Corporation	September 1991
Appeal to the Preliminary Flood Insurance Study for Long Valley Creek	Nimbus Engineers	June 1992
HEC-2 Input/Output Model Files	Varies	1990, 1992, 2006, 2009

1.2.3 FIS Hydrologic Study Documentation

The documents received provide information on hydrologic analyses conducted for the City of Lockwood in Storey County, Nevada, particularly for the development of the Rainbow Bend residential community. The Hydrologic Analysis for Rainbow Bend, Hydrology Update Report for Rainbow Bend, and Appeal to the Preliminary Flood Insurance Study for Long Valley Creek were prepared for Capriotti Construction Company, the apparent developers of the Rainbow Bend community. The purpose of these studies are to support the drainage infrastructure and provide justification for eliminating the requirement for flood insurance in this community.

The Hydrologic Analysis for Rainbow Bend describes flooding sources, including the Truckee River, LVC, and local runoff; and provides a description of the analysis of LVC, which was conducted using a soil conservation service (SCS). The report determines the 100-year storm peak flow as 6,424 cfs.

The preliminary FIS by FEMA provides the 100-year storm flow as 10,000 cfs. This peak flow value is comparable with documentation from USACE, which recommends a peak flow rate of 10,000 cfs, and agrees with subsequent FISs.

The Hydrology Update Report for the Rainbow Bend community by Summit Engineering Corporation (Summit) defines and discusses the discrepancies that exist between the FEMA report and the Summit Report, which differ by the 100-year storm flow calculated for LVC and the capacity of the constructed channel thorough the project. The report recommends modifying the channel to increase capacity and reduce flood insurance requirements.

The 1992 appeal to the preliminary FIS by Nimbus Engineers disputes the capacity of LVC as given in the FIS, and recommends reductions to the expected inundated depth within the SFHAs, but does not recommend changes to the 100-year inundation boundaries.

1.2.4 HEC-2 Model

The HEC-2 model was created by the USACE for the project area which analyzed the water surface profiles for steady gradually varied flow in LVC. The commutation, which uses the one-dimensional energy equation with energy loss due to friction supplemented with Manning's equation, is known as the standard step method. The flow assumption used in the model was 10,000 cfs which is comparable to a 100-year flood event in Lockwood. The N value determines the roughness of the channel in Manning's equation, but no recorded value was found for this iteration.

2.0 Hydraulic Modeling Methodology

Hydraulic modeling of the lower reach of LVC and its confluence with the Truckee River was completed using two-dimensional (2D) computations in HEC-RAS version 6.3.1. The previous model was created by DEC/J-U-B in 2020 using HEC-RAS version 5.0.7, which relied on a combination of rating curves and culverts to approximate bridge openings (JUB, 2020). Full documentation of the previous model is included in Appendix A. The existing conditions model was updated including improved representation of each bridge with 2D bridge structures possible in the newer HEC-RAS versions. The following section documents the creation of the updated existing conditions model.

2.1.1 Modeled Flow Scenarios

The 100-yr flood (one-percent annual chance exceedance flood) in LVC was the primary flood event used for updating the existing conditions model and modeling flood mitigation alternative designs. The 50-year flood (two-percent annual chance exceedance flood) was modeled for reference of existing conditions and performance of mitigation alternative designs during a smaller flood event. Peak flows during the 50-year and 100-year events are 6,180 cfs and 9,083 cfs respectively. The flow hydrographs are shown in Figure 2-1.

The 50-year and 100-year hydrographs from the previous model were retained in the updated model. Minor updates to the flow data include updating the specified EG slope for distributing flow along the boundary condition line for the two upstream inflow boundary conditions.

