

Section 4

Hydraulic Model Development

4.1 Introduction

This section provides a description of the methodology used to develop the hydraulic model for the Deadmans Run Watershed study. The objective was to produce an accurate hydraulic model for both the floodway and floodplain that reflects the inherent complexities in local topography and provides an effective tool for the City to use while addressing flood issues. The hydraulic model was used to simulate the watershed's primary stream network based on existing land use conditions and estimate water surface elevations for the design storms described in Section 3. The hydraulic modeling was performed using USACE's HEC-RAS Version 3.1.3 steady state option.

The following paragraphs present guidelines for developing the watershed HEC-RAS model and include:

- HEC-RAS model parameters
- Procedures for developing HEC-RAS model parameters and creating the Deadmans Run HEC-RAS model
- Procedures for modeling the Deadmans Run overflow
- Procedures for modeling hydraulic structures
- Procedures for using steady state flow option
- Procedures for defining the floodway
- Procedures and data used for model calibration
- Procedures for technical review and quality control of the hydraulic model
- Procedures for mapping the hydraulic model results
- Procedures for submitting results to FEMA

4.2 HEC-RAS Model Development

HEC-RAS model data requirements can be summarized into nine model parameters. Table 4-1 lists the nine parameters and the methods used to develop the data requirements. As shown in Table 4-1, the model parameters were developed using a combination of manual procedures and automation tools using ARC/INFO, ArcView GIS, and HEC-GeoRAS in conjunction with GIS data.

**Table 4-1
HEC-RAS Parameter Development**

HEC-RAS Model Parameter	Development Method	Data Requirements
Stream network	ArcView GIS	Stream centerline coverage with unique stream reach names
Cross sections (river station and geometry data)	ARC/INFO and HEC-GeoRAS	Triangular irregular network (TIN), cross section cut line coverage
Downstream reach lengths (channel and overbanks)	ARC/INFO and HEC-GeoRAS	Stream centerline and overbank (left and right) flow path coverage
Manning's n-values	ARC/INFO	Mannings n-value assigned using orthophotos and field observations
Roadway crossings	Manual input using field survey data and as-built information	Roadway profile and bridge or culvert opening
Expansion and contraction coefficients	Manual input using standard values and engineering judgment	Contours and cross section cut line coverage
Normal depth boundary conditions	ArcView GIS	Contours, stream centerline, and cross section cut line coverage
Ineffective flow areas	Manual input using standard procedures and engineering judgment	Contours and cross section cut line coverage
Channel bank stations	Manual input using standard procedures and engineering judgment	Cross section geometries (station and elevation data)

The paragraphs below describe the HEC-RAS model development procedures.

4.2.1 Stream Network, Cross Sections, and Reach Lengths

The first step in developing the HEC-RAS model was to create a HEC-RAS geometry file containing the stream network, cross section river stations and geometries, and channel and overbank downstream reach lengths. The stream network defines the extent of the model and can be defined as the main channel extending from "A" Street to the confluence with Salt Creek. Cross section river stations define the location of the cross section along the stream in feet measured from the Salt Creek confluence while cross section geometry includes station and elevation data. Downstream reach lengths define the distance to the next downstream cross section along the stream reach and along the left and right overbanks.

This study used HEC-GeoRAS in conjunction with ArcView GIS to prepare an ASCII text file that is directly imported by HEC-RAS, creating a geospatially referenced HEC-RAS geometry file. HEC-GeoRAS is a free software program developed by USACE HEC.

HEC-GeoRAS uses the following data to create the ASCII text import file:

Triangular Irregular Network

The TIN was created from the Lincoln/Lancaster County LiDAR information (2003) using ARC/INFO. The TIN is a surface representing the ground topography and is used in conjunction with the cross section cut line coverage to develop station and elevation information for cross section geometry data. A ground surface elevation was recorded at each station along the cross section cut line that crosses the TIN edge.

Stream Centerline Coverage

The stream centerline coverage was manually digitized in ArcView GIS to represent the thalweg of the main channel. HEC-GeoRAS requires a river name and reach name be

assigned to each line segment. For the purpose of this study, the river name was assigned “Deadmans Run” and the reach name was assigned “main channel.”

Cross Section Cut Line Coverage

The cross section cut line coverage is a GIS line coverage that identifies the location and extent of each cross section. The cross section cut line coverage was generated in ArcView GIS. Cut lines were placed in the same location as the effective FIS cross sections if the placement was deemed correct. Additional cut lines were located along the stream centerline at points that represent the average geometry of the stream reach and at changes in geometry, slope, channel, overbank roughness, and discharge. Available aerial photographs and contour information were used to lay out the cross section cut lines. The FEMA 500-year floodplain boundary was used as a guide in determining the extent of the cross sections. The average distance between cross sections was approximately 400 feet, with less distance between cross sections in the vicinity of structures and abrupt changes in channel geometry. The cross section cut lines are oriented from left to right looking downstream. Each cross section was identified by the stream name, reach name, and river station. The river station for each cross section is the cumulative distance from the model outfall in feet.

