THE UNIVERSITY OF WESTERN ONTARIO
DEPARTMENT OF CIVIL AND
ENVIRONMENTAL ENGINEERING

# Water Resources Research Report

## City of London: Vulnerability of Infrastructure to Climate Change

## Background Report #2
## Hydraulic Modeling and Floodplain Mapping

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## Executive Summary

The main objective of the research project currently under way is to provide an engineering assessment of the vulnerability of London's public infrastructure under projected rates of climate change with special emphasis on flooding. An original systematic procedure is used to gather and examine available data in order to develop an understanding of the relevant climatic effects and their interaction with municipal infrastructure. Assessment of climate change impacts on municipal infrastructure requires floodplain maps and inundation that will correspond to examined climate change scenarios. This report presents the results of hydraulic analyses used in floodplain mapping under changing climate.

Combined, climate and hydrologic modeling, were used to generate input flow data for hydraulic modelling. Standard computer software HEC-RAS is used for hydraulic computation of water elevation. The existing HEC-RAS models of the Upper Thames River basin are not georeferenced and therefore they cannot be used for hydraulic modeling under climate change. Consequently, it was necessary to develop new HEC-RAS models for the rivers and creeks of London that were considered in this project.

Geometric input data for new HEC-RAS models were created using HEC-GeoRAS software, which is an extension of ArcGIS computer package for spatial analysis. In the pre-processing phase the HEC-GeoRAS is used to create a digital terrain model from the contour lines shape file provided by the city of London. In the next step the following geometric data layers were generated: river center line, bank lines, flowpaths, cross sections, and bridges. Required attributes were assigned to each of the layers. In the last step of the pre-processing stage the input file for the HEC-RAS hydraulic analysis was prepared. The hydraulic analysis starts with the geometric data import, followed with the preparation of the hydraulic structures

data and flow data. A very detailed quality control was performed on the cross sections data generated during the pre-processing phase. The roughness coefficient values were determined using the existing HEC-RAS models and aerial photography of the basin. Data on bridges, taken from the existing models and drawings were integrated with the rest of the data.

Two climate scenarios (historic and wet) developed by climate and hydrologic modeling (Eum and Simonovic, 2009) were used and water surface elevation profiles were calculated for 100- and 250- year return periods. The computation results were used to assemble the HEC-RAS GIS export file for floodplain mapping. The Arc Map software package was used to create water surface GIS layer. Overlaying this layer with the terrain provided for calculation of floodplain boundaries and inundation depths. The floodplain maps generated using this process are used in vulnerability assessments of London's public infrastructure to climate change currently in progress.

The results of water surface profile computations are presented in tabular form for the 250-year flood under historic and wet climate scenarios. The final floodplain maps along Main Thames for both scenarios show minor deviation of the floodplain boundaries when compared with the existing floodplain lines. However, the water depth difference is up to 50 cm. The area upstream from the culvert on Pottersburg Creek (close to the intersection of Trafalgar St. and Clarke St.) is identified as critical due to the high extent of flooding. The flooding at this location is caused by insufficient culvert opening that creates a backwater effect. Areas of special concern are identified where the floodplain mapping results are not sufficiently accurate due to inaccuracies in the contour lines. The main recommendation based on the work presented in this report is that new georeferenced cross sections should be surveyed in order to increase the accuracy of the floodplain mapping process. The hydraulic analyses should be repeated with more accurate input data and the resulting floodplain maps should be revised accordingly.

## List of Acronyms

| | |
|---|---|
| ArcGIS | Arc Geographic Information System (Software package) |
| CNTRLIN.shp | Contour Line Shape File |
| DTM | Digital Terrain Model |
| HEC-HMS | Hydrologic Engineering Centre-Hydrologic Modeling System |
| HEC-GeoRAS | Hydrologic Engineering Centre-Geospatial River Analysis System |
| HEC-RAS | Hydrologic Engineering Centre-River Analysis System |
| LIDAR | Light Detection And Ranging |
| RAS | River Analysis System |
| TIN | Triangulated Irregular Network |
| USACE | United States Army Corps of Engineers |
| UTRCA | Upper Thames River Conservation Authority |
| UWO | University of Western Ontario |
| WG | Weather Generator |

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# 1. INTRODUCTION

## 1.1 Problem Definition

The climate is changing and reliable studies have already reported trends of global warming. Evidence of climate change can be found in verified observations of an increase in global ocean and air temperature. In addition, it is expected that the extent of anticipated climate change will be more severe in the future. One of the main findings from a recently completed study at the University of Western Ontario (on line documentation last accessed October 20, 2009 http://www.eng.uwo.ca/research/iclr/fids/cfcas-climate.html) is that flooding in the Upper Thames River basin will be more frequent and severe under the climate change. The study indicates that historic climate data, which are used in management (design, maintenance and operations) of public infrastructure, will no longer be appropriate.

The primary objective of the project initiated by the city of London is to provide an engineering assessment of the vulnerability of London's public infrastructure under projected climate change. The elements of infrastructure under consideration include: buildings within and adjacent to the floodplains, roads, bridges, culverts, wastewater treatment plants, storm water management networks, etc. An original systematic procedure is used in the study to gather and examine available data in order to develop an understanding of the relevant climatic effects and their interactions with infrastructure. The purpose of the work presented in this report is to provide the assessment procedure with the extent of inundation and water depths for two climate scenarios under consideration. The integrated hydraulic modeling system and spatial analysis software were used in the study.

In addition to the fact that climate change was not considered in the development of current floodplain maps, there are others reasons why the current (official) maps could not be used in the "*Vulnerability of Infrastructure to Climate Change*" project. Current floodplain maps were generated manually about 30 years ago. Recently, the paper maps were digitized and converted into shape file format. Floodplain lines from the current (official) floodplain maps represent only the floodplain boundaries, and do not provide the inundation depths that are required for an assessment of infrastructure vulnerability. Geometric data for current (official) hydraulic models are not georeferenced, since the use of GIS software was not in place at the time of data surveying (around 1970's and 1980's). Hence, the currently available geometric data cannot be used with the GIS computer software for spatial analyses.

### 1.2 Hydrologic input

A climate modelling in the study is performed using an original weather generator (WG) model that provides long sequences of meteorological variables for selected set of climate change scenarios. Meteorologic input is then is used with the hydrologic model of the basin to generate flow input data for hydraulic modeling. Details on climate and hydrologic modeling are presented in the report by Eum and Simonovic (2009). Two climate change scenarios are selected to represent the range of potential impact that climate change will have on the basin. The historic scenario is representing the lower bound of potential change and the wet scenario represents the upper bound of potential change.

## 1.3 Preparation of spatial data for hydraulic analysis

Set of tools and utilities provided with the ArcGIS computer package is utilized in the preparation of spatial data for the hydraulic analyses. HEC-GeoRAS is an extension of ArcGIS, which is used for the preparation of spatial data for input into hydraulic model HEC-RAS and the generation of GIS data from the output of HEC-RAS (USACE, 2005). These tasks are organised as RAS (River Analysis System) pre-processing and RAS post-processing. The pre-processing starts with the development of a Digital Terrain Model (DTM) in Triangulated Irregular Network (TIN) format. It is followed with the preparation of the following GIS layers: river center line, banks lines, flowpaths, cross sections, and bridges. The pre-processing ends with the preparation of the RAS GIS import file for the use with HEC-RAS computer program.

The main post-processing task is automatic delineation of floodplains based on the data contained in the RAS GIS output file and the original terrain TIN layer. The final step involves overlaying the water surface TIN with the terrain TIN to calculate the inundation depths and visualise the floodplain boundaries.

## 1.4 Hydraulic modelling

The Hydrologic Engineering Centre River Analysis System, shorter HEC-RAS, (USACE, 2006) is an integrated software system designed to perform one-dimensional water surface calculations. HEC-RAS system is comprised of a graphical user interface, separate hydraulic analysis components, data storage and management capabilities, and graphing and reporting facilities (USACE, 2002 b). HEC-RAS is able to take into consideration hydraulic effects of bridges, culverts, weirs, and other structures in the river and floodplain on water surface calculations.

HEC-RAS takes most of the data through the RAS GIS import file in order to complete the geometric data, hydraulic structure data and flow data input. In the study reported here, the Manning's roughness coefficient values and bridge data were used from the existing HEC-RAS models developed by the Upper Thames River Conservation Authority (UTRCA). Two sets of generated flow data are used for the historic and wet climate scenarios. The HEC-RAS computed water surface elevations stored in the RAS GIS export file are used in the floodplain mapping through the post-processing done with the assistance of HEC-GeoRAS.

### 1.5 Project boundaries

The spatial extension of the assessment project is limited to the city of London. The study area is determined based on the existing HEC-RAS models. The Dingman Creek is extended to the western boundary of the city (around 4.465 m) and to the eastern boundary of the city (around 5.592 m). The main branch of the Thames River model starts at the downstream cross section, which is located 11,135 m away from the "Fork" (merging point of the North and South branches of the Thames River) and ends at "Fork". The North branch model of the Thames River starts at "Fork" and ends upstream, around 14,281 meters from the "Fork", below the Fanshawe Dam. The South branch of the Thames River model starts at "Fork" and ends upstream, around 12,890 meters from the "Fork", close to the City's eastern boundary. The Medway Creek model starts at the confluence of Medway Creek and the North Thames River and ends upstream, around 12,534 meters from the confluence, close to the City's northern boundary. The Pottersburg Creek model starts at the confluence of the Pottersburg Creek and the South Thames River and ends upstream, around 14,213 meters from the confluence, at the City's eastern boundary. The Mud Creek model starts at the confluence of the Mud Creek and the Main

Thames River and ends upstream around 2,397 meters from the confluence. The Stoney Creek and tributaries model includes: Stoney Creek, Ballymonte Drain, Powel Drain and Norhdale Drain.

- The Stoney Creek model starts at the confluence of the Stoney Creek and the North Thames River and ends upstream around 10,028 meters from the confluence.
- The Ballymonte Drain model starts at the confluence of the Ballymonte Drain and the Stoney Creek and ends upstream around 2,483 meters from the confluence.
- The Powell Drain model starts at the confluence of the Powell Drain and the Stoney Creek and ends upstream around 1,299 meters from the confluence.
- The Northdale Drain model starts at the confluence of the Northdale Drain and the Powell Drain and ends upstream around 1,095 meters from the confluence.

The Dingman Creek and tributaries model includes the Dingman Creek and the following tributaries: 2 (D), 3(E), 4(F), 5(G), 6 (I), 7 (B-64), 8(B-62), 9(C-30), 10(R), 11 (P), 12 (J), 13 (K).

- Dingman Creek starts approximately at 9,538 m (close to the City’s western boundary) from the confluence of the Dingman Creek and the Main Thames River, and ends upstream at 35,049 m from its initial origin, very close to the City’s eastern boundary.
- Tributary 13 (K) starts at the confluence of the Tributary 13 and the Dingman Creek and ends approximately at 3, 039 m from the confluence.
- Tributary 12 (J) (Reach 1 and Reach 3) starts at the confluence of the Tributary 12 and the Dingman Creek and ends upstream, approximately at 2,845 m from the confluence. Reach 2 of the Tributary 12 starts at the merging point of Tributaries 1, 2 and 3, and ends upstream, approximately 902 m from the merging point.

- Tributary 11 (P) (Reach 1 and Reach 3) starts at the confluence of the Tributary 11 and the Dingman Creek and ends upstream, approximately at 3.333 m from the confluence. Reach 2 of Tributary 11 starts at the merging point of Tributaries 1, 2 and 3, and ends upstream, approximately at 223 m from the merging point.
- Tributary 10 (R) starts at the confluence of the Tributary 10 and the Dingman Creek and ends approximately at 784 m from the confluence.
- Tributary 9 (C-30) starts at the confluence of the Tributary 9 and the Dingman Creek and ends approximately at 1,557 m from the confluence.
- Tributary 8 (B-62) starts at the confluence of the Tributary 8 and the Dingman Creek and ends approximately at 1,294 m from the confluence.
- Tributary 7 (B-64) starts at the confluence of the Tributary 7 and the Dingman Creek and ends approximately at 2,216 m from the confluence.
- Tributary 6 (I) starts at the confluence of the Tributary 6 and the Dingman Creek and ends approximately at 2,564 m from the confluence.
- Tributary 5 (G), (Reach 1 and Reach 3) starts at the confluence of the Tributary 5 and the Dingman Creek and ends upstream, approximately at 2,082 m from the confluence. Reach 2 of Tributary 12 starts at the merging point of Tributaries 1, 2 and 3, and ends upstream, approximately at 1,387 m from the merging point.
- Tributary 4 (F), (Reach 1 and Reach 3) starts at the confluence of the Tributary 4 and the Dingman Creek and ends upstream, approximately at 2,267 m from the confluence. Reach 2 of Tributary 12 starts at the merging point of Tributaries 1, 2 and 3, and ends upstream, approximately at 749 m from the merging point.

- Tributary 3 (E) starts at the confluence of the Tributary 3 and the Dingman Creek and ends approximately at 4,476 m from the confluence.
- Tributary 2 (D) starts at the confluence of the Tributary 3 and the Dingman Creek and ends approximately at 5,112 m from the confluence.

### 1.6 Summary of the floodplain mapping results under climate change

Table 1.1 shows the inundation area for both climate scenarios and two return periods (100- and 250-year). For some rivers and creeks, the difference in flow between 100-years and 250-years is not significant, and hence, the difference between inundated areas is also not significant.

Table 1.1 Summary of the floodplain mapping results under climate change

| River/Creek | Area of Flooding ($m^2$) | | | |
|---|---|---|---|---|
| | Historic Climate Scenario | | Wet Climate Scenario | |
| | 100-Year Return Period | 250-Year Return Period | 100-Year Return Period | 250-Year Return Period |
| Main Thames River | 2,717,208 | 3,189,657 | 3,228,637 | 3,342,766 |
| North Thames River | 4,951,784 | 6,144,150 | 6,237,229 | 6,497,384 |
| South Thames River | 2,676,651 | 2,886,324 | 2,885,980 | 3,128,588 |
| Medway Creek | 1,143,686 | 1,219,177 | 1,170,080 | 1,242,106 |
| Stoney Creek and Tributaries | 974,141 | 1,030,558 | 1,008,950 | 1,104,061 |
| Pottersburg Creek | 2,853,112 | 3,069,149.00 | 3,063,310 | 3,283,552 |
| Mud Creek | 72,339 | 124,241 | 123,697 | 226,260 |
| Dingman Creek and Tributaries | 7,550,220 | 8,302,463 | 8,011,897 | 9,061,872 |

## 1.7 Report organization

Chapter 2 explains the methodology used in the reported work. The uses of HEC-GeoRAS for pre-processing and post-processing of data, as well as the HEC-RAS for hydraulic modeling, are presented step by step. Some basic concepts and equations are also presented in this chapter. The results of surface profile calculations and floodplain mapping are presented in Chapter 3. The HEC-RAS results were presented in tabular form. The floodplain mapping results are presented using (a) illustrative maps of selected areas, and (b) maps of locations of special concern. Chapter 4 describes data limitations and provides some recommendations for increasing the accuracy of surface elevation calculations and floodplain mapping.

# 2. METHODOLOGY

This chapter explains in detail the methodology applied in floodplain mapping under climate change. The traditional process of floodplain mapping based on the hydraulic calculations of water surface elevations was adopted for the local data conditions. The main objective was to bring the process into digital format for use of software tools for spatial analyses. The methodology used in the reported work consists of three steps: (i) Pre-processing of geometric data for HEC-RAS, using HEC-GeoRAS; (ii) Hydraulic analysis in HEC-RAS; and (iii) Post-processing of HEC-RAS results and floodplain mapping, using HEC-GeoRAS. Process diagram for using HEC-GeoRAS is shown in Figure 2.1:

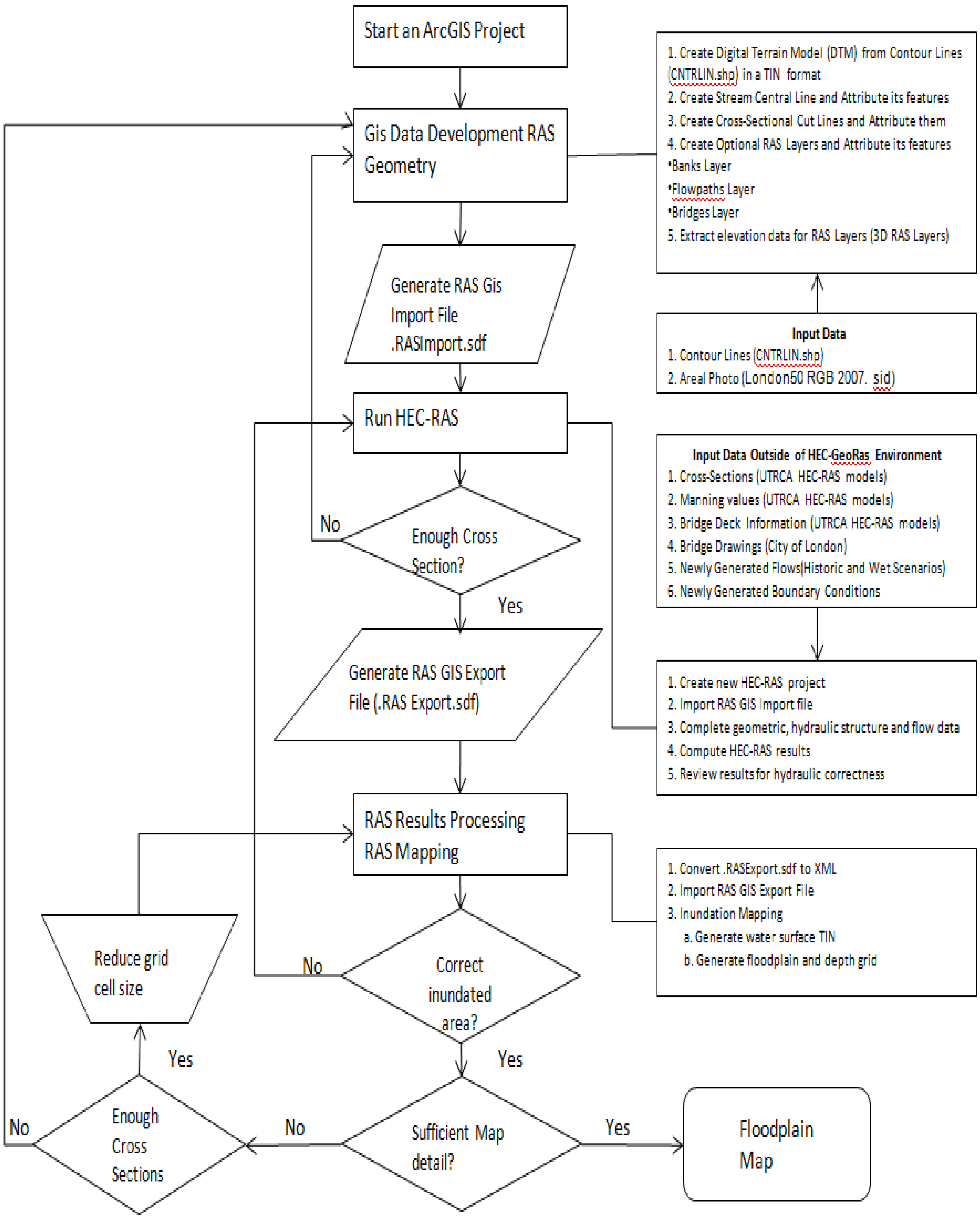


Figure 2.1 Process flow diagram for using HEC-GeoRAS (after USACE, 2005)

## 2.1 Pre-processing of geometric data

For efficient use of multiple software packages, a very rigorous data preparation procedure is implemented in the study.

### *2.1.1 Generation of Digital Terrain Model (DTM)*

The first step in the pre-processing stage was to create a Digital Terrain Model (DTM) of the river system in a Triangulated Irregular Network (TIN) format. The TIN must be constructed with a special care in order to provide for accurate analyses. Elevation data for each cross section is extracted from the TIN. The TIN also serves for determining floodplain boundaries and calculation of inundation depths.