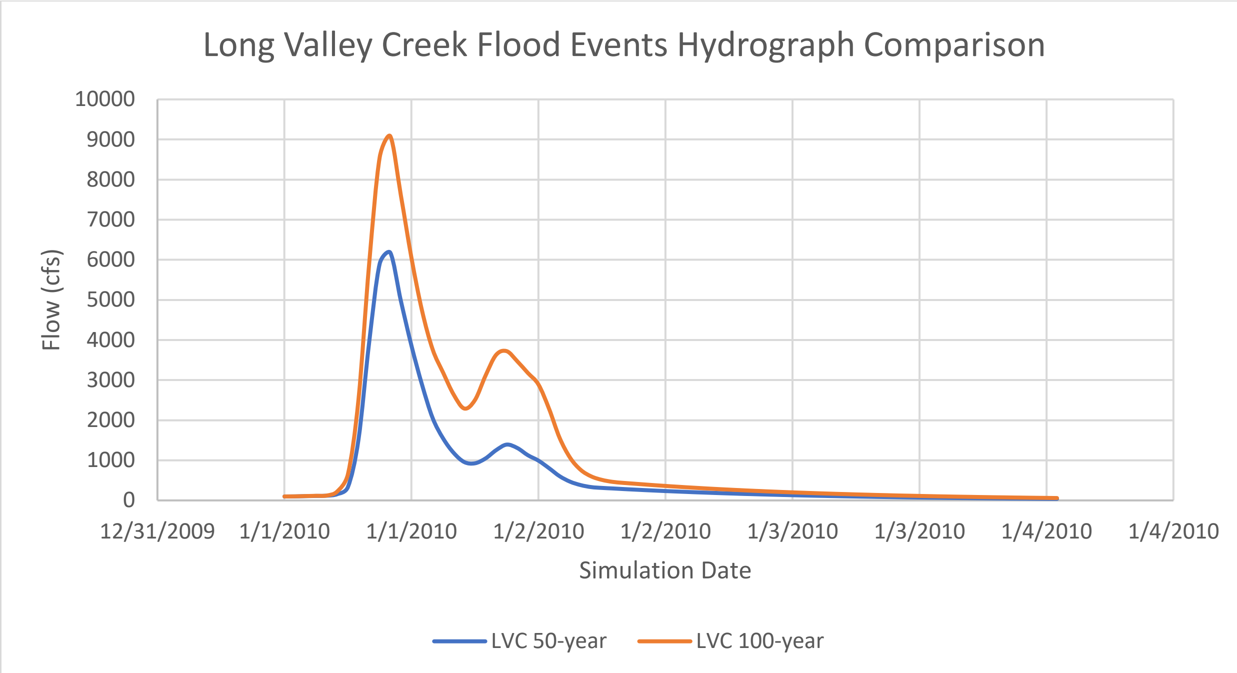

Figure 2-1 – Long Valley Creek 50-year and 100-year Flow Hydrographs

LVC converges with the Truckee River and was included in the HEC-RAS model. The normal depth downstream boundary categorized the friction slope for all events as 0.003, which was obtained from the HEC-RAS terrain. The Truckee River flow hydrograph vary for each flood event as follows:

- 10 year at 1600 cfs
- 25 year at 2975 cfs
- 50 year at 4000 cfs
- 100 year at 4000 cfs

2.2 Existing Conditions Model Updates

Updates to existing conditions from the previous model include updates to model terrain, and many elements of model geometry, most notably the bridge objects. Other relevant updates include increasing the resolution of modeled roughness, extension of boundary condition lines, and refinements to the 2D mesh.

2.2.1 Terrain

The previous model terrain was reviewed to determine the necessity of updating the terrain, primarily to remove homes represented in terrain and instead model structures as elevated n-values. The existing model terrain used in the previous model was retained for use in creating updated models due to the quality of terrain and decision to retain the previous modeling methodology for structures.

Model terrain in the vicinity of CDC Bridge and ADLC Bridge was modified in RAS Mapper with the terrain modifications feature to more accurately represent bridge abutments, wing walls, and other channel characteristics upstream, downstream, and through the opening of each bridge. The model terrain had poor representation of existing conditions at these bridge locations. The update to 2D bridge structures for all bridges relies on the model terrain for channel geometry in the vicinity of the bridge, making updates to terrain at these bridge locations critical. Images of pre- and post-modified model terrain is included in **Figure 2-2** and **Figure 2-3** for CDC and ADLC Bridges respectively.