Overbank Flow Path Coverage

The overbank flow path coverage is a GIS line coverage that represents the average left and right overbank flow paths between each cross section. The overbank flow path coverage was used to determine the downstream reach lengths for the left and right overbanks. The FEMA 500-year floodplain boundary and the contour information were used as a guide to locate the overbank flow paths. In general, the overbank flow path was located on each side of the stream halfway between the 500-year floodplain boundary and the channel bank. In areas where the 500-year floodplain is contained within the channel, the location of the overbank flow path was following the top of the channel bank.

4.2.2 Manning’s n-Values

The Manning’s n-values at each cross section were estimated using digital aerial and field photographs. Manning’s n-values are assigned with the purpose to represent land

**Table 4-2
Land Surface Characteristics and
Associated Manning’s n-Values¹**

Land Surface Type	Initial n-Value	Range of n-Value
Grass, urban and maintained	0.030	0.025 to 0.035
Trees and brush	0.090	0.035 to 0.160
Brush	0.060	0.035 to 0.160
Residential areas ²	0.150	0.035 to 10
University of Nebraska East Campus (developed area) ²	0.100	0.035 to 10
Agricultural, Pasture	0.035	0.025 to 0.050
Agricultural, Cultivated Areas	0.040	0.020 to 0.050
Pavement	0.020	0.013 to 0.025
Lake	0.025	0.0160 to 0.033

1. Source: *Open Channel Hydraulics*, Chow 1959.
2. These n-values will be used in developed areas to account for the loss of conveyance caused by buildings.

surface characteristics identified in Table 4-2. The initial n-values were used as a model starting point and were adjusted within the provided ranges during calibration. Horizontally varied Manning’s n-values were input in the HEC-RAS model to capture changes in land use spanning the cross section.

The overbank n-values were increased where buildings are located within the floodplain to account for conveyance loss. The n-values in these areas may range

from 0.030 for areas with few buildings to 0.15 for fully developed areas. If significant blockage is caused by buildings in the flood fringe, the developed areas were modeled as ineffective flow.

Channel n-values were manually adjusted using the HEC-RAS cross section data editor. A combination of digital aerial photos, field photographs, and site visits was used to select an appropriate n-value. Table 4-3 lists channel descriptions and associated ranges of n-values used for Deadmans Run.

**Table 4-3
Channel Descriptions and Associated Manning's n-Values¹**

Channel Description	Initial n-Value	Range of n-Value
Fabriform Mattress ² - clean channel and sidewalls	0.025	0.020 to 0.030
Fabriform Mattress - rock gabion, grass sidewalls	0.030	0.025 to 0.035
Fabriform Mattress - brush in channel, sidewalls	0.040	0.030 to 0.500
Natural, clean, straight	0.030	0.025 to 0.033
Natural, straight channels, weeds	0.035	0.030 to 0.040
Natural, clean, meandering	0.040	0.033 to 0.045
Natural, meandering, weedy	0.045	0.045 to 0.050
Natural, sluggish, weedy	0.070	0.050 to 0.080
Natural, very weedy, floodways with heavy timber and underbrush	0.100	0.075 to 0.150

1. Source: *Open Channel Hydraulics*, Chow 1959
2. Source: Construction Techniques, Incorporated (CONTECH)

4.2.3 Roadway Crossings and Dams

Bridge and culvert openings and roadway profiles were developed from data collected during field surveys. Field data were collected based on monument and GPS controls using standard field survey collection forms. These data were manually entered into the HEC-RAS model that was created using HEC-GeoRAS.

HEC-RAS requires four cross sections to be entered to define each hydraulic structure. The four cross sections include a downstream cross section where flow is fully expanded, a cross section at the downstream face of the structure, a cross section at the upstream face of the structure, and an upstream cross section before flow contraction. All four cross sections were cut from the LiDAR TIN. Where available, survey information was used to supplement the LiDAR topography at the upstream and downstream face cross sections.

The flow lengths between the bridge cross sections and the upstream and downstream cross sections were determined using ArcView GIS. The drainage structure location in river feet was estimated by intersecting the stream network coverage with structure cut lines.

**Table 4-4
Expansion and Contraction Coefficients¹**

Transition Type	Expansion Coefficient	Contraction Coefficient
Gradual	0.3	0.1
Roadway Crossing	0.5	0.3
Abrupt	0.8	0.6

1. Data from *HEC-RAS Hydraulic Manual*, Page 3-20

coefficients used in the model are listed in Table 4-4. The expansion and contraction coefficients were input manually using the HEC-RAS cross section data editor.

