This report explains why the Mouse River hydrologic and hydraulic models were developed, what the models simulate, and how a levee-floodwall project in urban areas would affect other parts of the Mouse River Valley.

Hydrologic modeling

Hydrologic models simulate the conversion of rainfall and/or snowmelt into surface runoff. Hydrologic model results include inflow hydrographs (Figure 1) that define inflow to a stream or river at a given location. These inflow hydrographs are used as inputs to the hydraulic model.

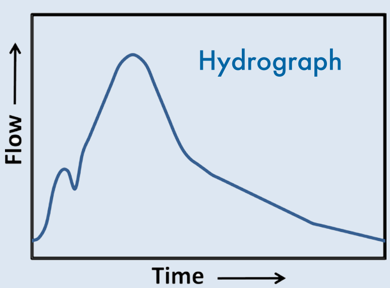

Figure 1: A hydrograph is a plot showing discharge versus time at a specific point in a river.

Hydraulic modeling

Hydraulic models simulate how the natural characteristics of a river system (e.g., topography and vegetation) and infrastructure (e.g., bridges and dams) affect the movement of water through a valley. Hydraulic model results provide water surface elevations that can be used to map inundation areas for a particular flood event.

The 2011 flood caused significant damage to public infrastructure, private property, and agricultural areas throughout the Mouse River Valley.

Study background

The record-breaking Mouse River flood of June 2011 caused hundreds of millions of dollars of damage in North Dakota. There was extensive damage to public and private infrastructure in urban areas, while the summer-long inundation in rural areas took agricultural lands out of production and caused significant damage to private farmsteads.

In the aftermath of the 2011 flood, residents and local officials requested the investigation of flood mitigation solutions that will reduce the risk of flood damages. The North Dakota State Water Commission (NDSWC) retained a consulting team led by Barr Engineering Co. to develop a Mouse River Enhanced Flood Protection Plan to address flooding issues throughout the Mouse River Valley. The first study completed for the plan was the *Preliminary Engineering Report* in February 2012, which defined flood risk reduction measures for urban areas along the Mouse River between Burlington and Velva as well as for Mouse River Park.

In June 2012, the NDSWC initiated three subsequent studies as part of the Mouse River Enhanced Flood Protection Plan; these focus on the full Mouse River Valley in North Dakota. For this study, Mouse River Valley and Mouse River watershed (Figure 2) refer to the North Dakota portion of the larger Souris River Basin.

The new studies were: (1) an initial assessment of erosion and sedimentation issues, which was completed in January 2013; (2) this hydrologic and hydraulic modeling report; (3) an evaluation of alternatives to reduce flood impacts in rural areas, which was completed concurrently with this report.

Study purpose

This study documents the development of hydrologic and hydraulic models for evaluating floodplain management alternatives in the Mouse River Valley. The immediate objective for these tools was to evaluate the effects of the levee-floodwall Project defined in the *Preliminary Engineering Report* (Figure 3) on areas upstream of Burlington and downstream of Velva. The long-term objective for the modeling effort was to provide baseline models for advancing the Mouse River Enhanced Flood

Protection Plan. To achieve the study objectives the engineering team developed:

(1) A hydrologic model to simulate runoff from ungaged portions of the Mouse River watershed for use in the hydraulic model.

(2) A baseline hydraulic model simulating the movement of water through the Mouse River Valley for existing conditions.

(3) A second hydraulic model representing future conditions after construction of the levee-floodwall Project defined in the *Preliminary Engineering Report*.

Model development

The Mouse River has a large and complex watershed (Figure 2). The area draining to the North Dakota reach of the Mouse River is roughly 8,000-square miles. The Mouse River channel through North Dakota is over 300 miles long and passes through 11 dams and more than 90 bridges. Historic stream flow data from U.S. Geological Survey (USGS) gaging stations was used to quantify surface runoff during past flood events. USGS gaging station data was available for the Mouse River and its four major tributaries (Des Lacs River, Wintering River, Deep River, and Willow Creek). However, many of the smaller coulees and creeks in the watershed are ungaged.

The engineering team conducted a four-day field investigation to document floodplain characteristics and verify collected data for bridges in the study area.