The Digital Terrain Model (DTM) is a representation of the topographical surface in terms of regularly spaced x, y, z, coordinates. The DTM can be developed from a number of sources including ground survey, photogrammetry, surface sensing and cartography. The TIN-based model has a vector-based data structure, but it can be converted into grid cells. In the TIN model, each point has defined x, y, and z coordinates. The coordinate z represents the height. These points are connected by their edges to form a network of overlapping triangles (finite surfaces) that represent the terrain surface (Lo and Yeung, 2005). The basis of TIN-based DTM is that a large series of these finite surfaces, sharing common horizontal edges, can be linked together and used to interpolate the XYZ coordinate of any point, even though actual measurements have not been obtained at that point.

The contour lines at an interval of 1 m (CNTRLIN.shp) in digital format shape file are used in TIN development. The data source of CNTRLIN.shp is: *City of London Mapping Data Distribution Disc* version 2007.00 [computer file]. London, Ontario: The Corporation of the City of London, 2007. The TIN development process starts by opening a new project in the ArcMap.

The CNTRLIN.shp is added to the map, and Interactive Selection Method “Add to Current Selection” is chosen from the Selection main window in order to create the desired size of the TIN. 3D Analyst Extension (Create/Modify TIN) is then used to complete TIN.

Figure 2.2 shows a typical problem in TIN development at a bridge location. Such a problem causes inaccurate cross section extraction in that area, as well as a break in floodplain mapping. The TIN Editor Extension was used for a manual TIN editing. Aerial Photos (London, 2007) and river bottom elevations from cross sections at bridge locations from existing HEC-RAS models are used during the process of TIN editing. This was a tedious, but necessary, step because a similar problem was experienced for all bridge locations, especially in the case of smaller rivers and creeks. Figure 2.3 shows the same area after TIN editing.

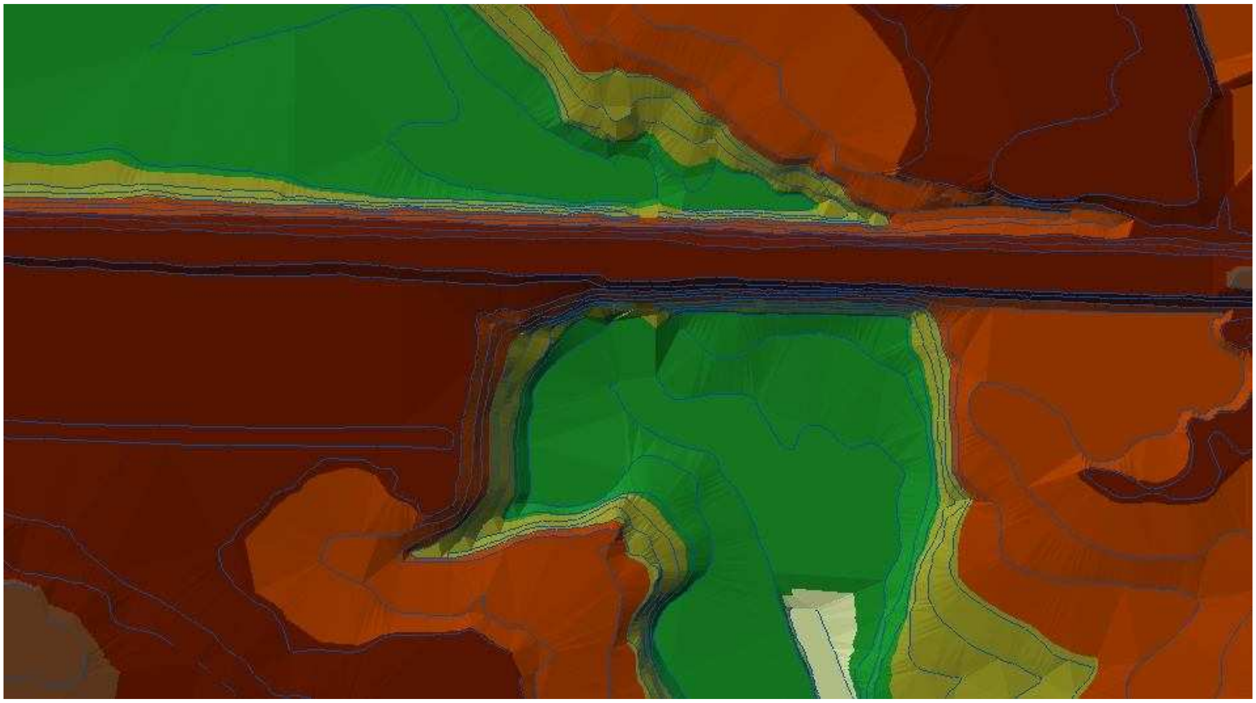

Figure 2.2 TIN before editing

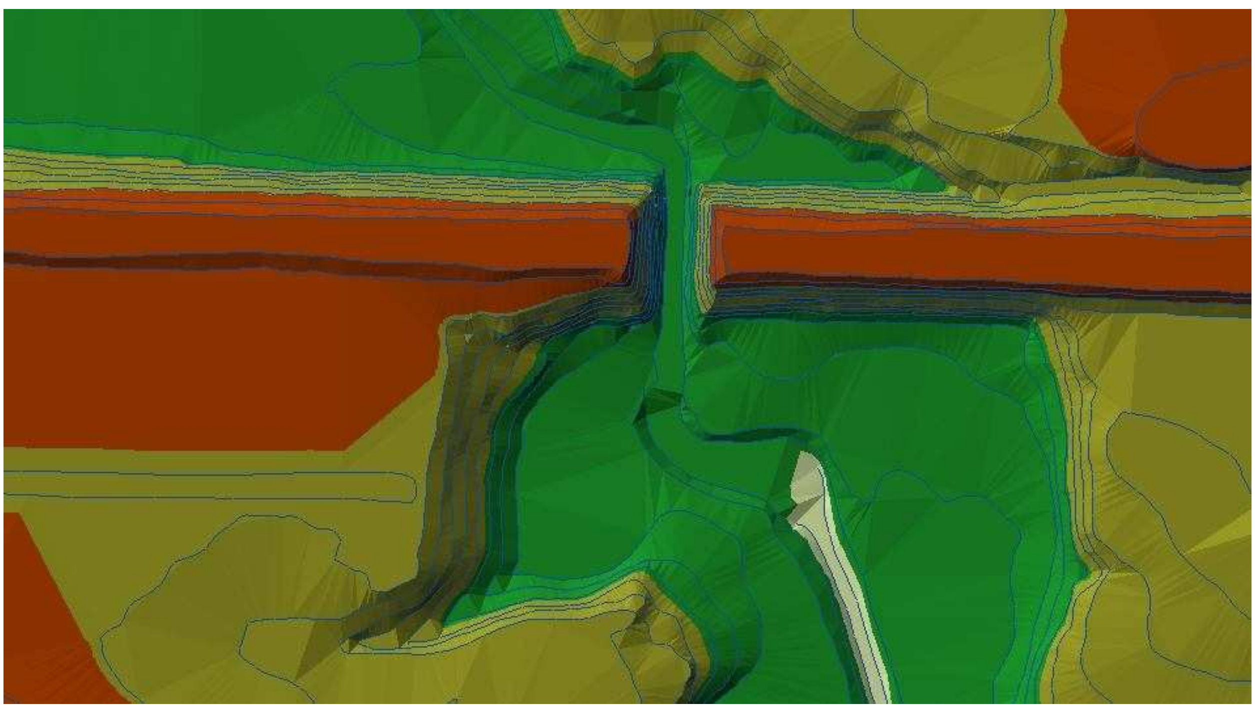

Figure 2.3 TIN after editing

*2.1.2 Creating of geometric data layers*

The empty ArcMap map is saved in the working directory and the TIN is added. As a result of this step, the appropriate coordinate system is automatically assigned in the ArcMap for the city of London: NAD_1983_UTM_Zone_17N. The main task of the pre-processing is to create the geometry data file for the use with HEC-RAS. The geometry data file contains important information about cross-sections, hydraulic structures, river bank points and other physical attributes of river channels (Merwade, 2006). The pre-processing is done using the HEC-GeoRAS for creating physical attributes in GIS, and then exporting them to the HEC-RAS geometry file. In HEC-GeoRAS, each attribute is stored in a separate feature class referred to as a RAS Layer (Merwade, 2006). Before creating river attributes in GIS, it was necessary to create empty GIS layers using the RAS Geometry menu on the HEC-GeoRAS toolbar. The RAS layers were created in one step and stored collectively in a GeoDatabase, which HEC-GeoRAS creates automatically. By default, this GeoDatabase is saved under the same name and at the same location as the ArcMap project. The RAS layers are created by selecting from the HEC-GeoRAS toolbar: "RAS Geometry"→ "Create RAS Layers"→ "All".

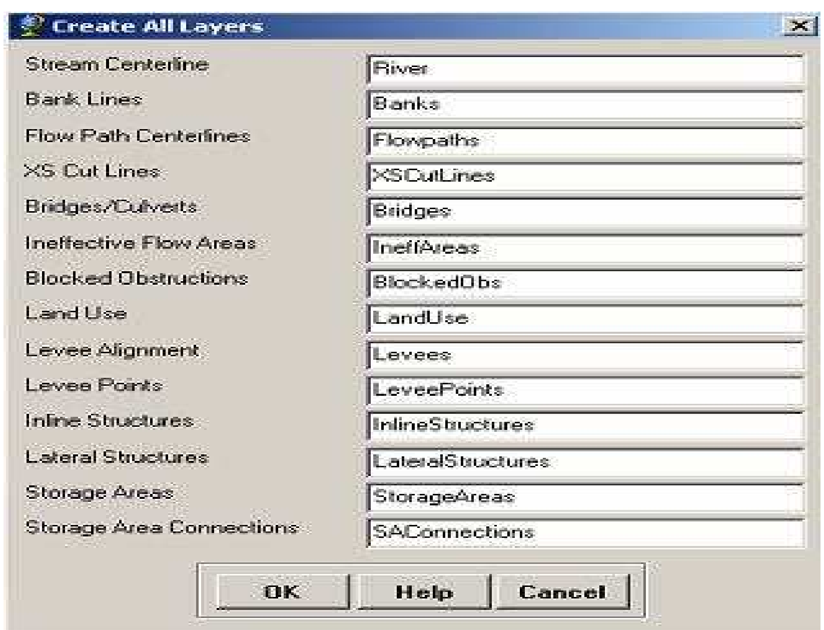

Figure 2.4 Window for selecting RAS layers

Figure 2.4 shows all available RAS layers. The following RAS layers are used in this project: river, banks, flowpaths, XsCutLines, bridges, levees, and InlineStructures. The following sections explain how each individual RAS layer created (digitized) is.

*Creating river center line*. The river centerline layer is very important, because it represents the river network for HEC-RAS. Digitizing of the stream centerline starts with selecting the sketch tool from the Editor Toolbar, and digitization proceeds in the direction of river flow. Therefore, the process begins at the uppermost end of the stream (defined by the project extent), and ends at the confluence (or the City of London boundary). Beside TINs, the digitizing process used the London Aerial Photo (London50 RGB, 2007). Another rule for creating the river center line is that the stream centerline must follow the path of lowest elevation. Therefore, the process of digitizing the river center line cannot rely only on the Aerial Photo only. The elevation from the TIN must be checked, too. Figures 2.5 and 2.6 illustrate the process of creating center line at the same location, using aerial photo and TIN, respectively.

Figure 2.5 Digitizing of river center line using Aerial Photo

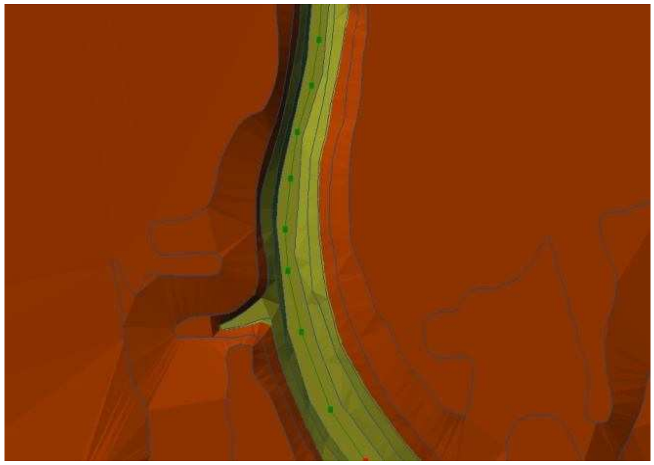

Figure 2.6 Digitizing of river center line using TIN

In the event when a river has more tributaries (e.g. Stoney and Dingman Creek), it is necessary to modify some of the editing options. The Snapping tool was used from the Editor Tool box to provide connectivity between reaches within the main stream, as well as the main stream and tributaries.

After digitizing all of the reaches, the next task is to name them. Each river in HEC-RAS, as well as each reach within a river, is assigned a unique name. This was accomplished by the selection of Assign RiverCode/ReachCode menu item and assigning appropriate names.

The next step is to check that the created reaches are connected, and then to populate the remaining attributes of the river layer. This is accomplished by selecting RAS "Geometry"→ "Stream Centerline Attributes"→ "Topology". This function is populated by the FromNode and ToNode attribute of the River layer. The Length/Stations fields are populated in a similar way. Figure 2.7 shows an attribute table for river GIS layer (Stoney Creek and Tributaries). The meaning of each attribute is explained below.

Attributes of River

| Shape * | OID * | Shape_Length | HydroID | River | Reach | FromNode | ToNode | ArcLength | FromSta | ToSta |
|---|---|---|---|---|---|---|---|---|---|---|
| Polyline | 1 | 3445.565382 | 1 | Stoney Creek | Middle R | 1 | 2 | 3445.565 | 2891.1765 | 6336.74 |
| Polyline | 2 | 3745.024575 | 2 | Stoney Creek | Upper R | 3 | 1 | 3745.025 | 6336.7417 | 10081.7 |
| Polyline | 3 | 1187.230463 | 3 | Northdale Drain | Reach 1 | 4 | 5 | 1187.231 | 0 | 1187.23 |
| Polyline | 4 | 1298.430941 | 4 | Powell Drain | Upper R | 6 | 5 | 1298.431 | 272.7799 | 1571.21 |
| Polyline | 5 | 2701.899294 | 5 | Ballymonte Drain | Reach 1 | 7 | 1 | 2701.899 | 0 | 2701.89 |
| Polyline | 6 | 2891.176479 | 6 | Stoney Creek | Lower R | 2 | 8 | 2891.177 | 0 | 2891.17 |
| Polyline | 7 | 272.77994 | 7 | Powell Drain | Lower R | 5 | 2 | 272.78 | 0 | 272.779 |

Record: 1 Show: All Selected Records (0 out of 7 Selected) Options

Figure 2.7 Attributes of the river (River Centerline) layer

HydroID is a unique number for a given feature in a geodatabase. The River and Reach attributes contain unique names for rivers and reaches, respectively. The FromNode and ToNode attributes define the connectivity between reaches. ArcLength is the actual length of the reach in map units, and is equal to Shape_Length. In HEC-RAS, distances are represented using station numbers measured from downstream to upstream. For example, each river has a station number of zero at the downstream end, and it is equal to the length of the river at the upstream end. Since the Figure 2.7 shows only one reach for the Ballymonte Drain tributary, the FromSta attribute is zero and the ToSta attribute is equal to the ArcLength.  Figure 2.7 for the Powel Drain has two reaches, the FromSta attribute for the Upper Reach = ToSta attribute of the lower reach, and the ToSta attribute for the upper reach is the sum of ArcLengths for the upper and the lower reach. Similarly, for Stoney Creek the ToSta attribute for the upper reach is the sum of ArcLengths for the upper, the middle, and the lower reach.

*Creating River Banks.* The bank lines layer is used to define river channel from overbank areas. This definition is important because Manning's n values are different for channel and for floodplain areas. Usually, the overbank areas have higher values of Manning's n due to vegetation or presence of residential areas. Since Manning's n values influence the accuracy of HEC-RAS modeling, this task is very important. The bank lines are created in similar fashion as the river centerline. On the Edit toolbar, select "Editor"→ "Start Editing". The task window of the Edit toolbar is set to "Create New Feature" and the target is set to "Banks". Figure 2.8 shows the Editor Toolbar and the process of creating River Banks Lines using Aerial Photo (London50 RGB 2007).

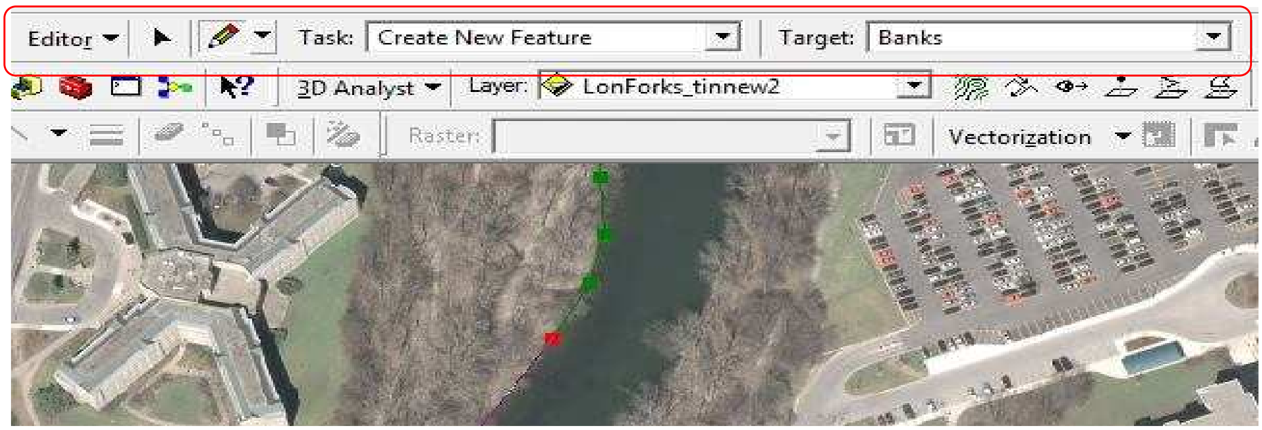


Figure 2.8 Digitizing of River Bank Lines

The digitizing of bank lines starts from the upstream end, with the left bank (looking in downstream direction) being digitized first. Since the Aerial Photo is used in digitizing of banks lines, river water surface elevation at the moment of taking the aerial photo may influence the banks line definition.

*Creating Flowpaths*. The flowpath layer is a set of lines that follows the center of mass of the water flowing down the river, during the flood event (Meyer and Olivera, 2007). The flowpath layer contains three types of lines: centerline, left overbank, and right overbank. For the main channel, the flowpath centerline is defined to be the same as the stream centerline. For floodplains, the flowpath centerlines are digitized to represent assumed water flow within the floodplain. The flowpath layer is used to determine the length between two neighbouring cross sections (required by HEC-RAS). Flowpath centerlines are also created in the upstream to downstream direction. To create left and right flowpaths, it is necessary to start Editing, then choose Create New Feature as the Task, followed by Flowpaths as the Target as shown in Figure 2.9.


Figure 2.9 Digitizing of Flowpaths

By using the Assign LineType button  , the Flowpath is labelled Right, Channel, Right looking in downstream direction.

*Creating Cross-sections.* Cross-sections are one of the most important inputs to HEC-RAS. Cross section cutlines are used to extract the elevation data from the terrain and to create a ground profile across the flow. The intersection of cutlines with other RAS layers such as centerline and flow path lines are used to compute HEC-RAS attributes such as bank stations (locations that separate main channel from the floodplain), and downstream reach lengths (distance between cross- sections).