4.2.4 Expansion and Contraction Coefficients

The expansion and contraction coefficients were estimated based on the ratio of expansion and contraction of the effective flow area in the floodplain occurring at cross sections and at roadway crossings. Typical

4.2.5 Boundary Conditions

Normal depth was used as the downstream boundary condition. This boundary condition requires the input of the energy grade line (EGL) slope at the downstream boundary. The downstream EGL slope can be approximated as the channel invert slope from the contour data. Therefore, the slope between the two most downstream cross sections was used to calculate the normal depth boundary condition for each reach. This slope was calculated in ArcView GIS using the elevation contour data, cross section cut line coverage, and stream centerline coverage.

4.2.6 Ineffective Flow Areas

Ineffective flow areas were determined using the cross section plots and contour information. The following situations required the use of the ineffective flow area option:

- Floodplain areas significantly below the top of the channel bank that are not hydraulically connected to the channel downstream.
- Floodplain areas within the hydraulic shadow of roadway encroachments caused by contraction and expansion of flow through the bridge or culvert openings. These will be estimated using 4:1 expansion and 1:1 contraction ratios.
- Floodplain areas within the hydraulic shadow of other obstructions or irregularities in the stream valley floodplain.
- Floodplain areas that are significantly blocked by buildings.

Ineffective flow areas were input manually using the HEC-RAS cross section data editor.

4.2.7 Channel Bank Stations

The bank stations were located and entered manually by graphically editing the cross sections within HEC-RAS. The bank stations were verified by comparing samples of channel bank stations from the field survey, the GIS-generated cross section geometries, and conditions during field reconnaissance.

4.3 Modeling Deadmans Run West Tributary

The Deadmans Run West Tributary discussed in Section 3.2.7 used the same procedure described above to develop the a separate hydraulic model for this area; however, at cross sections where flow has overtopped the main channel, each reach's cross sections were clipped to avoid double accounting conveyance. The hydraulic model incorporated the flow diversion from the main channel to the West Tributary by using an iterative process to balance stages between the two models. Flows along the main channel were systematically modified along with the West Tributary flows, keeping the total flow constant, until the flood stage is equal on both reaches. The Deadmans Run West Tributary model was created to refine the main channel flood stages and was not mapped as a separate tributary.

4.4 Steady Flow Water Surface Profiles

Stream profiles were developed depicting the 2-, 10-, 50-, 100-, and 500-year water surface elevations. With the exception of the area near the West Tributary discussed on the previous page, flow change locations were coordinated with HEC-HMS junctions and input into HEC-RAS at geographically correct load points.

4.5 Floodway Determination

A floodway was modeled for the Deadmans Run main channel. The floodway is determined from the floodplain model by encroaching the left and right overbanks of each cross section to produce a target rise in water surface elevation. The encroachments simulate fill within the floodplain that reduces conveyance of flood flows.

A 1-foot rise criterion was used to determine the encroachment stations at each cross section. Initially, Encroachment Method 4 was used to estimate encroachment stations at each cross section. Encroachment Method 4 automates the floodway modeling process by computing the encroachment station so that conveyance within the encroached cross section (with a target water level) is equal to the conveyance of the natural cross section at the natural water level. The higher water level for the encroached cross section was specified as a fixed amount above the natural profile. A target increase of 1.0 foot was used for this analysis. Once the encroachment stations were determined by HEC-RAS using Encroachment Method 4, each cross section was reviewed and adjusted if necessary to meet the target 1-foot rise.

The downstream boundary condition for the floodway model was the same normal depth that was used to calculate the 1-percent-annual-chance natural flood profile. In addition, the main channel floodway determination adjacent to the Deadmans Run West Tributary used the clipped cross sections and the final flow (after the iterative analysis) described in Section 4.3.

4.6 Model Calibration and Verification

Precipitation information is available from the University of Nebraska's Institute of Agriculture and Natural Resources for a period of record from August 1986 to the present. However, because of the lack of any stream gauge information along the main channel, the HEC-RAS model was not calibrated using historical water surface elevation data.

The HEC-RAS model results were verified by comparing the results to any available high water marks or historical aerial photos. In addition, information obtained from public meetings was used to verify the model results.

4.7 Quality Control

After the HEC-RAS model was developed, a computer program called CHECK-RAS was used to check the reasonableness of the HEC-RAS data to verify that the model assumptions and results meet FEMA requirements and the limitations of the HEC-RAS program.

CHECK-RAS consists of five checking routines:

- NT (Manning's roughness coefficients and transition loss coefficients)
- XS (cross sections)
- Structures
- Floodways
- Profiles

The HEC-RAS model was checked using each of the five routines. All warnings and errors that occurred were evaluated by the engineer to determine if modifications were warranted.

4.8 HEC-RAS Product

Two separate HEC-RAS models were created, one for the main channel and the other for the West Tributary. Both models and the resulting output water surface elevations are included in Appendix A under the Computer Models, Hydraulics folder. In addition, the design data for each modeled drainage structure are provided in Appendix C. The CHECK-RAS review comments and flow loading discussed in Section 4.4, as well as the flow iterations used to develop flow inputs to the HEC-RAS model near the West Tributary, are included in tabular format in Appendix A under the same folder.