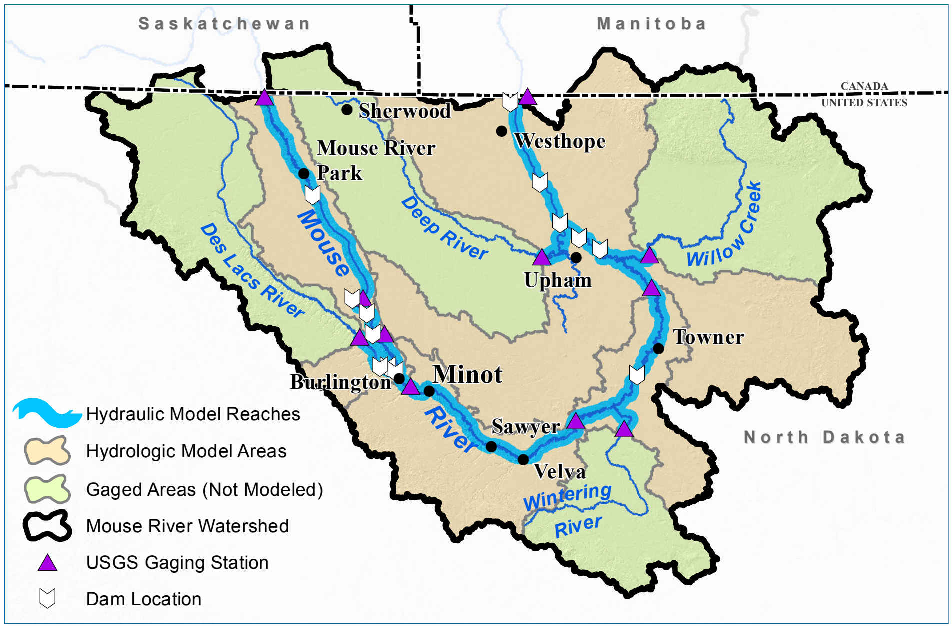

Figure 2: The hydrologic model calculated runoff from ungaged areas of the Mouse River watershed, and the hydraulic model simulated flow in the Mouse River and portions of its four major tributaries.

A hydrologic model was developed to simulate the timing and quantity of runoff from ungaged portions of the Mouse River watershed (Figure 2) for selected historic storm events. Every storm event is a unique combination of factors related to precipitation, temperature, topography, land cover, and soil properties. Simulating runoff from the Mouse River watershed was complicated by a topography characterized by prairie potholes, which reduce the effective area that contributes runoff to the river system during a given storm event. The hydrologic model calculated inflow hydrographs that were inputs for modeling floodplain hydraulics.

Previously developed hydraulic models of the Mouse River Valley were incapable of simulating the complexities of such a large natural system to the degree necessary to advance the Mouse River Enhanced Flood Protection Plan. The previous hydraulic models were steady-state simulations. More sophisticated unsteady flow modeling methods were necessary to evaluate impacts from the proposed levee-floodwall Project on other parts of the Mouse River Valley (steady-state vs. unsteady flow).

Steady-state vs. unsteady flow

Steady-state modeling creates a snapshot of flood conditions for a specific flow, irrespective of time. This modeling approach typically uses a peak flow rate to calculate the maximum water surface elevation for a flood. For example, the hydraulic model for the *Preliminary Engineering Report* was a steady-state model that simulated the design flow rate of 27,400 cfs to establish top-of-levee elevations.

Unsteady flow modeling simulates changes in flow, stage, and velocity over the duration of a flood event. The hydraulic model for this study routes flood hydrographs (Figure 1) through the Mouse River Valley (Figure 2) to represent the effects of dams, bridges, and other restrictions on flows over the course of each simulated flood event. Incorporating a time component significantly increases the complexity of the hydraulic model.

Hydraulic model simulations were developed for the 2009, 2010, and 2011 flood events. These flood events were selected because they: (1) were significant flood events that would be remembered by community stakeholders, (2) had better available climate and stream monitoring data than previous flood events, and (3) represented a wide range of flood magnitudes for both spring and summer flooding. The 2009 flood event was a significant spring flood that resulted in prolonged inundation of agricultural areas. The 2010 flood event was a summer flood that had minimal impact on urban areas, but damaged agricultural areas in McHenry and Bottineau counties. The 2011 flood event is the flood of record and the design flood for the levee-floodwall Project defined in the *Preliminary Engineering Report*.