A significant amount of cut lines are drawn at the same location where the existing UTRCA cross sections are surveyed. UTRCA Cross Section Shape files (line), which show location, shape and length of surveyed cross sections, are used in the creation of this layer. Some of the UTRCA cross sections were modified to meet criteria (rules) for the appropriate drawing of cut lines. A few important rules were followed during the process of drawing cross section cut lines (Meyer and Olivera, 2007):

- Cut lines are drawn perpendicular to the direction of flow. At some locations, “dog-leg” shapes of cross-section are used.
- Cut lines are drawn directionally from left to right bank, looking at downstream direction.
- Cut lines are extended far enough on either side of the channel to encompass the entire portion of the floodplain. Where it is possible, they end at the same elevation at both ends.
- Cut lines do not intersect each other.
- Cut lines are spaced close enough to account for notable changes in the hydraulics or geometry of the stream, such as changes in discharge, slope, cross section shape, roughness or presence of hydraulic structures (bridges, levees, weirs.)
- Each bridge intersection requires 4 cut lines, 2 upstream of the bridge and 2 downstream of the bridge. In Figure 2.10, Lc represents the contraction reach length and Le is the expansion reach length (typically, Lc < Le). These distances can be determined with a high degree of accuracy by conducting field investigation during high flows. Since there was no field investigation data, distances between cross-sections 1and 2 and cross-sections 3 and 4, are determined by examining the TIN to locate the points in the channel where the flow is fully expanded or contracted. Then, cross sections 1 and 4 are located at these points. Also, information from the existing HEC-RAS models are used. Cross-sections 2 and 3 are placed within a short distance of the upstream and downstream ends of the bridge. The purpose of placing these cross-sections near the bridge is to capture the natural

ground elevations directly next to the bridge. Usually, cross-sections 2 and 3 are drawn at the toe of the bridge embankment on their respective sides of the bridge. In addition to TINs and existing HEC-RAS models, Aerial Photo (London50 RGB 2007) are used.

To draw cross sections, it is necessary to start an editing session and select Create New Feature from the Task menu and XSCutLines from the Target menu (see Figure 2.11). The next important step is to populate the attribute table of the XSCutLines feature class, which is digitized. From the HEC-Geo RAS toolbar, “RAS Geometry”→ “XS Cut Line Attributes”→ “All” is selected. Figure 2.12 shows the pop-up window for populating the attribute table. The drop-down menu is used to select the correct layer name for each item on the list and to populate the attribute table of the XSCutLines feature class. The XS Cut Lines Profiles is a new feature class that is created in the following way: The 2D feature class XSCutLines is intersected with the TIN to create a feature class with 3D cross section. After that, the attribute table and cross-sections are examined in order to check their correctness. Figures 2.13 and 2.14 show examples of an adequately populated attribute table of XSCutLines and of an adequate definition of cross-section, respectively.

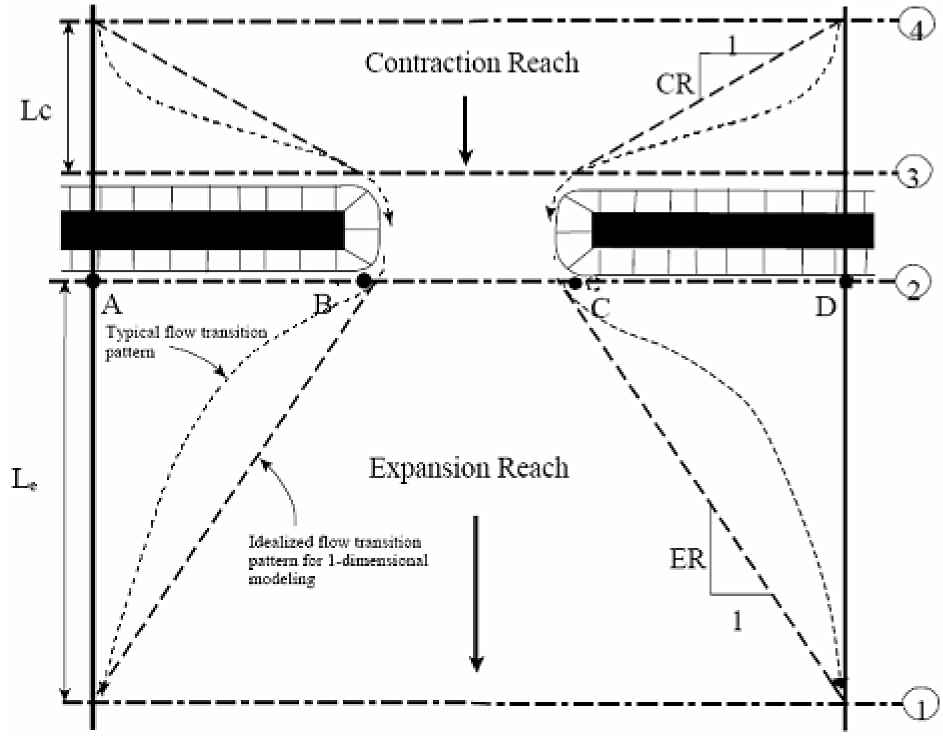


Figure 2.10 Location of bridge cross-sections (after USACE, 2002 b)

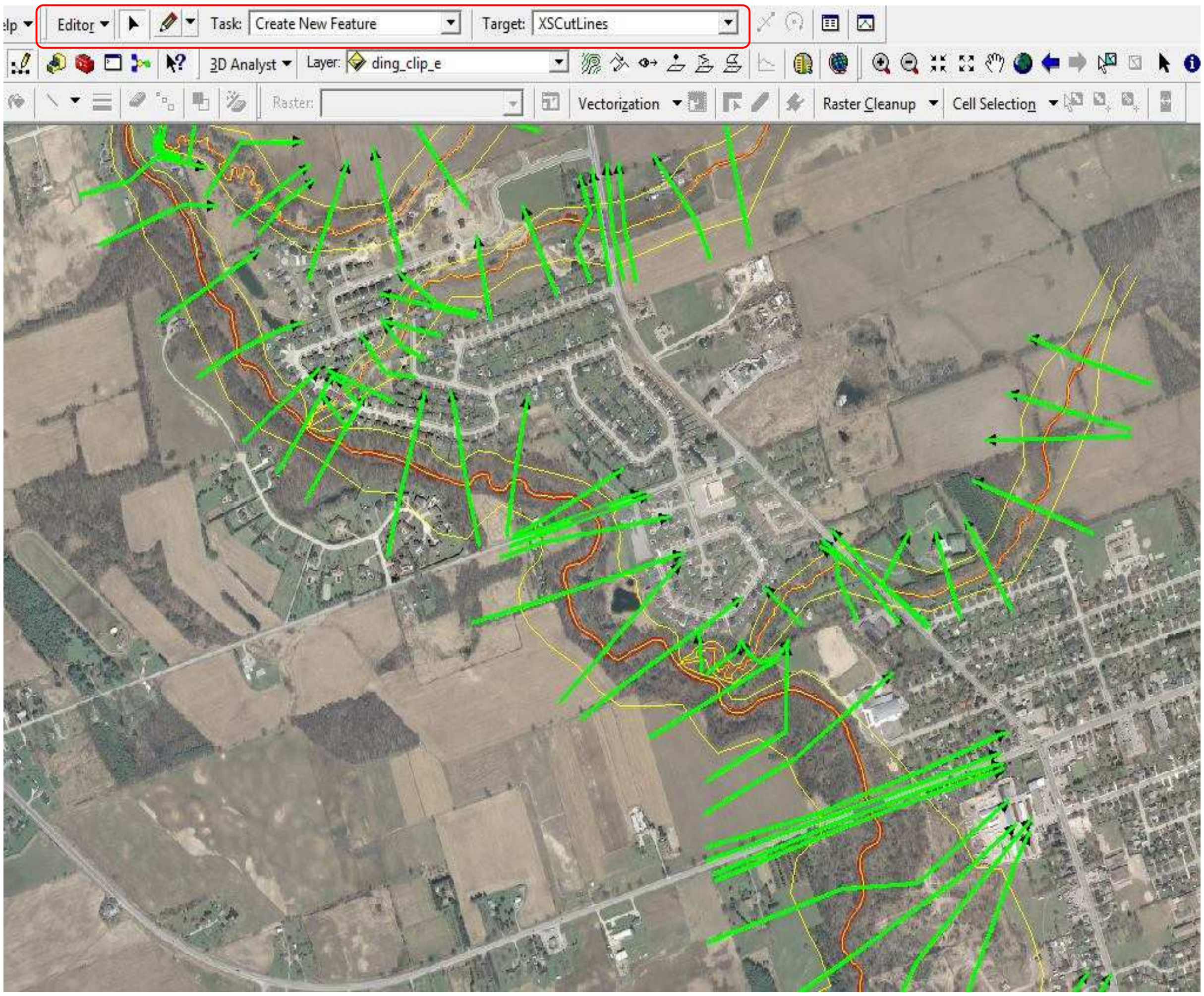


Figure 2.11 Cross sections and commands used for their cutting

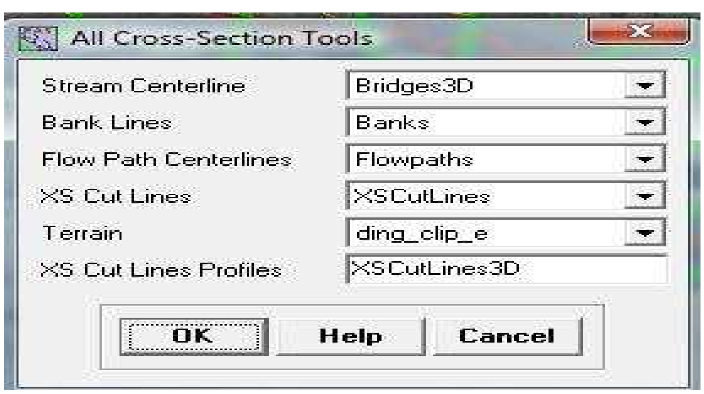


Figure 2.12 Pop-up window for populating attribute table of XSCutLines feature class

Attributes of XSCutLines

| Shape * | OID * | Shape_Length | HydroID | Station | River | Reach | LeftBank | RightBank | LLength | ChLength | RLength |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Polyline | 212 | 245.486729 | 375 | 6028.5835 | Dingman Cree | Reach 1 | 0.6528 | 0.70643 | 145.023 | 150.949 | 107.06 |
| Polyline | 213 | 191.842112 | 376 | 5877.6348 | Dingman Cree | Reach 1 | 0.41563 | 0.47909 | 43.98 | 129.67 | 170.596 |
| Polyline | 214 | 206.561751 | 377 | 5747.9648 | Dingman Cree | Reach 1 | 0.63863 | 0.69483 | 19.145 | 21.857 | 25.903 |
| Polyline | 215 | 219.60252 | 378 | 5726.1074 | Dingman Cree | Reach 1 | 0.55761 | 0.60012 | 15.678 | 13.819 | 19.079 |
| Polyline | 216 | 214.947032 | 379 | 5712.2881 | Dingman Cree | Reach 1 | 0.55585 | 0.59151 | 24.877 | 34.809 | 18.455 |
| Polyline | 217 | 268.137968 | 380 | 5677.479 | Dingman Cree | Reach 1 | 0.46784 | 0.50941 | 160.056 | 90.149 | 6.835 |
| Polyline | 218 | 346.233964 | 381 | 5529.8887 | Dingman Cree | Reach 1 | 0.43422 | 0.46832 | 213.489 | 175.18 | 87.752 |
| Polyline | 219 | 512.463817 | 382 | 5354.709 | Dingman Cree | Reach 1 | 0.24131 | 0.26684 | 104.76 | 161.301 | 113.767 |
| Polyline | 220 | 400.830151 | 383 | 5193.4082 | Dingman Cree | Reach 1 | 0.32471 | 0.35735 | 11.201 | 26.844 | 39.022 |
| Polyline | 221 | 302.792297 | 384 | 5018.7739 | Dingman Cree | Reach 1 | 0.60607 | 0.643 | 18.778 | 97.912 | 124.021 |
| Polyline | 222 | 234.912974 | 385 | 4920.8623 | Dingman Cree | Reach 1 | 0.7618 | 0.80558 | 86.056 | 92.878 | 44.583 |
| Polyline | 223 | 388.615931 | 386 | 5166.564 | Dingman Cree | Reach 1 | 0.36376 | 0.39318 | 7.456 | 9.948 | 10.249 |
| Polyline | 224 | 377.987027 | 387 | 5156.6157 | Dingman Cree | Reach 1 | 0.37872 | 0.41196 | 28.03 | 31.315 | 34.081 |
| Polyline | 225 | 380.729692 | 388 | 5125.3008 | Dingman Cree | Reach 1 | 0.33783 | 0.3683 | 21.772 | 106.527 | 123.218 |
| Polyline | 226 | 382.201096 | 389 | 8586.916 | Dingman Cree | Reach 1 | 0.44906 | 0.48454 | 184.76 | 161.893 | 139.527 |
| Polyline | 227 | 291.783173 | 390 | 7656.0723 | Dingman Cree | Reach 1 | 0.60673 | 0.65455 | 27.382 | 29.691 | 30.951 |

Figure 2.13 Example of adequately populated attribute table of XSCutLines

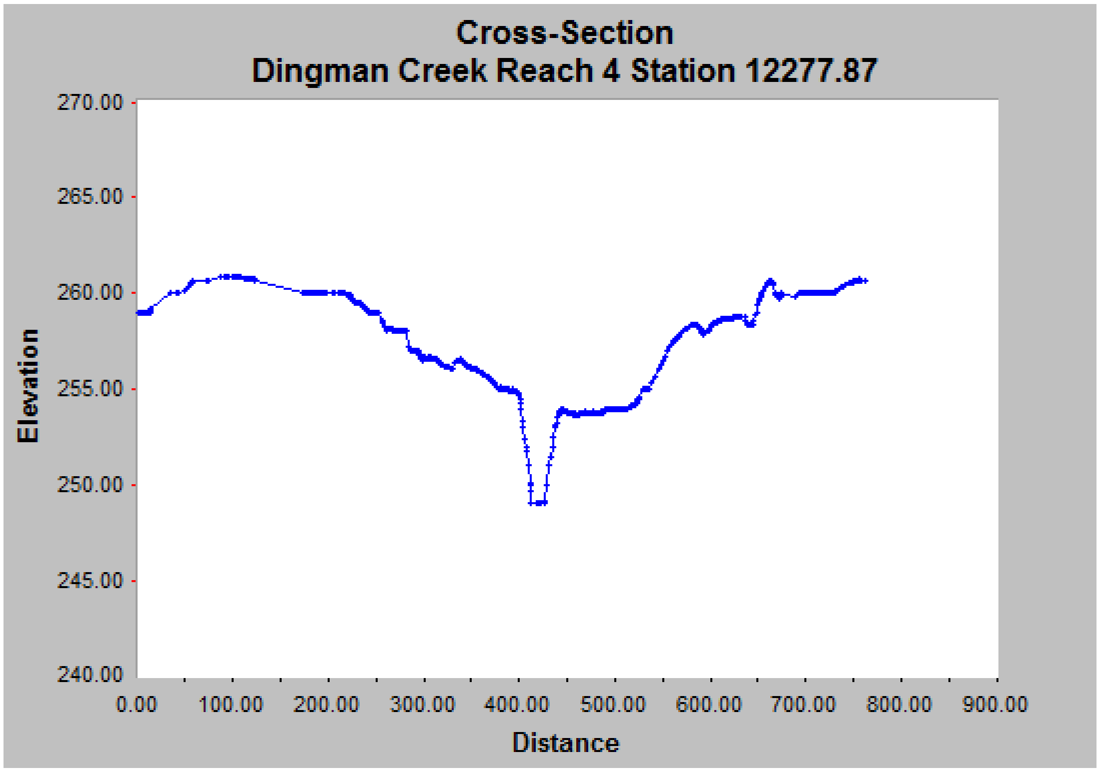


Figure 2.14 Example of adequate definition of cross-section

*Creating Bridges and Culverts.* After creating cross-sections, the next step is to define bridges, culverts and other structures along the river. Bridges and culverts are created in a similar way to the cross section layer. As Figure 2.15 shows, from the Editor Toolbar select Create New Feature for the Task and Bridges as the Target. Bridge lines are digitized from the left overbank to the right overbank, looking in the downstream direction. TINs and Aerial Photo (London, 2007) are used to locate each bridge and draw a line along the centerline of the bridge without intersecting the cross sections. The Bridge line is drawn with a high degree of accuracy to ensure that the sectional topography is well represented.

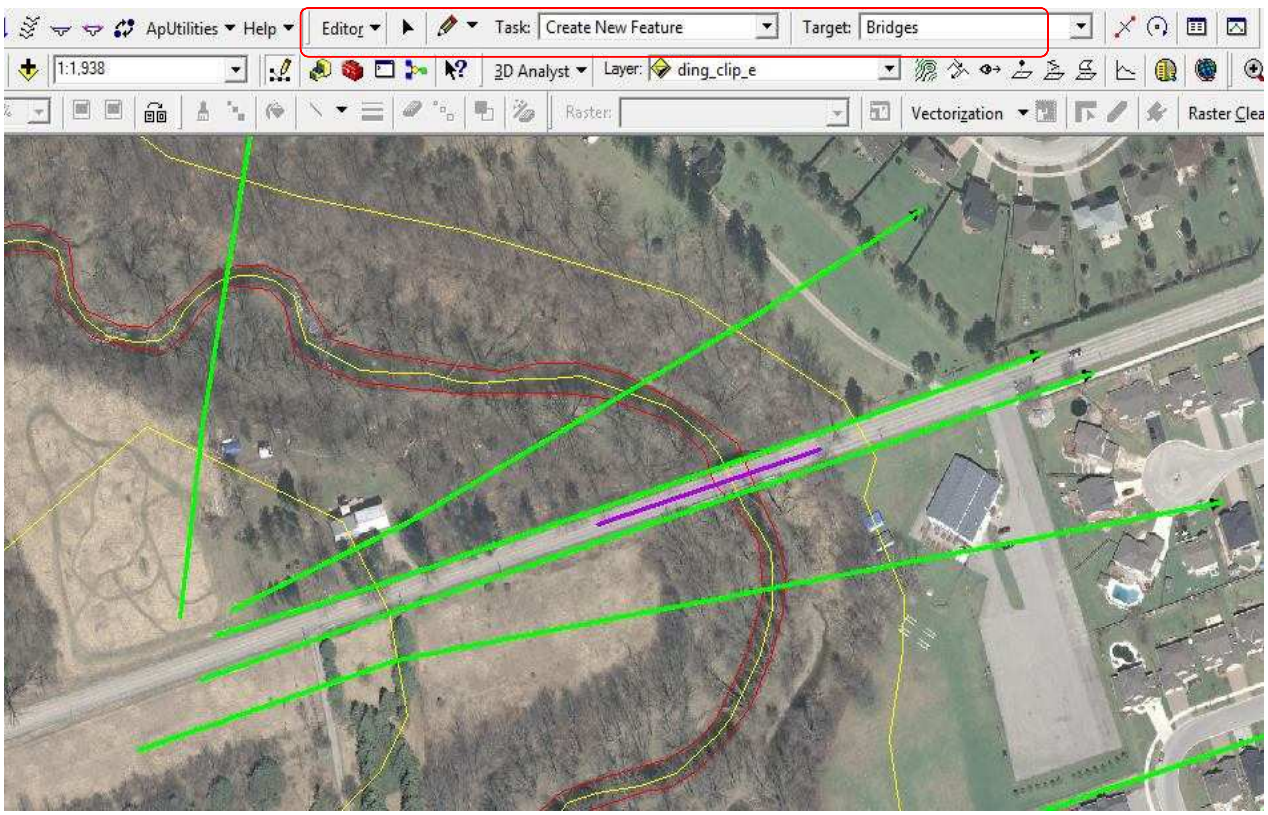


Figure 2.15 Bridge and commands for bridge digitizing

The next step after digitizing the bridges/culverts is to label them with the terms as River/Reach, as well as to provide a station number for these features. This is accomplished using the following procedure: “RAS Geometry”→ “Bridge/Culverts”→ “River/Reach Names” to assign river/reach names. The next step is as follows: “RAS Geometry”→ “Bridge/Culverts”→ “Stationing” to assign station numbers. Similar to cross-sections, the Bridges feature class stores 2D polylines, which are converted to 3D by selecting “RAS Geometry”→ “Bridge/Culverts”→ “Elevations” to create a new 3DBridges feature class. Despite the fact that information from the existing HEC-RAS models is used for the most of bridge deck data in HEC-RAS, it is necessary to provide deck data for bridges that are missing from the original models.