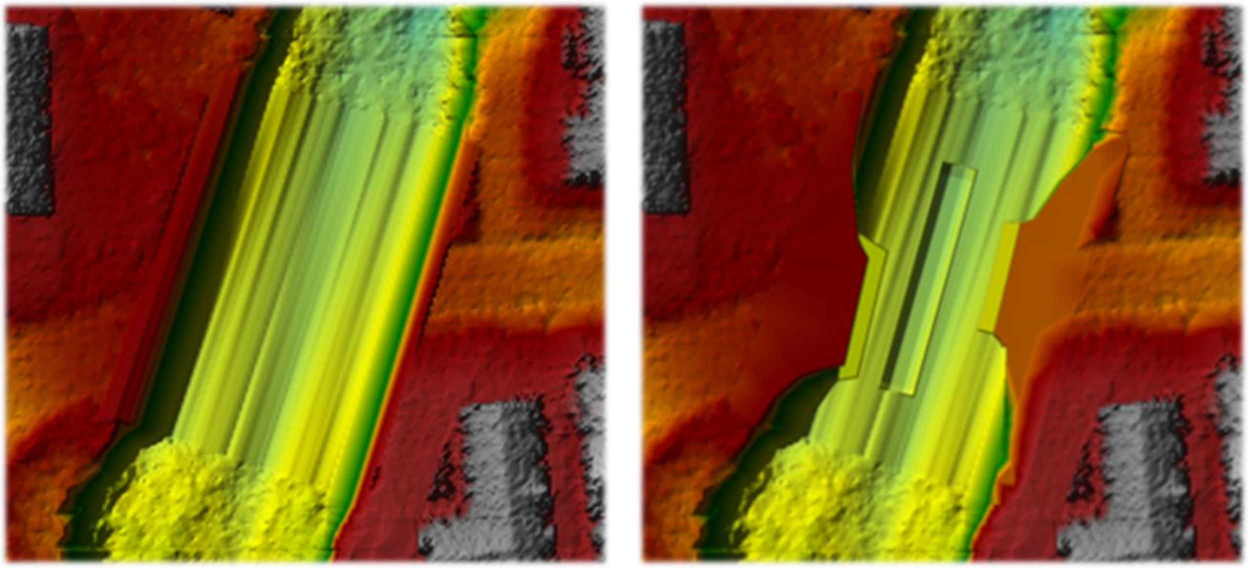

Figure 2-2 - Cercle De La Cerese Bridge Pre- (Left) and Post- (Right) Terrain Modification

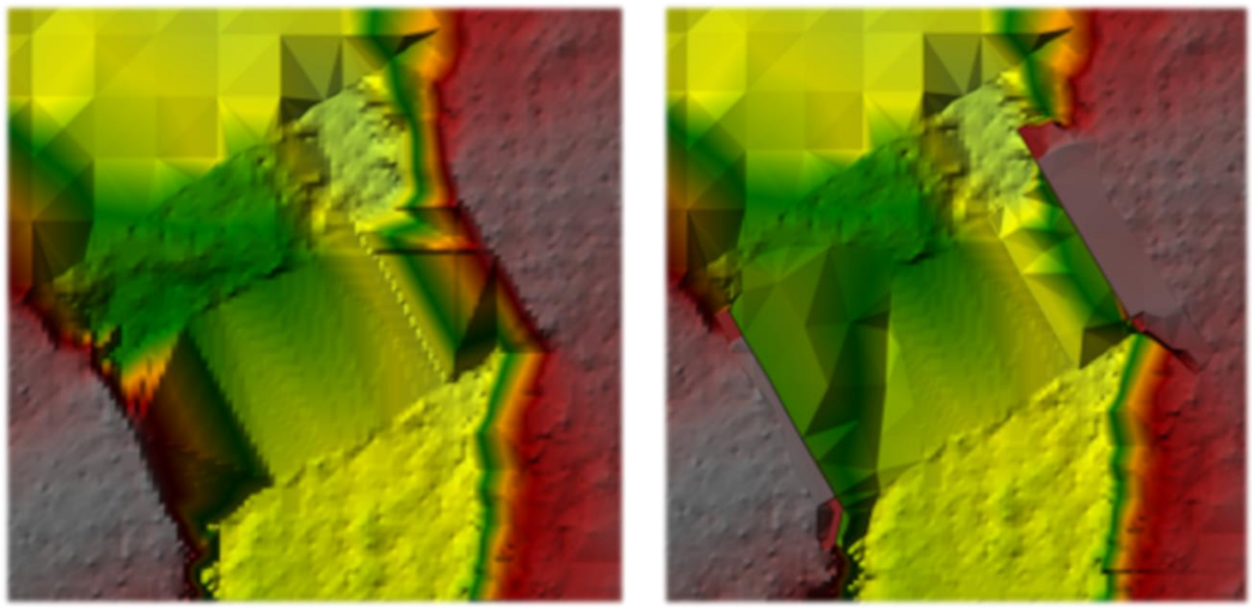

Figure 2-3 – Avenue De La Couleurs Bridge Pre- (Left) and Post- (Right) Terrain Modification

2.2.2 Geometry

The 2D model geometry was adapted from the previous model. Geometry updates are detailed in the remainder of this section.