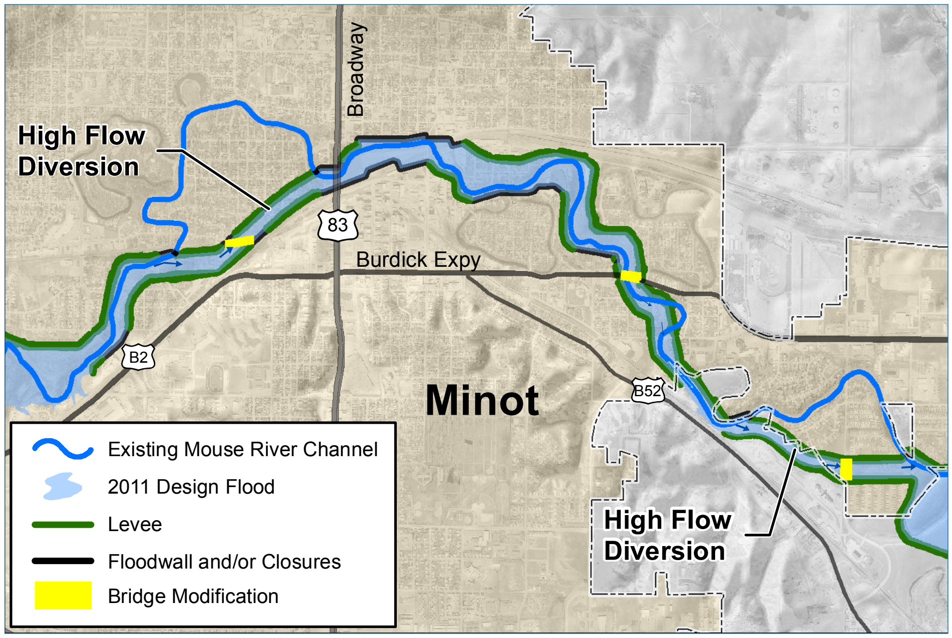

Figure 3: The Project features defined in the Preliminary Engineering Report include levees, floodwalls, channel excavations, channel realignments, bridge modifications, and two high-flow diversion channels in Minot.

Evaluating project impacts

The hydraulic models developed for this study were used to evaluate the effects of the proposed levee-floodwall Project throughout the Mouse River Valley.

With-Project modeled water surface elevations were compared to existing conditions water surface elevations for the three simulated flood events (Figure 4). The proposed Project would impact water surface elevations in the vicinity of the Project features, but would have minimal impact on flood elevations upstream of Burlington and downstream of Velva.

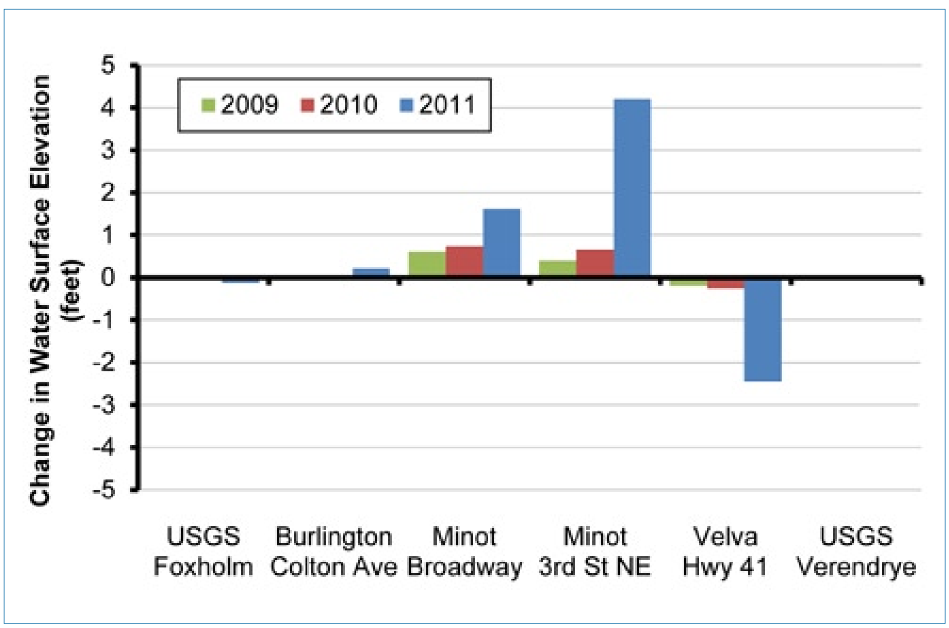

Figure 4: The Project would increase water surface elevations in the vicinity of Minot, but would have minimal impact upstream of Burlington and downstream of Velva.

Application of modeling tools

The hydrologic and hydraulic models are tools that will have broad application for the Mouse River Valley. The hydrologic model provides a framework for future hydrologic simulations for the Mouse River watershed, and the hydraulic models are being used to evaluate alternatives for reducing flood risk in rural areas of the Mouse River Valley.

The models have already been shared with the U.S. Army Corps of Engineers and National Weather Service to assist with flood forecasting during 2013 and in the future.

As the community moves forward with development and implementation of the Mouse River Enhanced Flood Protection Plan, the hydrologic and hydraulic models will be an important resource for evaluating and sizing floodplain management alternatives.