### *2.1.3 Exporting GIS Data to HEC-RAS*

The last step is to create a GIS import file for HEC-RAS so that it could import the GIS data to create the geometry file. Firstly, it is necessary to define which layers would be exported to HEC-RAS. The tabs “RAS Geometry”→ “Layer Setup” are selected from the HEC-GeoRAS toolbar. The Layer Setup window has four tabs: Required Surface, Required Layers, Optional Layers and Optional Tables. The Required Surface option is used for choosing TIN for export. The Required Layers option is used for entering the River Layer, XSCutLines Layer and XSCutLines 3D Layer. The Optional Layers option is used for entering other RAS layers. Figure 16 shows a typical RAS Layers definition at Optional Layers tab. Other RAS Layers, which are not used in the project, show a Null value. Export of GIS Data is performed in the following way: The menu item “RAS Geometry”→ “Extract GIS DATA” is selected from the HEC-GeoRas toolbar. The default name GIS2RAS is accepted and saved in Maps folder.

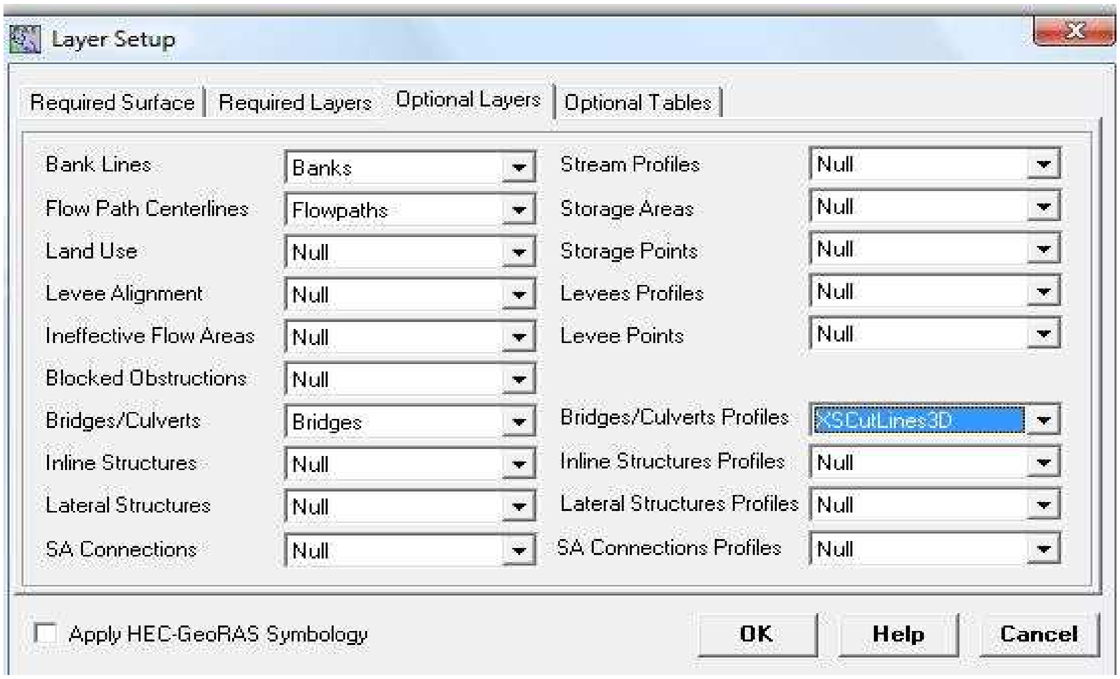


Figure 2.16 Optional Layers definition

For more GIS details, specific extensions or commands consult: HEC-GeoRAS4_Users Manual.pdf, September 2005 available on line from the US Army Corps of Engineers Hydrologic Engineering Center website: http://www.hec.usace.army.mil/software/hec-ras/hec-georas_downloads.html.

## 2.2 Hydraulic analysis

### *2.2.1 HEC-RAS basic concepts and equations*

HEC-RAS is an integrated software system, designed for interactive use in a multi-tasking environment and used to perform one-dimensional water surface calculations. HEC-RAS system is comprised of a graphical user interface, separate hydraulic analysis components, data storage and management capabilities, and graphing and reporting facilities (USACE, 2002 b).The most recent version of HEC-RAS supports steady and unsteady flow water surface profile calculations, sediment transport computations, and water temperature analysis (USACE, 2002 b). HEC-RAS is currently capable of performing one–dimensional water surface profile calculations for steady gradually varied flow in natural or constructed channels. It can handle a full network of channels or single river reach. Within steady flow it can be model subcritical, supercritical or mixed flow regime.

Computation engine of HEC-RAS is based on the solution of the one-dimensional energy equation. Energy losses are evaluated by friction (Manning's formula), contraction, and expansion. In cases where the water surface profile is rapidly varied, use of the momentum equitation is necessary. These cases include: mixed flow regime calculations, bridge hydraulic calculations and evaluation of profiles at river confluence. HEC-RAS is capable of calculating effects of bridges, culverts, dam's weirs, and other structures in the river and floodplain. The brief introduction of main concept and equations follows.

*Steady and Unsteady Flow***.** Flow in an open channel is steady if the depth, discharge, and mean velocity of flow at a particular location does not change with time, or if it can be assumed constant during the time period under consideration. If the depth, discharge and velocity of flow at some point changes with time, the flow is unsteady. A time factor is taken into account explicitly in the case of unsteady flow analysis, while steady flow analysis neglect time factors altogether.

*Uniform and Non Uniform Flow.* We say that channel flow is uniform if the depth, the discharge and the mean velocity do not change in space. This implies that the energy grade line, water surface elevation and channel bottom are all parallel for uniform flow. This type of flow rarely occurs in reality. Non-uniform flow is sometimes designated as varied flow and can be further classified as gradually varied and rapidly varied. The flow is rapidly varied if the spatial changes to the flow occur rapidly and the pressure distribution is not hydrostatic, otherwise it is gradually varied. Based on these classifications the steady flow can be uniform or varied. The unsteady flow is usually varied, as the unsteady uniform flow is practically impossible, because it would require that the water surface fluctuates from time to time while remaining parallel to the channel bottom (Chow, 1959). The basic assumption of the gradually varied flow computation is that the streamlines are practically parallel and hydrostatic pressure distribution prevails over the channel section. The head loss at a section is the same as with a uniform flow that has the same hydraulic radius of the section. Accordingly, the uniform flow equation may be used to evaluate the energy slope of a gradually varied flow, while the corresponding coefficient of roughness developed primarily for uniform flow is applicable to the gradually varied flow (Chow, 1959). These assumptions are valid for most river flows including flood flows. The assumption of hydrostatic pressure distribution requires the stream to have a small slope of 1:10 or less. Most floodplain studies are performed on streams which meet this requirement (USACE, 2002 b).

*Subcritical and Supercritical Flow.* The effect of gravity upon the state of flow is defined by a ratio of inertial force to gravitational force as the dimensionless Froude Number.

$$F = \frac{V}{\sqrt{gL}} \tag{2.1}$$

where,

F = Froude number (dimensionless)

V = mean channel flow velocity (m/s)

g = acceleration due to gravity (m/s2) and

L = characteristic length (m).

In open channel flow, the characteristic length is often taken as the hydraulic depth D, which is defined as the cross sectional area channel normal to the direction of flow divided by the width of the free surface. The flow is classified as subcritical, critical or supercritical, depending on the Froude number. When the Froude number is less than 1, the effect of gravitational force is less than the inertial force and the state of flow is referred to as subcritical flow. When inertial and the gravitational forces are equal, the Froude number is equal to unity and the flow is said to be at the critical stage. When the inertial forces exceed the gravitational force, the Froude number is greater than 1, and the flow is referred to as supercritical flow. The flow regime is an important criterion for the calculation of water surface profiles. When the state of flow is subcritical, the state of flow is controlled by channel characteristics at the downstream end of the river reach. In the case of supercritical flow, the flow is governed by the upstream end of the river reach.

*Continuity Equation.* In the steady open channel flow analysis, the continuity equation states that flow remain constant between adjacent cross-sections.

$$Q = A_1 V_1 = A_2 V_2 \tag{2.2}$$

Where:

$Q$ = flow rate/discharge ($m^3/s$)

$V_1, V_2$ = mean flow velocity (m/s) and

$A_1, A_2$ = cross-sectional flow area ($m^2$).

This equation allows tracing of changes in a cross-sectional area and velocity from location to location.

*Energy Equation.* Gradually varied water surface profiles are based on the principle of the conservation of energy, which states that the sum of the kinetic energy and potential energy at a particular cross section is equal to the sum of the potential and kinetic energy at any other cross section plus or minus energy loss or gains between the sections (Figure 2.17). Water surface is calculated from one cross section to the next by solving the energy equation written as:

$$Y_2 + Z_2 + \frac{\alpha_2 V_2^2}{2g} = Y_1 + Z_1 + \frac{\alpha_1 V_1^2}{2g} + h_e \tag{2.3}$$

where,

$Y_1, Y_2$ = depth of water at cross sections (m)

$Z_1, Z_2$ = elevation of main channel inverts (m)

$V_1, V_2$ = average velocities (total discharge/total flow area)

$g$ = gravitational acceleration

$\alpha_1, \alpha_2$ = velocity weighting coefficients (dimensionless) and

$h_e$= energy head loss (m).

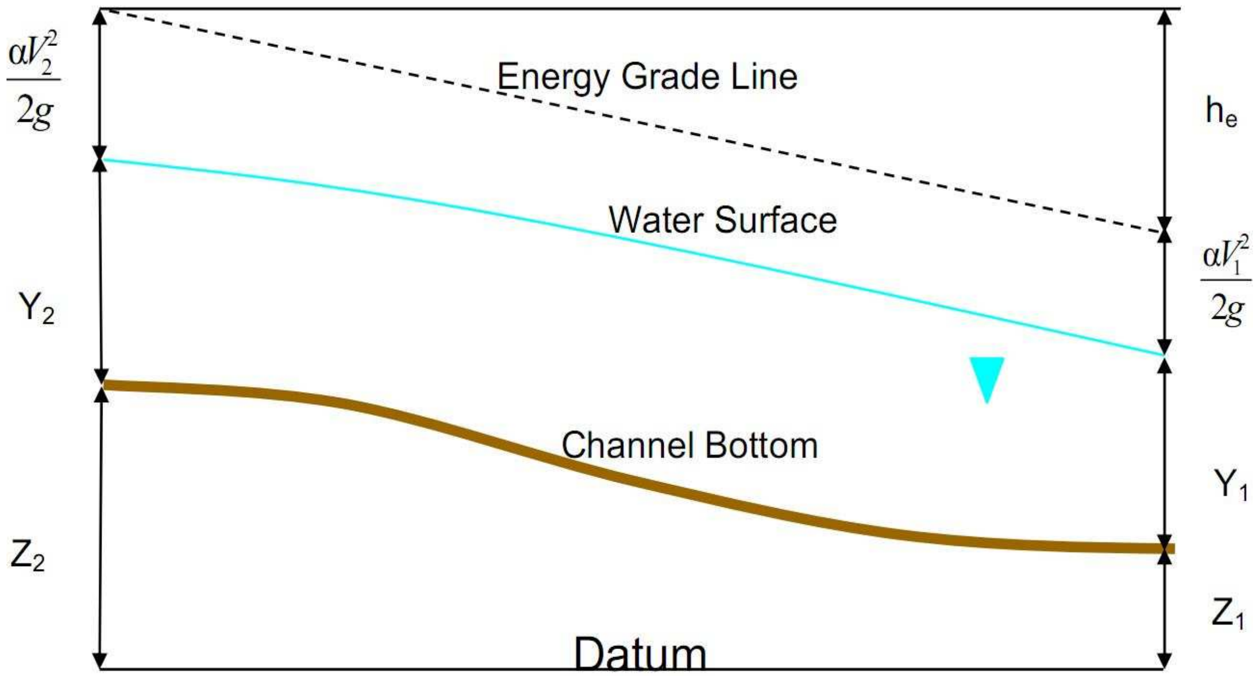


Figure 2.17 Representation of terms in the energy equation (after USACE, 2002 b)

Based on the energy equation, the energy head loss is the sum of friction losses and expansion, or contraction of coefficient.

$$h_e = L\overline{S_f} + C\left|\frac{\alpha_2 V_2^2}{2g} - \frac{\alpha_1 V_1^2}{2g}\right| \tag{2.4}$$

where,

$L$ = reach length between the adjacent cross sections

$S_f$ = friction slope between the two sections and

$C$ = expansion or contraction loss coefficient (dimensionless).

The magnitude of α depends upon the channel characteristics. Typical values of α, is shown in Table 2.1.

Table 2.1 Magnitude of α (after Debo and Reese, 2002)

| Channel | Value of α | | |
|---|---|---|---|
| | Min. | Avg. | Max. |
| Regular Channel | 1.1 | 1.15 | 1.2 |
| Natural Channel | 1.15 | 1.3 | 1.5 |
| Natural Channel-flooded overbanks | 1.5 | 1.75 | 2 |

*Manning's Loss Coefficient.* The energy losses due to the roughness of the river bed are usually evaluated in terms of Manning's Equation:

$$Q = KS_f^{1/2} \tag{2.5}$$

$$K = \frac{1}{n}AR^{2/3} \tag{2.6}$$

where:

K = conveyance of the section ($m^3s^{-1}$)
n = Manning's roughness coefficient ($m^{-1/3}s$) and
R = hydraulic radius (m).

Selecting the appropriate Manning's *n* value is very important for accurate computation of water surface profiles. The value of Manning's *n* is highly variable and depends upon a number of factors including: surface roughness, channel irregularities, channel alignment, size and shape of channel, scour and deposition, vegetation, obstructions, stage and discharge, seasonal change, temperature, suspended materials and bed load (USACE,2002 b). The *n* value decreases with increases in stage and discharge. When the water depth is shallow, irregularities of the channel bottom are exposed and their effect may become pronounced. However, the *n* value may be large at high stages if the banks are rough and grassy (Chow, 1959).

If there is observed water surface data (high water marks, gagged data), Manning's *n* values should be calibrated. If there is no observed data (like in this study), then values of *n* obtained from another stream with similar conditions should be used. There are several references available listing the typical *n* values. Excerpts of the n value from Chow (1959) for natural streams are given in the Table 2.2.

Table 2.1 Manning's *n* values

| Type of Channel and Description | Minimum | Normal | Maximum |
|---|---|---|---|
| A. *Natural Streams* | | | |
| 1. **Main Channels** | | | |
| a. Clean, straight, full, no rifts or deep pools | 0.025 | 0.030 | 0.033 |
| b. Same as above, but more stones and weeds | 0.030 | 0.035 | 0.040 |
| c. Clean, winding, some pools and shoals | 0.033 | 0.040 | 0.045 |
| d. Same as above, but some weeds and stones | 0.035 | 0.045 | 0.050 |
| e. Same as above, lower stages, more ineffective slopes and sections | 0.040 | 0.048 | 0.055 |
| f. Same as "d" but more stones | 0.045 | 0.050 | 0.060 |
| g. Sluggish reaches, weedy. deep pools | 0.050 | 0.070 | 0.080 |
| h. Very weedy reaches, deep pools, or floodways with heavy stands of timber and brush | 0.070 | 0.100 | 0.150 |
| 2. **Flood Plains** | | | |
| a. Pasture no brush | | | |
| 1. Short grass | 0.025 | 0.030 | 0.035 |
| 2. High grass | 0.030 | 0.035 | 0.050 |
| b. Cultivated areas | | | |
| 1. No crop | 0.020 | 0.030 | 0.040 |
| 2. Mature row crops | 0.025 | 0.035 | 0.045 |
| 3. Mature field crops | 0.030 | 0.040 | 0.050 |
| c. Brush | | | |
| 1. Scattered brush, heavy weeds | 0.035 | 0.050 | 0.070 |
| 2. Light brush and trees, in winter | 0.035 | 0.050 | 0.060 |
| 3. Light brush and trees, in summer | 0.040 | 0.060 | 0.080 |
| 4. Medium to dense brush, in winter | 0.045 | 0.070 | 0.110 |
| 5. Medium to dense brush, in summer | 0.070 | 0.100 | 0.160 |
| d. Trees | | | |
| 1. Cleared land with tree stumps, no sprouts | 0.030 | 0.040 | 0.050 |
| 2. Same as above, but heavy sprouts | 0.050 | 0.060 | 0.080 |
| 3. Heavy stand of timber, few down trees, little undergrowth, flow below branches | 0.080 | 0.100 | 0.120 |
| 4. Same as above, but with flow into branches | 0.100 | 0.120 | 0.160 |
| 5. Dense willows, summer, straight | 0.110 | 0.150 | 0.200 |
| 3. **Mountain Streams, no vegetation in channel, banks usually steep, with trees and brush on banks submerged** | | | |
| a. Bottom: gravels, cobbles, and few boulders | 0.030 | 0.040 | 0.050 |
| b. Bottom: cobbles with large boulders | 0.040 | 0.050 | 0.070 |

Table 2.1 Manning's *n* values-continued

| Type of Channel and Description | Minimum | Normal | Maximum |
|---|---|---|---|
| B. *Lined or Built-Up Channels* | | | |
| 1. **Concrete** | | | |
| a. Trowel finish | 0.011 | 0.013 | |
| b. Float Finish | 0.013 | 0.015 | 0.015 |
| c. Finished, with gravel bottom | 0.015 | 0.017 | 0.016 |
| d. Unfinished | 0.014 | 0.017 | 0.020 |
| e. Gunite, good section | 0.016 | 0.019 | 0.020 |
| f. Gunite, wavy section | 0.018 | 0.022 | 0.023 |
| g. On good excavated rock | 0.017 | 0.020 | 0.025 |
| h. On irregular excavated rock | 0.022 | 0.027 | |
| 2. **Concrete bottom float finished with sides of:** | | | |
| a. Dressed stone in mortar | 0.015 | 0.017 | 0.020 |
| b. Random stone in mortar | 0.017 | 0.020 | 0.024 |
| c. Cement rubble masonry, plastered | 0.016 | 0.020 | 0.024 |
| d. Cement rubble masonry | 0.020 | 0.025 | 0.030 |
| e. Dry rubble on riprap | 0.020 | 0.030 | 0.035 |
| 3. **Gravel bottom with sides of:** | | | |
| a. Formed concrete | 0.017 | 0.020 | 0.025 |
| b. Random stone in mortar | 0.020 | 0.023 | 0.026 |
| c. Dry rubble or riprap | 0.023 | 0.033 | 0.036 |
| 4. **Brick** | | | |
| a. Glazed | 0.011 | 0.013 | 0.015 |
| b. In cement mortar | 0.012 | 0.015 | 0.018 |
| 5. **Metal** | | | |
| a. Smooth steel surfaces | 0.011 | 0.012 | 0.014 |
| b. Corrugated metal | 0.021 | 0.025 | 0.030 |
| 6. **Asphalt** | | | |
| a. Smooth | 0.013 | 0.013 | |
| b. Rough | 0.016 | 0.016 | |
| 7. **Vegetal lining** | 0.030 | | 0.500 |

Table 2.1 Manning's *n* values-continued

| Type of Channel and Description | Minimum | Normal | Maximum |
|---|---|---|---|
| C. *Excavated or Dredged Channels* | | | |
| 1. **Earth, straight and uniform** | | | |
| a. Clean, recently completed | 0.016 | 0.018 | 0.020 |
| b. Clean, after weathering | 0.018 | 0.022 | 0.025 |
| c. Gravel, uniform section, clean | 0.022 | 0.025 | 0.030 |
| d. With short grass, few weeds | 0.022 | 0.027 | 0.033 |
| 2. **Earth, winding and sluggish** | | | |
| a. No vegetation | 0.023 | 0.025 | 0.030 |
| b. Grass, some weeds | 0.025 | 0.030 | 0.033 |
| c. Dense weeds or aquatic plants in deep channels | 0.030 | 0.035 | 0.040 |
| d. Earth bottom and rubble side | 0.028 | 0.030 | 0.035 |
| e. Stony bottom and weedy banks | 0.025 | 0.035 | 0.040 |
| f. Cobble bottom and clean sides | 0.030 | 0.040 | 0.050 |
| 3. **Dragline-excavated or dredged** | | | |
| a. No vegetation | 0.025 | 0.028 | 0.033 |
| b. Light brush on banks | 0.035 | 0.050 | 0.060 |
| 4. **Rock cuts** | | | |
| a. Smooth and uniform | 0.025 | 0.035 | 0.040 |
| b. Jagged and irregular | 0.035 | 0.040 | 0.050 |
| 5. **Channels not maintained, weeds and brush** | | | |
| a. Clean bottom, brush on sides | 0.040 | 0.050 | 0.080 |
| b. Same as above, highest stage of flow | 0.045 | 0.070 | 0.110 |
| c. Dense weeds, high as flow depth | 0.050 | 0.080 | 0.120 |
| d. Dense brush, high stage | 0.080 | 0.100 | 0.140 |

There are various methods and empirical formulae available for the estimation of the Manning's *n* value. Cowen (1956) developed a procedure for the estimation of formula for *n* as a function of type and size of the bed materials and channel properties. In Cowen's procedure, the *n* value is determined by the following equation:

$$n = (n_b + n_1 + n_2 + n_3 + n_4)m \tag{2.7}$$

where,

$n_b$ = base value of *n* for straight uniform & smooth channel in natural materials
$n_1$ = value added to correct surface irregularities
$n_2$ = value for variation in size and shape of channel
$n_3$ = value for obstructions
$n_4$ = value for vegetation and flow conditions and
$m$ = correcting factor to take account of the meandering of channel.