2.2.2.1 2D Flow Area

The default cell size for the 2D area was reduced from 40-ft x 40-ft to 25-ft x 25-ft to better represent flow around structures. All breaklines in the model were adjusted to represent terrain and conveyance of water more accurately along the channel overbanks. Mesh arrangement along breaklines was iteratively adjusted to improved cell orientation and reduce instances of irregular cell shapes and abrupt transitions in cell size.

2.2.2.2 Boundary Conditions

The boundary condition lines were updated including the upstream inflow boundary conditions for the Truckee River and LVC and the downstream normal depth boundary condition. Boundary condition lines were extended to better capture the full width of flow during the model simulation.

2.2.2.3 N-Values

The model uses the same n-value delineation as the previous model, with the addition of 2D area manning's n refinement regions along the full length of LVC to represent boulder fields and larger riprap. Representation of roughness in the channel was updated to include n-values ranging from 0.05 to 0.06 in addition to the base channel n-value equal to 0.035. The neighborhood roads are represented by a value of 0.02.

2.2.2.4 2D Bridge Structures

The previous model's representation of bridges relied on rating curves and culverts which were replaced with 2D bridge structure connections in the updated existing conditions model. Previously implemented bridge coordinates representing the low chord and high chord within the bridge abutments were adjusted in excel to be approximately spatially accurate when applied to structure centerlines. Bridge slope, which was previously omitted, was approximated based on the model terrain and field photos and applied accordingly while adjusting bridge coordinates. Bridge geometry outside of the abutments was extended to tie into adjacent terrain on the overbanks. Bridge geometry was iteratively adjusted with intent to balance reasonable tie in of the bridge deck with adjacent terrain and best approximate the height of the bridge opening. The bridge

The CDC Bridge was modeled with the structure centerline parallel to the road alignment and with the structure centerline perpendicular to flow to tests the effect of the structure centerline alignment on flow conveyance. The sensitivity test indicated that the model with the structure centerline parallel to the road (not perpendicular to flow) had routed approximately 9% more flow through the bridge, approximately proportional to the additional opening length when using a structure centerline not perpendicular to flow. The structure centerline perpendicular to flow was retained for the updated existing conditions model. Terrain modifications were completed at this bridge to facilitate the specification of more accurate bridge opening geometry in the channel, which included the left and right abutments, concrete benches, and the concrete low flow channel.

The ADLC bridge was modeled both with the bridge low chord and the pipe invert as the low chord to evaluate the effect of the pipe obstructing flow. Minor increases in inundation were observed due to the reduced flow area and were therefore retained in the updated existing conditions model. Terrain modifications were completed at this bridge to better approximate channel geometry through the bridge, upstream and downstream concrete wingwalls, and bridge span from abutment to abutment.

The high chord for each of the five bridges was sensitivity tested with representation as the bridge deck and a fully obstructed guard separately. The final model setup uses the bridge deck as the high chord elevation for each bridge with a relatively low weir coefficient equal to 2.2. Other selections used in setting up each 2D bridge structure include:

- Pressure and/or Weir for High Flow Method
- Energy and Momentum Low Flow Method
- Horizontally varied n-values for each of the four bridge cross sections for all bridges
- Bridge ineffective regions

2.2.3 Unsteady Computation Options and Tolerances

Updates to the unsteady flow computation options and tolerances include the following:

- Reduction of computation interval from 1 second to 0.5 seconds.

- Addition of 12 hours of initial conditions time with a ramp up fraction equal to 0.25
- Switch from diffusion wave to full momentum (SWE-ELM) 2D equation set.
- Mapping output interval from 10 to 5 minutes

Model run time from the previous to updated model stayed the same at approximately two hours despite the reduced cell size, reduced computation interval, and updated equation set.

3.0 Limitations

- The hydrologic and hydraulic models used in this analysis were created based on land use and hydrologic soil group conditions at the time of the study, of which land use is especially prone to change over time. Since the model is based on these parameters, it is critical to update the model over time to reflect up-to-date conditions. The model is considered sufficiently accurate based on the current data available and for its intended purpose on the date this report was submitted.
- The nearest flow gages were along the Truckee River at Vista and Tracy. There are no active monitoring locations along LVC.