Limerinos (1970) related the *n* related value as the function of bed materials and hydraulic radius:

$$n = \frac{0.0926R^{-0.16}}{1.16 + 2\log(R/d_{84})} \tag{2.8}$$

where,

$R$ = hydraulic radius (feet) and
$d_{84}$= particle size diameter that is equal to or exceeds 84% of particle (feet).

Limerinos selected the reaches that had a minimum amount of roughness that were caused by factors other than the bed materials, and so these base *n* values should be increased to take account of other factors as shown in Cowen's method (USACE, 2002 b). This equation was developed for the data range of hydraulic radius 1.0 to 6.0 and $d_{84}$ 1.5 to 250 mm.

*Expansion and Contraction Coefficients.* The following equation is used for the determination of contraction and expansion losses.

$$h_{ce} = C\left|\frac{\alpha_1 V_1^2}{2g} - \frac{\alpha_2 V_2^2}{2g}\right| \tag{2.9}$$

where: $C$ = the contraction or expansion coefficient.

The coefficient of expansion and the coefficient of contraction are introduced to take into account losses due to the expansion or contraction of flow caused by changes in the cross sections. The losses due to these fluctuations are significant, particularly at points where there is an abrupt change in the cross section – for example at bridges.  Typical values of expansion and contraction coefficients for subcritical flow are given in Table 2.3.

Table 2.2 Subcritical Flow Expansion and Contraction Coefficient (USACE, 2002 b)

| Type of Channel | Contraction | Expansion |
|---|---|---|
| No transition | 0.00 | 0.00 |
| Gradual transition | 0.10 | 0.30 |
| Typical bridge sections | 0.30 | 0.50 |
| Abrupt transition | 0.60 | 0.80 |

*Friction Loss Evaluation.* Manning's equation is used for the calculation of energy slope as follows:

$$S_f = \left(\frac{Q}{K}\right)^2 \qquad (2.10)$$

There are also a few other alternative expressions for the representation of reach friction slope in HEC-RAS computer program.

### *2.2.2 Computation method*

The method of computation of water surface profiles for gradually varied flow is based on the assumption that the slope of the energy grade line at a section is equal to the energy slope for a uniform flow with the velocity and hydraulic radius of the section (Chow, 1959). Some of the basic steps in the computation of water surface profiles in HEC-RAS are explained below.

*Cross Section Subdivision for Conveyance Calculations.* The determination of the conveyance coefficient in HEC-RAS involves subdivision of flow into units based on Manning's coefficient *n* (Figure 2.18). The conveyance for each subdivision is calculated by using Equation (2.6). The total conveyance for the cross section is obtained by adding the three subdivision conveyances (left, channel, and right).

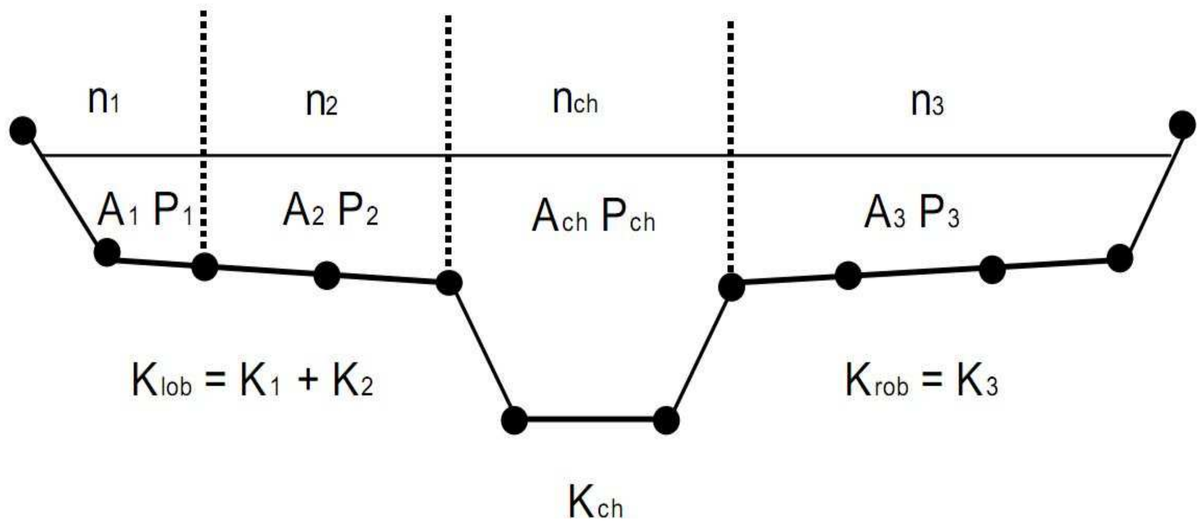


Figure 2.18 Conveyance Subdivision Method (after USACE, 2002 b)

*Mean Kinetic Energy Head Calculation.* Mean kinetic energy head for each cross section is obtained by computing the flow weighted kinetic energy heads for three subsections of the cross sections (main channel, right and left overbank). Figure 2.19 illustrates the mean kinetic energy calculation process for the cross section with the main channel and the right overbank.

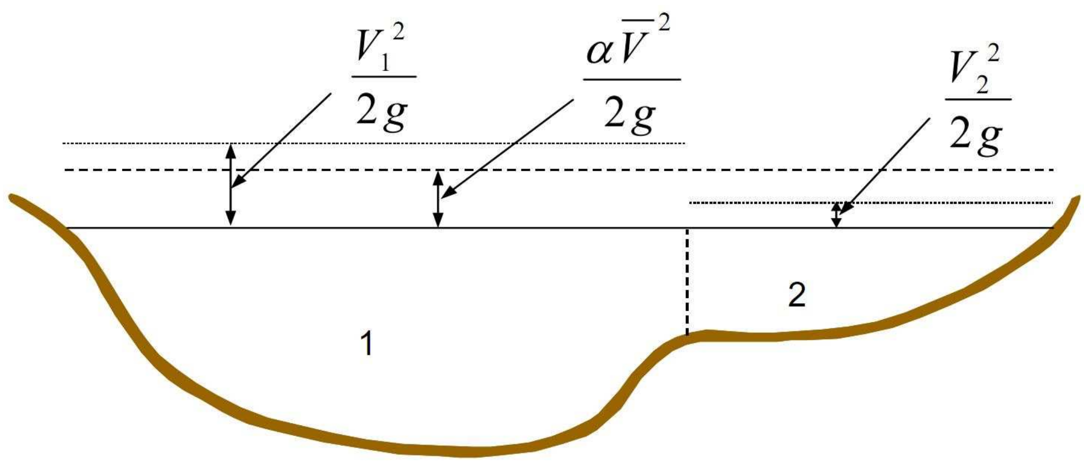


Figure 2.19 Example of Mean Energy calculation (after USACE, 2002 b)

$\boldsymbol{V_1}$ is mean velocity for the main channel and $\boldsymbol{V_2}$ is mean velocity for the right overbank.
The calculation of the mean energy head requires the velocity weighing coefficient α. The following equation, which is written in terms of conveyance and area, shows the calculation of α:

$$\alpha = \frac{(A_t)^2\left[\frac{K_{lob}^3}{A_{lob}^2} + \frac{K_{ch}^3}{A_{ch}^2} + \frac{K_{rob}^3}{A_{rob}^2}\right]}{K_t^3} \qquad (2.10)$$

where:
$A_t$ = total flow area of the cross section
$A_{lob}$, $A_{ch}$, $A_{rob}$ = flow areas of left overbank, main channel, and right overbank, respectively
$K_t$ = total conveyance of the cross section and
$K_{lob}$, $K_{ch}$, $K_{rob}$ = conveyance of left overbank, main channel and right overbank respectively.

*Standard Step Method.* The Standard Step Method can be used for both prismatic and non-prismatic channels, including the adjacent floodplain. This method can be applied to compute steady, gradually varied flow, and can also be used for both subcritical and supercritical flow. The computation for this method is based on the energy Equation (2.4) by steps from station to station. Depending upon the conditions of flow (subcritical or supercritical), the computations must be made in different directions. For subcritical flow that is under downstream control, the computation starts from downstream and proceeds upstream. For supercritical flow that is under upstream control, the computation starts from upstream and proceeds downstream. The computation steps used in this procedure for the subcritical flow are as follows (USACE, 2002 b):

1. Assume the water surface elevation at the upstream cross section.
2. Based on the assumed water surface elevation, determine the corresponding total conveyance and velocity head.
3. With values from step 2, calculate the frictional slope $S_f$ and solve Equation (2.4) for energy head loss ($h_e$)
4. With values from steps 2 and 3, solve Equation (2.3) for water surface elevation WS2.
5. The computed value of WS2 is compared with the assumed value in step 1, and steps 1 through 5 are repeated until the values agree with the predefined tolerance (.003 m).

### *2.2.3 Step by step modelling using HEC-RAS*

The following section presents brief manual for use of HEC-RAS program for computation of water surface profiles. The main objective of this presentation is to provide assistance to those who may not be familiar with the HESC-RAS computer program.

*Creating HEC-RAS project and importing geometry.* The initial step for using the program involves opening of the main HEC-RAS interface window and entering the title and file name.

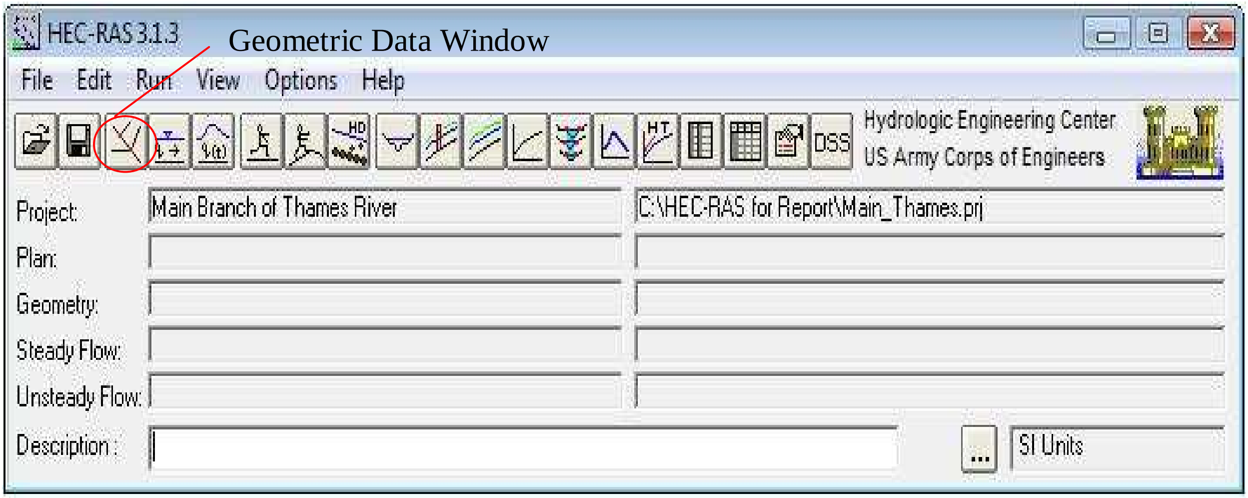


Figure 2.20 The main HEC-RAS window with the title and file name

The Geometric Data Window opens from the main HEC-RAS user window. To enter the geometry select: “File”→ “Import Geometry Data”→ “GIS Format”→ “Browse for Desired RAS GIS Import File (GIS2RAS.RASImpor.sdf)”. Firstly, from the Import Options window, SI (metric) units are selected. Then, “River and Reach Stream Lines” are selected. Cross sections and bridges for importing are checked by selecting tab “Cross Sections and IB Nodes” (Figure 2.21). The Geometry Data are saved in the Geometric Data window. Figure 2.22 shows the Geometric Data window with the georeferenced river system.

The next step involves the use of Cross Section Points Filter, because some cross-sections may have duplicate points or a high number of points (over 500). “Tools” and then the “Cross Section Points Filter” are selected from the Geometric Data window. For all rivers and tributaries, cross sections were filtered to 250 points.

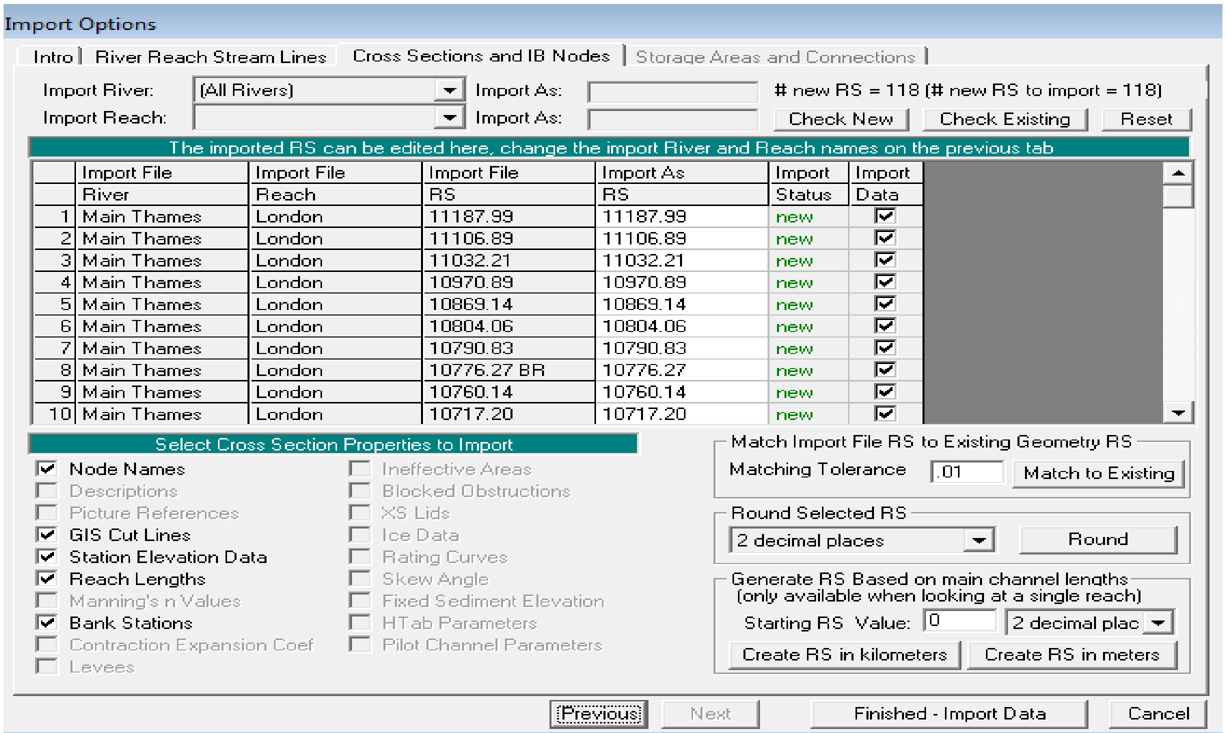


Figure 2.21 Import options window

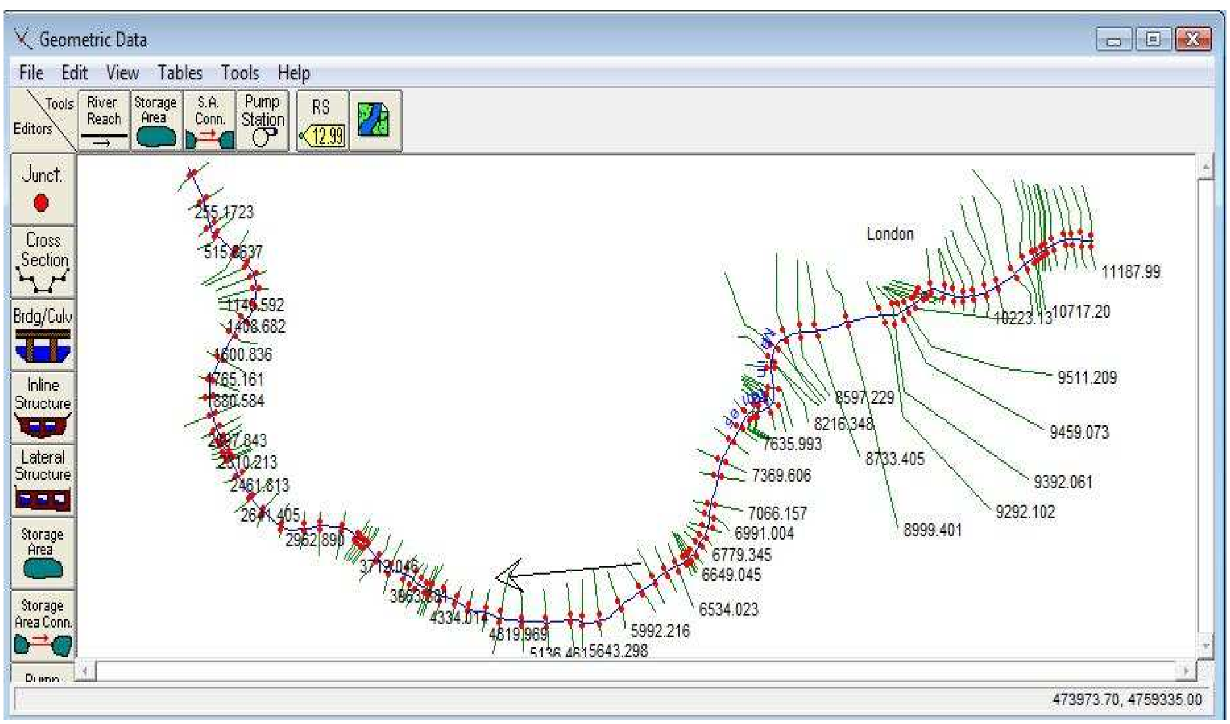


Figure 2.22 Geometric data window

The following sections describe steps and adjustments performed for geometric data completion.

*Cross-sections quality control.* First, the newly generated cross-sections are compared with the existing UTRCA cross-sections at the same locations. A significant difference in channel bottom elevation is subsequently observed. The newly generated cross-sections (using HEC-Geo RAS) usually have channel bottom elevation 1 m higher than the UTRCA cross-sections. The discrepancy between the cross sections is due to the TIN accuracy. Such a difference in channel bottom elevation would have produced inaccurate HEC-RAS water surface profiles.

In addition, many of the newly generated cross-sections look like the “mirror image” of the UTRCA cross-sections. The left side of some generated cross sections corresponds to the right side of the UTRCA cross sections, the and right side corresponds to the left side. The reason for this”mirror image” problem is inconsistency in the UTRCA cross-sections surveying. Since most of the UTRCA cross-sections were surveyed in the 1970s’ and 1980s’, a surveying standard - from left to right, looking in downstream direction was probably not used.

The difference in overbank areas is observed for some cross-sections too. Considering that the UTRCA cross-sections are surveyed more than 30 years ago, it is quite possible that some overbank areas did change.

The channel bottom elevation of newly generated cross sections is edited in order to make newly generated cross sections similar to the UTRCA cross section in the river channel area. The process of river bottom editing starts in HEC-GeoRAS pre-processing and the first step is TIN editing. TIN Editor Extension is used for editing of TIN’s contour lines. Basically, contour lines are extended within rivers (creeks). The criterion used in contour lines extension is to match the channel bottom elevation of surveyed UTRCA cross-sections. To achieve this task it is necessary to use UTRCA cross section shape files to determine the location of UTRCA cross-sections on the map during the TIN editing process. Generally, elevations of newly generated contour lines are slightly above the channel bottom elevations of the UTRCA cross-sections. Process is so demanding that it was not possible to change contour elevation for every cross-section. This problem is addressed through cross-section editing in the HEC-RAS. Although it is possible to edit cross-sections directly in the HEC-RAS, TIN editing is necessary to provide for floodplain mapping. Without the extension of the TIN's contour lines (TIN editing), floodplain lines would remain discontinued at many locations, especially in the case of smaller creeks.

After the new TIN is created, attributes are assigned for GIS Layers (River, XS Cut Lines, Bridges, etc) as explained in the pre-processing. As mentioned earlier, use of the same contour line elevation for few cross sections in pre-processing resulted in an irregularity of the longitudinal profile. Longitudinal sections consisted of cross-sections with the same elevation. This problem is addressed by editing the cross-sections channel bottom elevations in the HEC-RAS. From the Geometric Data window, Graphical Cross Sections Edit option is chosen from the Tools tab, to start the editing process. First, the editing of cross-sections, which have corresponding UTRCA (surveyed) cross-sections at the same locations, has been done. In order to increase the accuracy of HEC-RAS modelling and floodplain mapping for this project, more cross-sections are generated between the existing UTRCA cross-sections. Channel bottom elevations of these cross-sections are edited using the interpolation between 2 already edited cross sections. After the completion of this tedious task, the geometric data completion continues.

*Determination of bank points.* In some cross sections, the bank stations are found to be improperly located. Some of them ended on the river bottom and some at different elevations. First, the HEC-RAS model is run with a small return period (2 or 5 yr of historic flows). Then bank stations were corrected manually based on the water surface elevation results. The bank stations of surveyed UTRCA cross-sections, are also used to perform these manual corrections.

*Manning's n values.* Manning's n values are part of the Geometry data required for HEC-RAS modelling. Since UTRCA HEC-RAS models are from the 1980's, revision of Manning's *n* values is necessary. In some cases, a horizontal variation in *n* values is used to increase accuracy for Manning's value. For this project, Manning's *n* values are adopted based on Chow (1959), Aerial photo (London50 RGB 2007) and *n* values from existing UTRCA HEC-RAS models. For residential areas, n = 0.08 - 0.12 is used, and for industrial areas, n = 0.1.

*Bridge data.* The main source for Bridge Data (Deck/Roadway Data) is the existing set of UTRCA HEC-RAS models. The data for missing and newly built bridges are obtained from the City of London. The appropriate placing of bridge cross-sections (four for each bridge) is explained in the pre-processing section. The bridge bounding cross-sections 2 and 3 are shown in Figure 2.23, below.

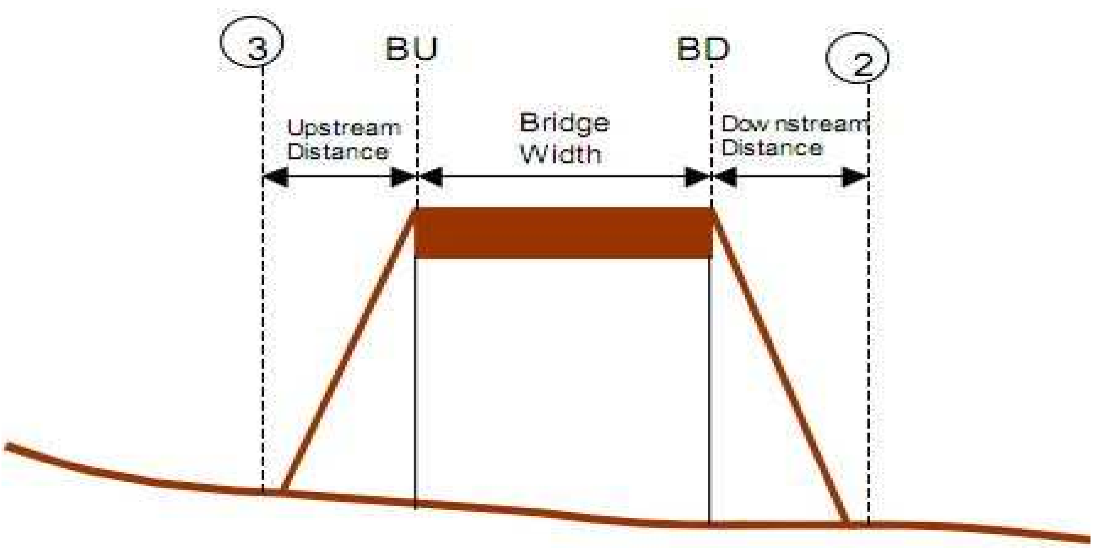


Figure 2.23 Bridge bounding cross sections (after USACE 2006)

HEC-RAS automatically adds two more cross sections, immediately inside the upstream (BU for bridge upstream) and downstream (BD for bridge downstream) bridge faces. These two new cross sections appear in the Bridge/Culvert Data Editor window. The bridge deck editor is used to describe the area that is blocked out by the bridge deck and road embankment. Since the difference in cross sections (HEC-GeoRAS cross sections and existing UTRCA cross sections) it is not possible to copy and paste bridge deck data. Stations data from the Deck/Roadway Data Editor (UTRCA HEC-RAS models) is manually adjusted to correspond to stations in HEC-GeoRAS cross sections. This process was tedious, but the only solution for using bridge deck data from UTRCA HEC-RAS models. Especial difficulty is experienced for bridges under the slope and UTRCA bridge bounding cross sections surveyed in opposite directions.

For missing bridges (not present in UTRCA HEC-RAS models), the bridge deck data is obtained from drawings and combined with extracted bridge deck elevations in pre-processing. Ne bridges are added to the model at the following locations:

Main Branch of Thames River

- Bridge 1 (Oxford St W)
- Bridge 2 (Boler Rd)
- Bridge 4 (Foot Bridge at Thames Valley Golf Course)
- Bridge 5 (Wonderland Rd S)
- Bridge 6 (Railway bridge at Greenway Park)

North Branch of Thames River

- Bridge 6 (Gibbons Park Foot Bridge)
- Bridge 11 (Clarke Road)

Pottersburg Creek

- Bridge 4
- Culvert 4

Dingman Creek and Tributaries

- Dingman Creek (Reach 13)-Bridge 39
- Tributary 13 (K)-Culvert 28
- Tributary 12 (J)-Culvert 22
- Tributary 10 (R)-Culvert 6 and Culvert 7

In the existing UTRCA HEC-RAS for North Thames, two bridges at Richmond Street are modeled separately. In this study, these two bridges are modeled as one bridge because the distance between bridges is only about 1m and there is no contraction and expansion of flow between bridges. Bridge Geometry (bridge openings, high cord and low cord elevation, peers) is virtually identical for both bridges.

It was observed that bridge 13 (Parkhurst Ave) on Pottersburg Creek is replaced with new bridge. A technical documentation for the new bridge is used for entering its geometric properties. Bridge geometry from UTRCA and UWO HEC-RAS models, and bridge photo, are shown in Figures 2.24, 2.25 and 2.26.

Figure 2.24 Parkhurst Ave Bridge (after City of London)

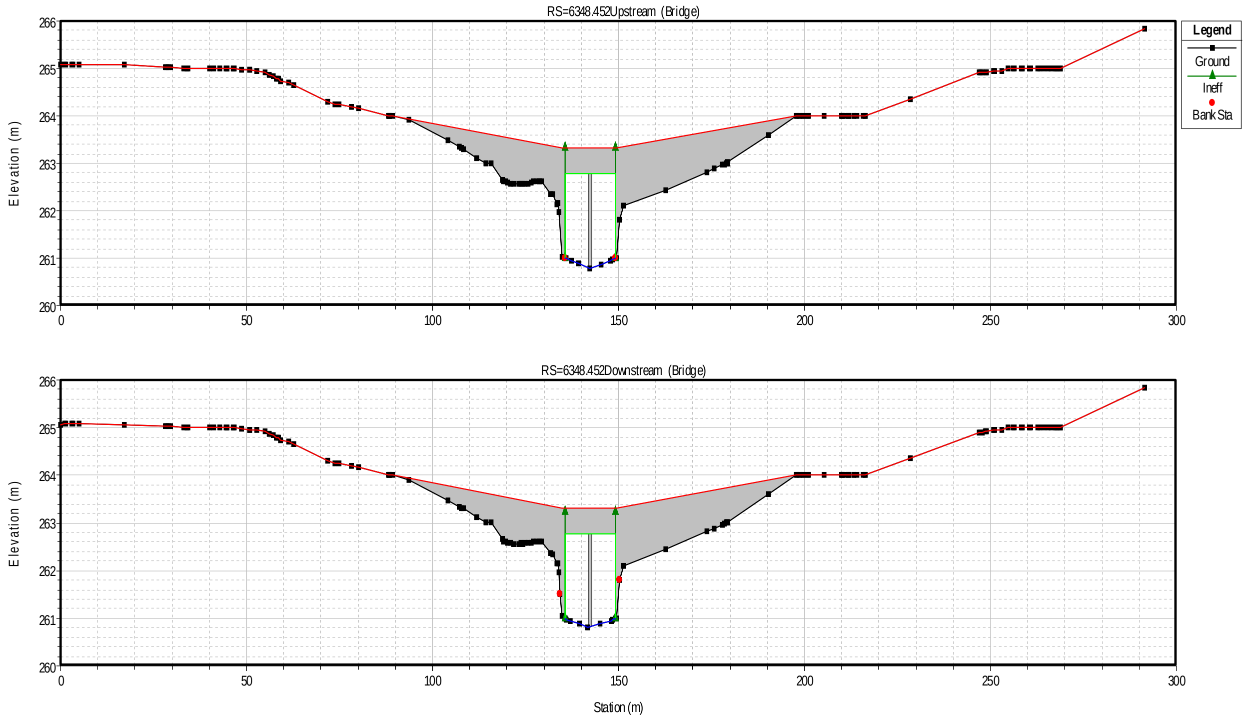


Figure 2.25 Parkhurst Ave Bridge (UWO HEC-RAS)

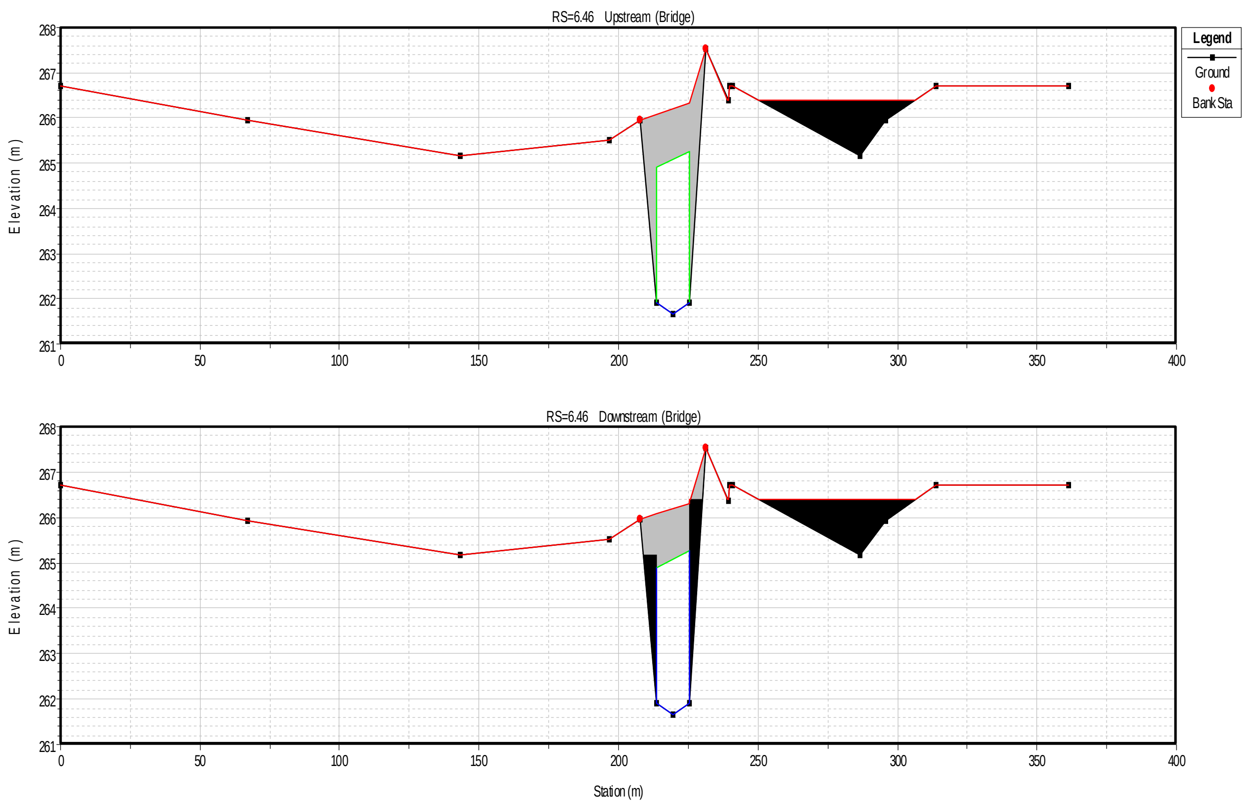


Figure 2.26 Parkhurst Ave Bridge (existing UTRCA HEC-RAS)

Data for the Wonderland Bridge on the Dingman Creek is used from the third sources, DELCAN HEC-RAS model, instead of UTRCA HEC-RAS model. The new bridge is constructed in the place of the old culvert and that change has not yet been incorporated in the existing UTRCA Dingman HEC-RAS model.

The following bridge modeling approach is adopted for all bridges. For low flow conditions if bridge has no peers, energy (standard step) equation is used and if bridge has peers the Yarnell (class A only) calculation is implemented. For high flow conditions pressure and/or weir method is used for all bridges

*Levees.* At some cross sections, levee option is used in HEC-RAS in order to correctly distribute flow between the river channel and the overbanks. This option is originally introduced to represent the existing levees (dikes). When levee is in place, no water can enter the floodplain until the levee elevation is exceeded (USACE, 2002 b).

In the Medway HEC-RAS model developed in this study, the levee is set on the left side of the river (approximate length is 300 m) to represent a man-made vertical wall. Levee is set at 7 cross sections. It starts at the cross section 739.48 m and ends at cross section 1031.450 m.

Levees are also used for the cross sections with a lower elevation of overbank area. However, they are only used in cases where the overbank area could not convey flow until the channel is overtopped. Figures 2.2.7 and 2.28 show HEC-RAS results for a cross section with and without levee.

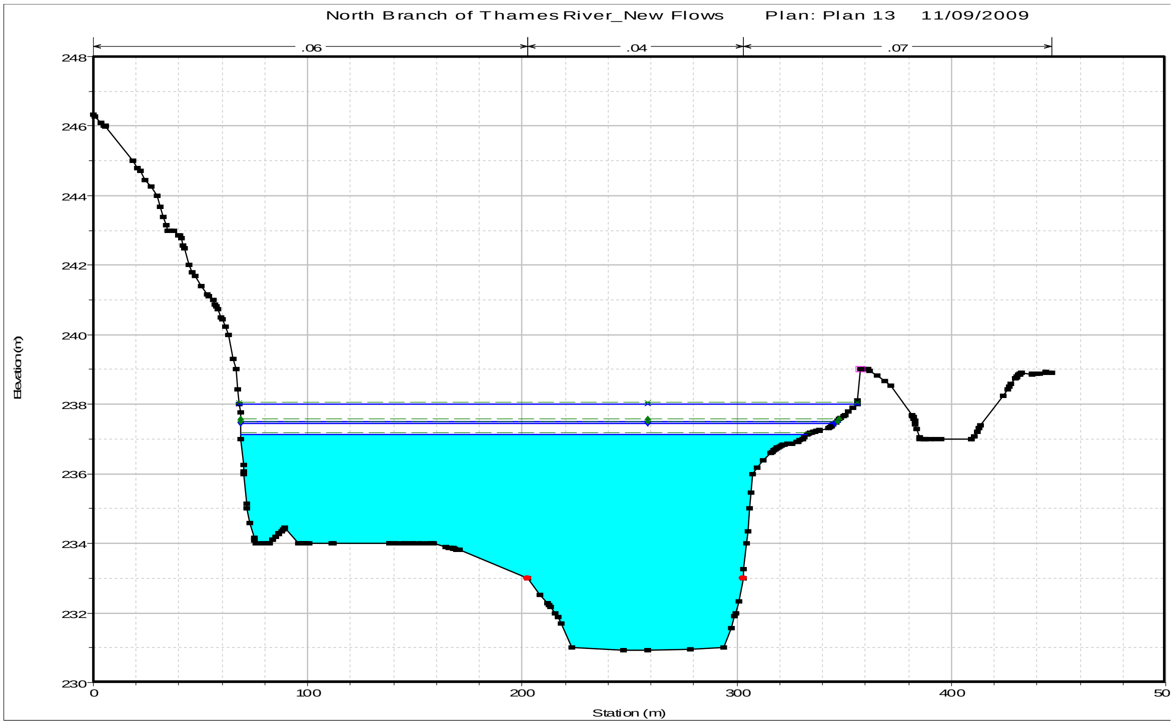


Figure 2.27 A cross section at the North Thames River with the levee

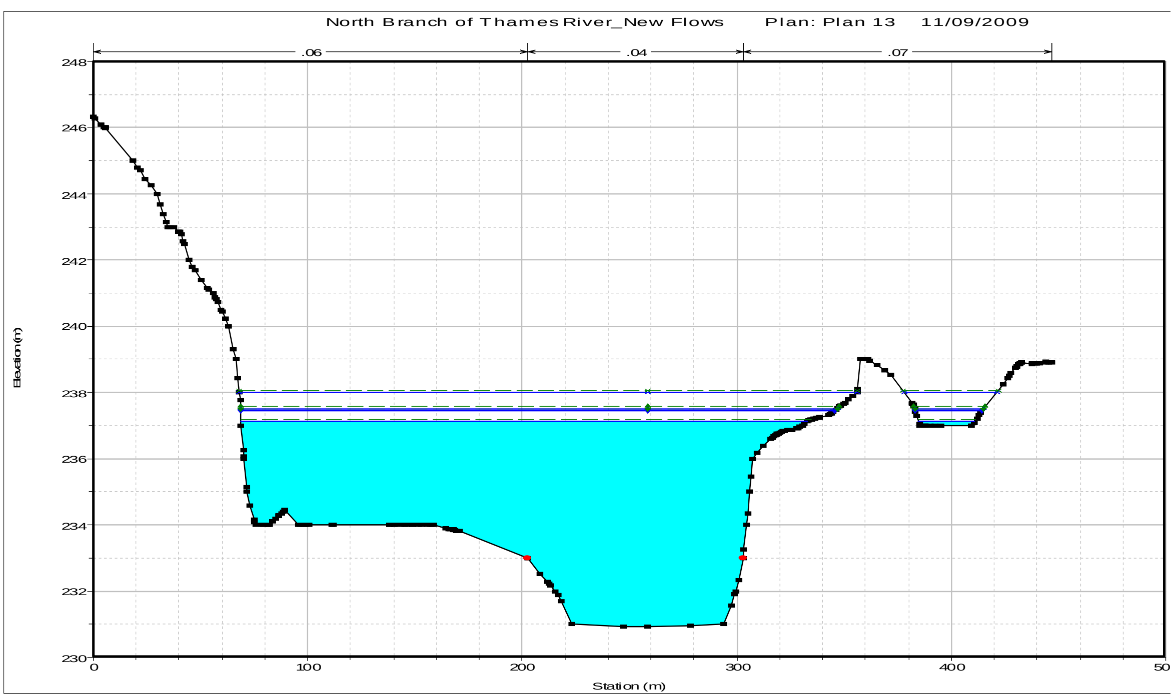


Figure 2.28 A cross section at the North Thames River without the levee

*Flow data and boundary conditions.* The hydraulic analysis is performed using flow data for climate scenarios named: Historic Climate Scenario and Wet Climate Scenario. For both climate scenarios, steady flow data are entered for the flow return periods of 100- and 250-years. Flow changes are entered at the same locations as in the existing UTRCA HEC-RAS models. More information on climate and hydrologic modeling is provided in the report by Eum and Simonovic (2009).

Since no observed flow data (Known Water Surface) is available, it was very important to choose appropriate Steady Flow Boundary Conditions. Usually, if there is no observed data, the normal depth is used. However, another approach for setting the boundary conditions is used in this study. First, the existing UTRCA HEC-RAS model "Thames River from Byron to Delaware" is run with new flow data for both climate scenarios and both return periods. The above mentioned HEC-RAS model is long enough (about 20 km) so the influence of boundary conditions at the first cross section do not affect the upstream results. Then, the calculated surface water elevation at the last cross section, which is also the first cross section for the UTRCA HEC-RAS model "Main Branch of Thames River," is used as boundary condition for the climate change calculations. Since the metric system is used, Known Water Surface is in meters. The last cross section of this model is at "Fork" – a location at which the North Thames and South Thames converge to form the Main Thames River. The model is then run with the climate change flow data and the results at the above mentioned cross section are used as boundary conditions for UTRCA HEC-RAS models: "North Thames" and "South Thames". After these two models were run with the climate change flow data, boundary conditions are determined for each tributary. For example, results from the first downstream cross section (UTRCA Xs # 3.885) at the North Thames, after confluence with the Medway Creek, are used as boundary conditions for the Medway Creek. Results for other creeks are determined in a similar fashion. Table 2.3 shows boundary conditions for all rivers and creeks, with the exception of the Dingman Creek. The Dingman Creek model starts 12 km from the confluence with the main branch of the Thames River, and the boundary conditions could not be determined here. Instead, a normal depth is used as the boundary condition for the Dingman Creek.

Table 2.3 Flow and boundary conditions

| North Thames | Historic Climate Scenario | | Wet Climate Scenario | |
|---|---|---|---|---|
| Event | 100 year | 250 year | 100 year | 250 year |
| Flow ($m^3$/sec) | 902.43 | 1031.54 | 1099.53 | 1258.11 |
| Boundary Conditions (m) | 235.2 | 235.79 | 235.95 | 236.58 |

| South Thames | Historic Climate Scenario | | Wet Climate Scenario | |
|---|---|---|---|---|
| Event | 100 year | 250 year | 100 year | 250 year |
| Flow ($m^3$/sec) | 569.33 | 655.74 | 655.66 | 754.23 |
| Boundary Conditions (m) | 235.2 | 235.79 | 235.78 | 236.58 |

| Main Thames | Historic Climate Scenario | | Wet Climate Scenario | |
|---|---|---|---|---|
| Event | 100 year | 250 year | 100 year | 250 year |
| Flow ($m^3$/sec) | 1414.98 | 1618.52 | 1658.24 | 1895.57 |
| Boundary Conditions (m) | 225.61 | 226.12 | 226.22 | 226.77 |

| Medway Creek | Historic Climate Scenario | | Wet Climate Scenario | |
|---|---|---|---|---|
| Event | 100 year | 250 year | 100 year | 250 year |
| Flow ($m^3$/sec) | 70.96 | 80.58 | 72.14 | 83.96 |
| Boundary Conditions (m) | 239.43 | 239.8 | 239.8 | 240.2 |

| Stoney Creek | Historic Scenario | | Wet Climate Scenario | |
|---|---|---|---|---|
| Event | 100 year | 250 year | 100 year | 250 year |
| Flow ($m^3$/sec) | 55.92 | 64.5 | 62.18 | 71.53 |
| Boundary Conditions (m) | 242.51 | 242.73 | 242.87 | 243.14 |

| Mud Creek | Historic Climate Scenario | | Wet Climate Scenario | |
|---|---|---|---|---|
| Event | 100 year | 250 year | 100 year | 250 year |
| Flow ($m^3$/sec) | 9.4 | 10.81 | 10.23 | 11.72 |
| Boundary Conditions (m) | 233.97 | 234.59 | 234.59 | 235.41 |

| Pottersburg Creek | Historic Climate Scenario | | Wet Climate Scenario | |
|---|---|---|---|---|
| Event | 100 year | 250 year | 100 year | 250 year |
| Flow ($m^3$/sec) | 123.45 | 143.3 | 141.43 | 163.69 |
| Boundary Conditions (m) | 241.99 | 242.3 | 242.3 | 242.62 |

As it can be seen from Table 2.3, the Main Thames River flow for the wet climate scenario and return period of 100 years is higher than the flow for the historic climate scenario and 250 years return period. Accordingly, the water surface elevation results at the last cross section of the Main Thames (located at "Fork") follow the same pattern. The results at this cross section are used as boundary conditions for the North Thames and the South Thames. Since the South Thames 250-year flow for the historic climate scenario is slightly larger than the 100-year wet climate scenario flow, it is necessary to make an assumption about boundary conditions. The South Thames boundary conditions for 100 year wet climate scenario and 250 year historic climate scenario are equalized to avoid situations where the higher flow has a lower value for the boundary condition. Similar assumptions are used for the Medway Creek and the Mud Creek.

*HEC-RAS computation and data export.* After the geometric data is completed and the steady flow data and new boundary conditions are entered, the HEC-RAS system is executed for the subcritical flow profile. The output results are checked for hydraulic correctness.

The final step involves export of the computation results (water surface elevation) back to GIS. The following computational steps are used from the main HEC-RAS window: "File"→ "Export GIS Data". In the GIS export window, all four profile results (for the four flow scenarios) are selected and exported using the default format "RASexport.sdf". Figure 2.29 shows the GIS Export window and the selected profiles used for export.

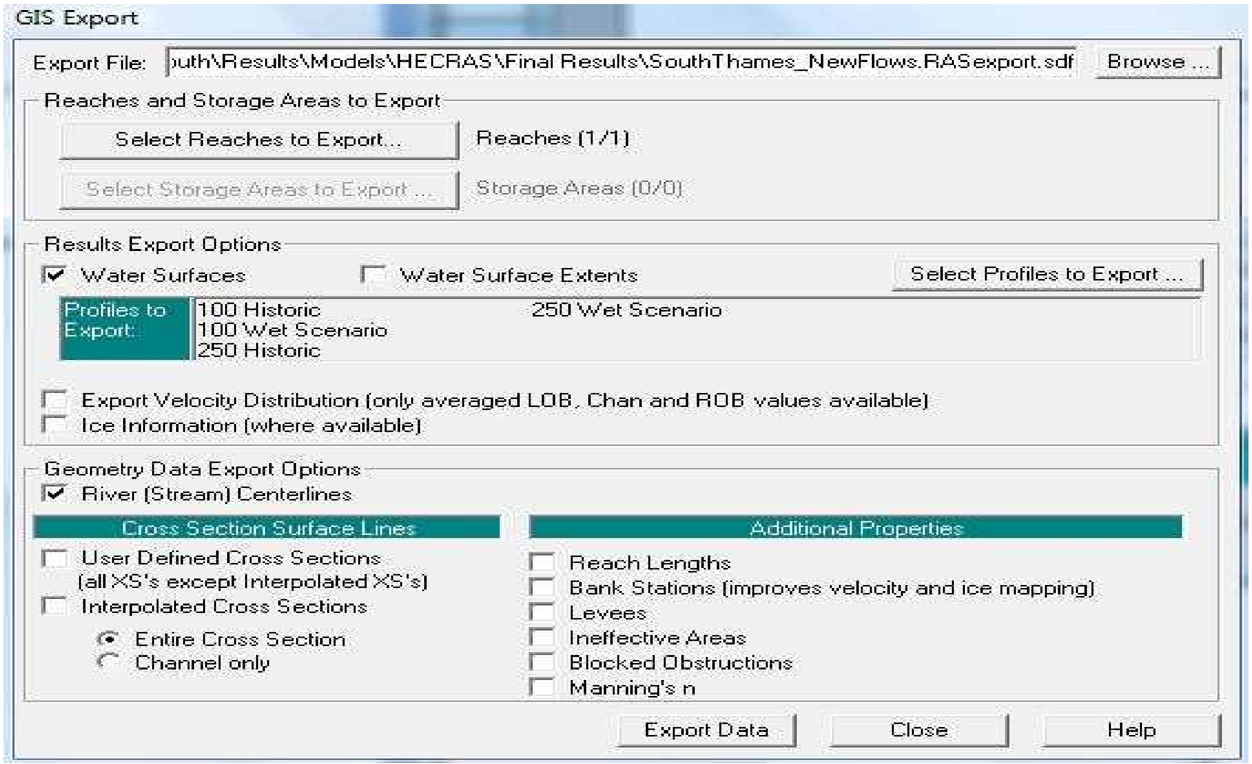


Figure 2.29 GIS export window in the HEC-RAS

## 2.3. Post-processing of hydraulic results and floodplain mapping

The post-processing of computation results is performed using the same maps which where used for the pre-processing of geometry data. The only additions to these maps are new map layers. The exceptions are made for the Dingman Creek and the Pottersburg Creek. For these, post-processing is performed using new maps. Due to the large area covered by the Dingman Creek, its post-processing is quite complicated and requires the creation of a very large TIN. Hardware limitations (when using resolution of 2 map units) required floodplain mapping of the Dingman Creek to be done using two maps. Detailed explanation of the data post-processing follows.

### *2.3.1 Data import from HEC-RAS*

*Formatting.* The process starts with opening a desired ArcMap for post-processing. Since the HEC-GeoRAS cannot read the proprietary spatial data format (.RASExport.sdf) file created in the HEC-RAS, it is necessary to convert it into the XML file format, supported by HEC-GeoRAS. This is achieved by selecting the "Import RAS SDF File" option from the HEC-Geo RAS Toolbar.

*Layer setup.* Establishing the Layer Setup is a necessary step for processing the HEC-RAS results. In the Layer Setup window, the type of analysis and the input and output data are identified. Figure 2.30 shows a typical Layer Setup window from the data post-processing. For the post-processing analyses, the rasterization cell size is set to 2 map units. Basically, a smaller number of map units results in a better representation of the resulting floodplain boundary during the floodplain delineation. Since at some places (especially at the Dingman tributaries) the floodplain lines are too coarse, an attempt is made to rasterization cell size to 1 map unit. However, the program is not able to handle this resolution, and two map units are used as the best possible rasterization cell size.

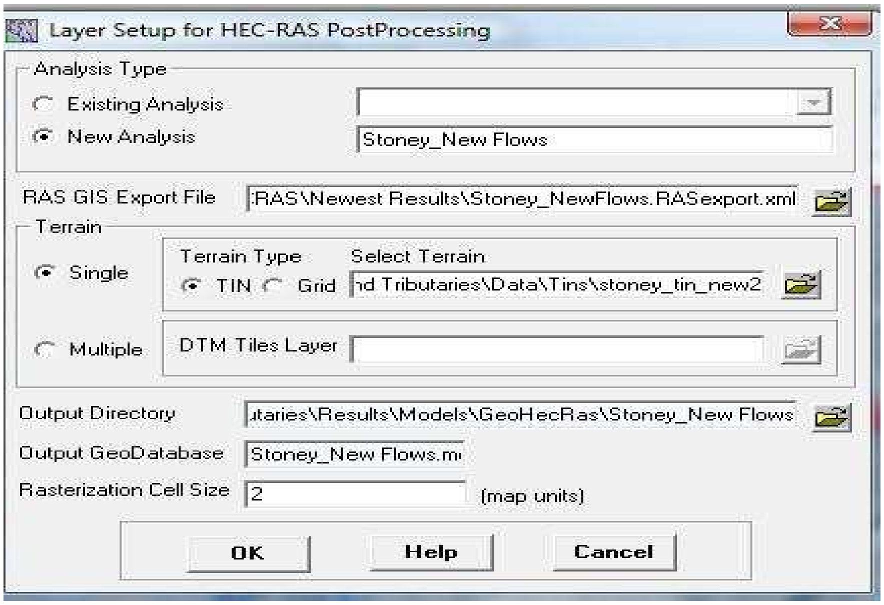


Figure 2.30 Layer setup window

*Reading RAS GIS export file.* After input data is entered in the layer setup, the HEC-RAS results have to be imported into the GIS in order to continue with the post-processing. The following computational steps are selected from the HEC-GeoRAS toolbar: "RAS Mapping"→ "Read RAS GIS Export File". This selection introduces a new data frame with the following feature classes: River2D, XS Cut Lines, and Bounding Polygon.

*2.3.2 Floodplain mapping*

Floodplain mapping is performed using the water surface elevations on the XS cut lines, within the limits of the bounding polygon. Floodplain mapping is completed in two steps, which are explained in following paragraphs.

*Water surface TIN.* The first step is to create a water surface TIN from the cross section water surface elevations. The following computational steps are selected from the HEC-GeoRAS toolbar: “RAS Mapping”→ “Inundation Mapping”→ “Water Surface Generation”. All four water surface profiles are selected from the window, as shown in Figure 2.31.

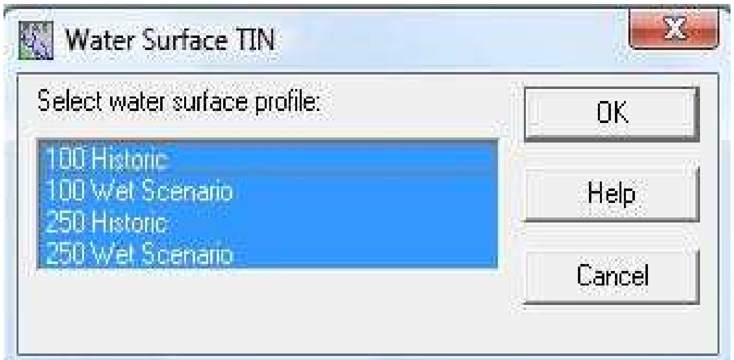


Figure 2.31 Selected water surface profiles for the water surface TIN generation

For each selected water surface profile, a water surface TIN is created without consideration of the terrain model. The TIN is created using the ArcGIS triangulation method. This allowed for the creation of a surface using cut lines as hard break lines with constant elevation. Also, areas which are of little interest are still included in the water surface TIN. These areas are removed in the process of delineation with the bounding polygon. Figure 2.32 shows the water surface TIN.

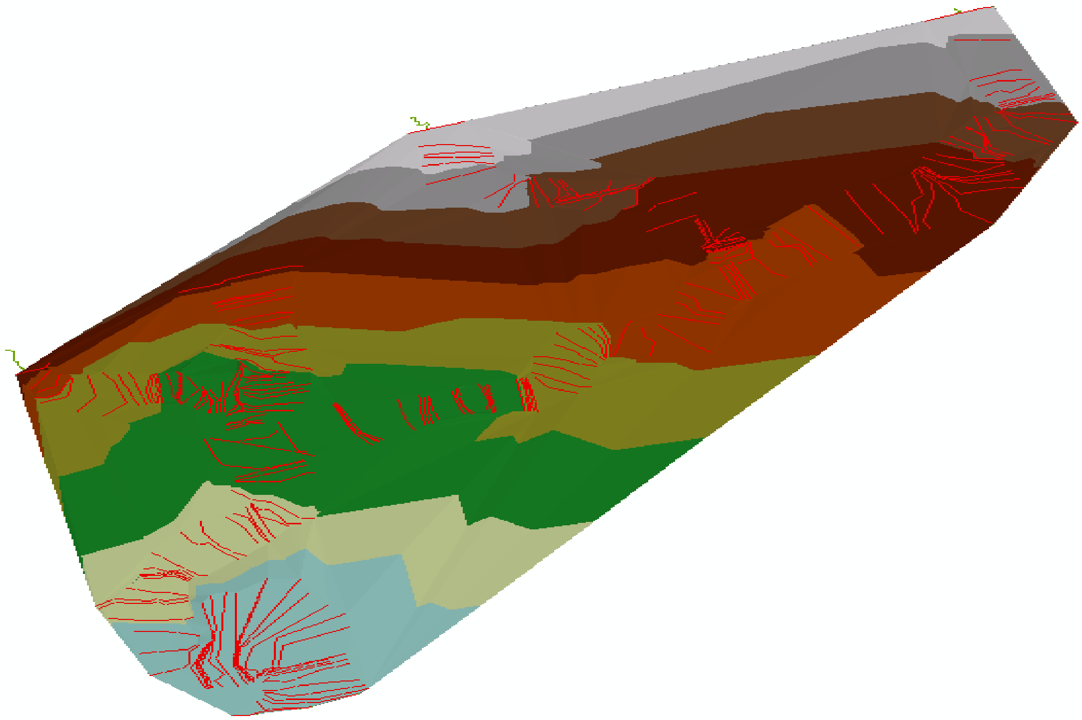

Figure 2.32 Water surface TIN (the Stoney Creek and Tributaries)

*Floodplain delineation.* The following computational procedure is used from the HEC-GeoRAS toolbar: “RAS Mapping”→“InundationMapping”→“Floodplain Delineation”→“GRID Intersection”. Again, all four water surface profiles are selected from the window, Figure 2.33. The water surface TIN is converted into a grid based on the rasterization cell size. Then, it is compared with the TIN terrain model, which is also in grid format, allowing the elevation difference to be calculated within the bounding polygon. The areas with positive results (where water surface is higher than the terrain elevation) are included in the floodplain area (inundation depth grid), and the areas with negative results are considered as dry. The depth grid has prefix “d” (“d” is for depth) before the profile name, e.g. d 250 Historic. Then, the floodplain boundary feature class is created based on the depth grid. The flood boundary has prefix “b” (“b” is for boundary), before the profile name, e.g. b 250 Historic. The floodplain boundary and the depth grid are added to the analysis map. The feature classes named b 100 Historic, b 100 Wet Scenario, b 250 Historic, and b 250 Wet Scenario represent the floodplain boundary feature classes on the analysis map. The grids d 100 Historic, d 100 Wet Scenario, d 250 Historic, and d 250 Wet Scenario represent the water inundation depths within the delineated floodplains.

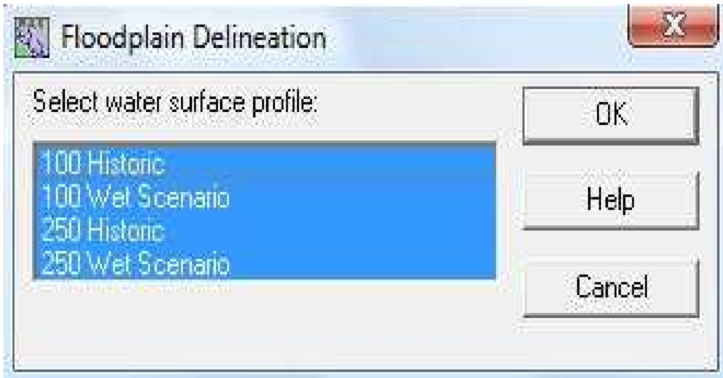


Figure 2.33 Selected water surface profiles for the floodplain delineation

Figure 2.34 shows floodplain results from the HEC-GeoRas model at one section of the Stoney Creek and Tributaries. The floodplain boundary (b 250 Wet Scenario) is represented by a yellow line. The inundation depth grid is represented with different hues of blue. The largest value of water depth is represented by a dark blue, and the smallest value of water depth is represented by a light blue. By using the “identify tool” button, water depth at any point can be easily identified. For example, in Figure 2.34, the arrow points to a water depth of 2.249m. More flood plain results are presented in the next chapter of the report.

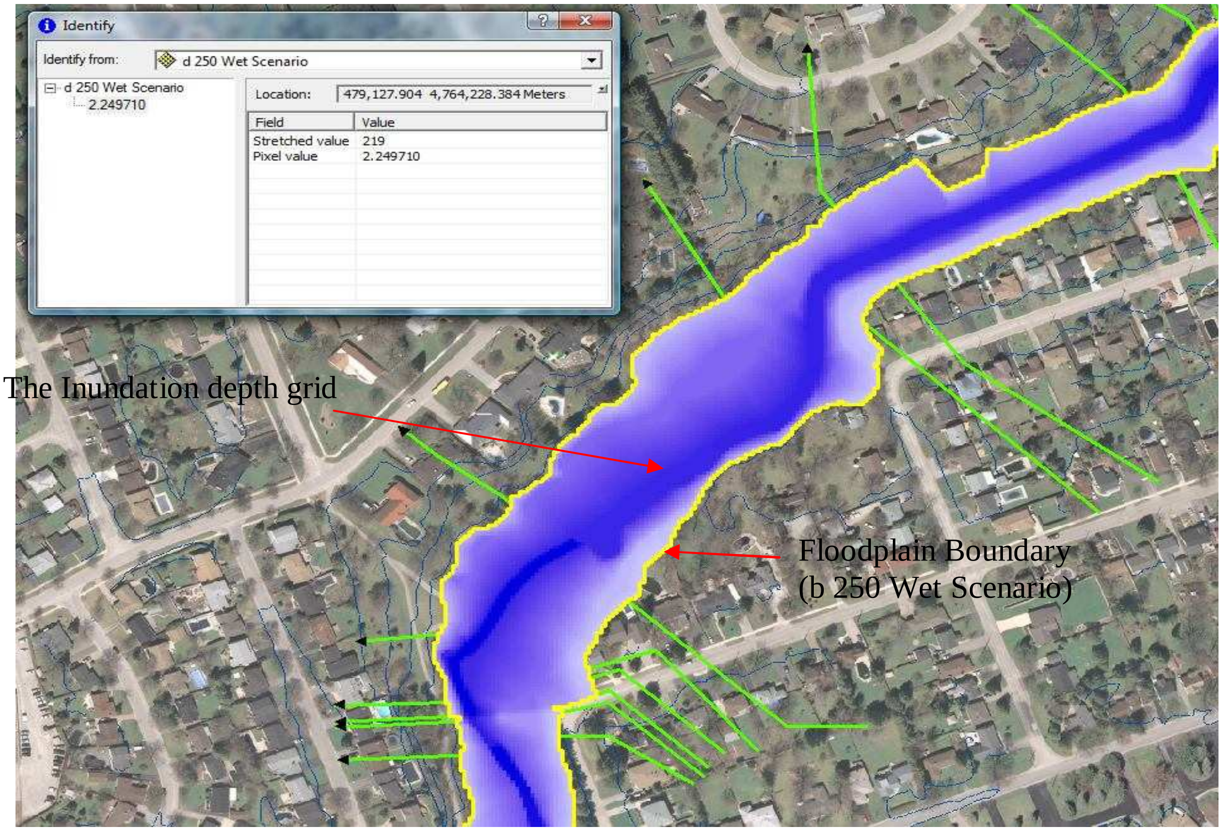


Figure 2.34 Floodplain results for one section of the Stoney Creek

### *2.3.3. Review and editing the floodplain results*

The first review step is to verify that the cross sections are wide enough to allow for the proper floodplain delineation. In the verification process it was noticed that at some location further extension of the cross sections is required. This ended up in the repetition of all steps for modified cross sections: assignment of new attributes, export of a new RAS GIS file to HEC-RAS, running HEC-RAS, export of HEC-RAS results to ArcGIS, and the floodplain mapping.

Another problem is noticed in the floodplain delineation of levee areas close to the "Fork" (merging point of the North Thames and the South Thames). At some cross sections where levee points are not overtopped, the floodplain results are not satisfactory. The calculated dry areas pointed to another deficiency of the floodplain mapping process.  Figure 2.35 shows a typical problem in floodplain mapping at the Main Thames River. In the figure the dry area is pointed to by an arrow. The terrain close to the river at both bounding cross sections is high, and water could not overtop it.  Since terrain elevation of the dry area is lower then the water surface elevation at the upstream cross section, this area should be flooded.

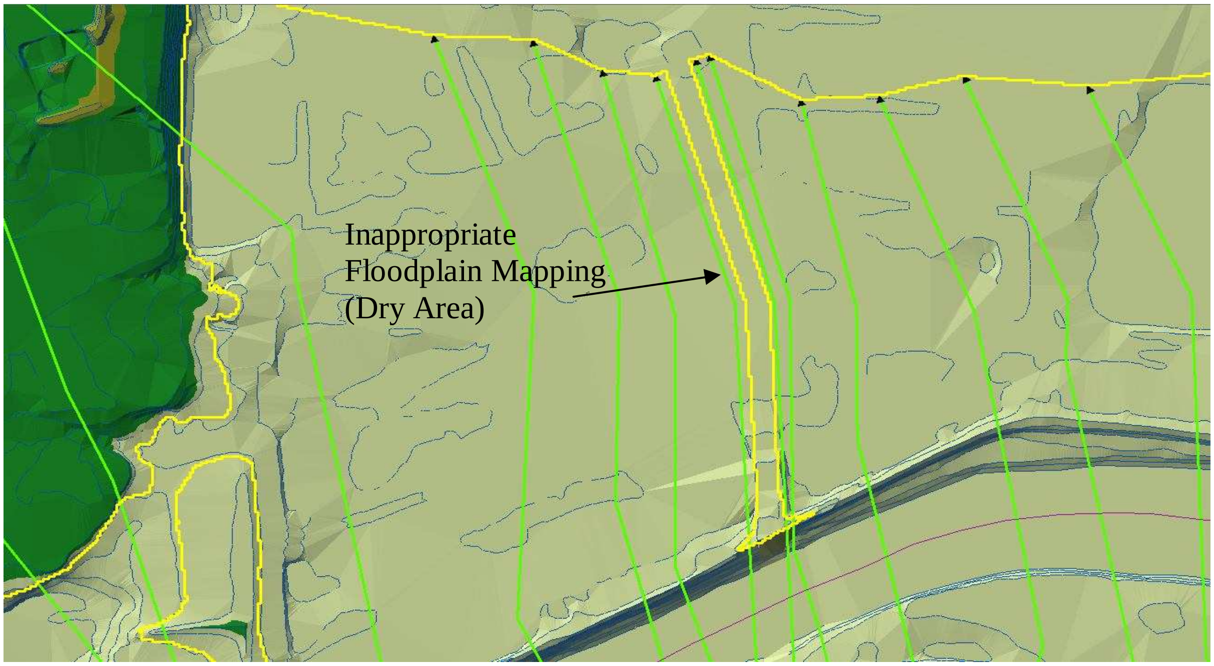


Figure 2.35 Problem in the floodplain mapping at the Main Thames

The situation at the North Thames is even more severe than the situation at the Main Thames River. The first attempt at addressing this problem is tried at the level of the HEC-RAS. The area behind the levees at the North Thames and the Main Thames are modeled by using an ineffective option instead of the appropriate levee option. Also, an ineffective option is used in the existing UTRCA HEC-RAS modeling of the North Thames and the Main Thames. After re-adjustment the floodplain results were slightly improved, but still not at an acceptable level. Consequently, it was necessary to manually edit the flood plain results at these locations. Figure 2.36 shows the edited floodplain results at the same area.

Figure 2.36 Manually edited floodplain results at the Main Thames

Another problem in the floodplain mapping is observed when the water surface elevations of two neighbouring cross sections were not within the same contour line (e.g. one cross section has WS = 235.9 m, and upstream cross section has WS = 236.15 m). The floodplain line at some of these areas followed a straight line instead of following the more accurate contour line. These areas were carefully analyzed. As a result, some of them were manually edited while others, particularly those areas that fell within residential zones, were left unedited as areas of special concern. This problem is further discussed in the following chapter.

## 3. RESULTS OF THE ANALYSES

In this chapter final results obtained using the process presented in previous chapters are presented and discussed.

### 3.1 Results of hydraulic analyses

HEC-RAS results consist of cross section water surface elevations for flows of 100 year and 250 year return periods for both, historic and wet climate scenarios. In addition to water surface elevations, values of other hydraulic parameters are available for each cross section from HEC-RAS outputs. These parameters include: flows, minimal channel elevation, channel velocity, flow area, and critical water surface. HEC-RAS outputs are available in both, graphical and tabular form. In graphical form, HEC-RAS output can be viewed as water surface profiles, general profiles, rating curves, and X-Y-Z perspective plots.

HEC-RAS results are presented in this Chapter in tabular form (Tables 3.1 to 3.8) for all rivers and creeks, including selected cross sections (at the beginning, in the middle, around the confluence, and at the end of the model) as illustration of modelling results. The detailed modelling output is available on the CD Rom attached to this report. HEC-RAS results are also presented for selected locations discussed in the floodplain mapping results.

The table headings, not indicated by full names, are as follows: “River Sta” - river station of each cross section; “Q Total” - flow used for each climate scenario; “W.S. Elev” - water surface elevations; “Vel Chnl” - velocity in the channel; “Froude # Chl” - Froude number.

Table 3.1 HEC-RAS results for the Main Thames River

| River | Reach | River Sta | Profile | Q Total | W.S. Elev | Vel Chnl | Flow Area | Froude # Chl |
|---|---|---|---|---|---|---|---|---|
| | | | | (m3/s) | (m) | (m/s) | (m2) | |
| Main Thames | London | 11187.99 | 250-Historic | 1614.99 | 235.89 | 2.13 | 829.3 | 0.26 |
| Main Thames | London | 11187.99 | 250-Wet Scenario | 1891.88 | 236.59 | 1.71 | 1777.24 | 0.2 |
| | | | | | | | | |
| Main Thames | London | 11106.89 | 250-Historic | 1614.99 | 235.91 | 1.94 | 1053.63 | 0.24 |
| Main Thames | London | 11106.89 | 250-Wet Scenario | 1891.88 | 236.6 | 1.53 | 2105.79 | 0.18 |
| | | | | | | | | |
| Main Thames | London | 10804.06 | 250-Historic | 1614.99 | 235.77 | 2.09 | 796.09 | 0.26 |
| Main Thames | London | 10804.06 | 250-Wet Scenario | 1891.88 | 236.34 | 2.24 | 873.19 | 0.27 |
| | | | | | | | | |
| Main Thames | London | 10790.83 | 250-Historic | 1614.99 | 235.75 | 2.14 | 861.24 | 0.25 |
| Main Thames | London | 10790.83 | 250-Wet Scenario | 1891.88 | 236.32 | 2.32 | 945.61 | 0.26 |
| | | | | | | | | |
| Main Thames | London | 10776.27 | | Bridge | | | | |
| | | | | | | | | |
| Main Thames | London | 10760.14 | 250-Historic | 1614.99 | 235.73 | 2.17 | 857.24 | 0.26 |
| Main Thames | London | 10760.14 | 250-Wet Scenario | 1891.88 | 236.29 | 2.34 | 940.75 | 0.27 |
| | | | | | | | | |
| Main Thames | London | 10717.2 | 250-Historic | 1614.99 | 235.57 | 2.62 | 693.42 | 0.31 |
| Main Thames | London | 10717.2 | 250-Wet Scenario | 1891.88 | 236.32 | 2.22 | 1965.07 | 0.25 |
| | | | | | | | | |
| Main Thames | London | 10324.57 | 250-Historic | 1614.99 | 235.48 | 2.29 | 980.95 | 0.27 |
| Main Thames | London | 10324.57 | 250-Wet Scenario | 1891.88 | 236.1 | 2.42 | 1149.83 | 0.28 |
| | | | | | | | | |
| Main Thames | London | 9949.081 | 250-Historic | 1614.99 | 235.44 | 1.9 | 1287.29 | 0.22 |
| Main Thames | London | 9949.081 | 250-Wet Scenario | 1891.88 | 236.06 | 2.03 | 1436.76 | 0.23 |
| | | | | | | | | |
| Main Thames | London | 9670.926 | 250-Historic | 1614.99 | 235.19 | 2.25 | 749.18 | 0.27 |
| Main Thames | London | 9670.926 | 250-Wet Scenario | 1891.88 | 235.78 | 2.44 | 817.9 | 0.28 |
| | | | | | | | | |
| Main Thames | London | 9655.252 | | Bridge | | | | |
| | | | | | | | | |
| Main Thames | London | 9640.715 | 250-Historic | 1614.99 | 235.16 | 2.26 | 747.24 | 0.27 |
| Main Thames | London | 9640.715 | 250-Wet Scenario | 1891.88 | 235.74 | 2.44 | 815.11 | 0.28 |
| | | | | | | | | |
| Main Thames | London | 9459.073 | 250-Historic | 1614.99 | 235.29 | 0.96 | 4680.68 | 0.11 |
| Main Thames | London | 9459.073 | 250-Wet Scenario | 1891.88 | 235.89 | 0.97 | 5500.8 | 0.11 |
| | | | | | | | | |
| Main Thames | London | 9292.102 | 250-Historic | 1616.25 | 235.27 | 1.06 | 3419.84 | 0.12 |
| Main Thames | London | 9292.102 | 250-Wet Scenario | 1892.72 | 235.87 | 1.1 | 3895.52 | 0.12 |
| | | | | | | | | |
| Main Thames | London | 8999.401 | 250-Historic | 1616.25 | 234.99 | 2.26 | 795.86 | 0.27 |
| Main Thames | London | 8999.401 | 250-Wet Scenario | 1892.72 | 235.56 | 2.41 | 907.79 | 0.28 |
| | | | | | | | | |
| Main Thames | London | 8597.229 | 250-Historic | 1616.25 | 234.98 | 1.38 | 1952.69 | 0.16 |
| Main Thames | London | 8597.229 | 250-Wet Scenario | 1892.72 | 235.58 | 1.4 | 2294.01 | 0.16 |
| | | | | | | | | |
| Main Thames | London | 8216.348 | 250-Historic | 1617.55 | 234.88 | 1.61 | 1748.93 | 0.19 |
| Main Thames | London | 8216.348 | 250-Wet Scenario | 1893.57 | 235.49 | 1.62 | 2054.87 | 0.18 |
| | | | | | | | | |
| Main Thames | London | 7845.231 | 250-Historic | 1617.55 | 234.73 | 1.77 | 1116.42 | 0.21 |
| Main Thames | London | 7845.231 | 250-Wet Scenario | 1893.57 | 235.32 | 1.88 | 1255.86 | 0.21 |
| | | | | | | | | |
| Main Thames | London | 7831.712 | 250-Historic | 1617.55 | 234.74 | 1.67 | 1134.44 | 0.2 |
| Main Thames | London | 7831.712 | 250-Wet Scenario | 1893.57 | 235.33 | 1.77 | 1263.61 | 0.2 |
| | | | | | | | | |
| Main Thames | London | 7809.424 | | Bridge | | | | |
| | | | | | | | | |

Table 3.1 HEC-RAS results for the Main Thames River-continued

| River | Reach | River Sta | Profile | Q Total | W.S. Elev | Vel Chnl | Flow Area | Froude # Chl |
|---|---|---|---|---|---|---|---|---|
| | | | | (m3/s) | (m) | (m/s) | (m2) | |
| Main Thames | London | 7793.904 | 250-Historic | 1617.55 | 234.72 | 1.67 | 1129.49 | 0.2 |
| Main Thames | London | 7793.904 | 250-Wet Scenario | 1893.57 | 235.31 | 1.77 | 1258.59 | 0.2 |
| | | | | | | | | |
| Main Thames | London | 7743.635 | 250-Historic | 1617.55 | 234.67 | 1.77 | 1012.67 | 0.21 |
| Main Thames | London | 7743.635 | 250-Wet Scenario | 1893.57 | 235.25 | 1.91 | 1110.9 | 0.21 |
| | | | | | | | | |
| Main Thames | London | 7066.157 | 250-Historic | 1617.55 | 234.21 | 2.17 | 847.81 | 0.25 |
| Main Thames | London | 7066.157 | 250-Wet Scenario | 1893.57 | 234.76 | 2.35 | 940.24 | 0.26 |
| | | | | | | | | |
| Main Thames | London | 6836.473 | 250-Historic | 1617.55 | 234.06 | 2.38 | 802.71 | 0.27 |
| Main Thames | London | 6836.473 | 250-Wet Scenario | 1893.57 | 234.59 | 2.55 | 889.3 | 0.28 |
| | | | | | | | | |
| Main Thames | London | 6661.459 | 250-Historic | 1617.55 | 234.01 | 2.14 | 934.04 | 0.24 |
| Main Thames | London | 6661.459 | 250-Wet Scenario | 1893.57 | 234.55 | 2.29 | 1037.79 | 0.25 |
| | | | | | | | | |
| Main Thames | London | 6649.045 | 250-Historic | 1617.55 | 234 | 2.17 | 918.43 | 0.25 |
| Main Thames | London | 6649.045 | 250-Wet Scenario | 1893.57 | 234.54 | 2.32 | 1019.21 | 0.26 |
| | | | | | | | | |
| Main Thames | London | 6644.485 | | Bridge | | | | |
| | | | | | | | | |
| Main Thames | London | 6640.114 | 250-Historic | 1617.55 | 233.98 | 2.17 | 914.81 | 0.25 |
| Main Thames | London | 6640.114 | 250-Wet Scenario | 1893.57 | 234.52 | 2.33 | 1014.48 | 0.26 |
| | | | | | | | | |
| Main Thames | London | 6613.312 | 250-Historic | 1617.55 | 233.97 | 2.13 | 918.57 | 0.25 |
| Main Thames | London | 6613.312 | 250-Wet Scenario | 1893.57 | 234.51 | 2.28 | 1022.58 | 0.26 |
| | | | | | | | | |
| Main Thames | London | 5790.817 | 250-Historic | 1617.55 | 233.41 | 2.53 | 745.58 | 0.3 |
| Main Thames | London | 5790.817 | 250-Wet Scenario | 1893.57 | 233.9 | 2.7 | 847.87 | 0.31 |
| | | | | | | | | |
| Main Thames | London | 4951.774 | 250-Historic | 1617.55 | 233.11 | 2.06 | 851.9 | 0.23 |
| Main Thames | London | 4951.774 | 250-Wet Scenario | 1893.57 | 233.56 | 2.27 | 920.32 | 0.25 |
| | | | | | | | | |
| Main Thames | London | 4334.014 | 250-Historic | 1617.55 | 232.9 | 1.95 | 899.13 | 0.21 |
| Main Thames | London | 4334.014 | 250-Wet Scenario | 1893.57 | 233.33 | 2.16 | 957.16 | 0.23 |
| | | | | | | | | |
| Main Thames | London | 4316.46 | 250-Historic | 1617.55 | 232.75 | 2.52 | 746.43 | 0.27 |
| Main Thames | London | 4316.46 | 250-Wet Scenario | 1893.57 | 233.13 | 2.81 | 791.61 | 0.3 |
| | | | | | | | | |
| Main Thames | London | 4304.175 | | Bridge | | | | |
| | | | | | | | | |
| Main Thames | London | 4292.937 | 250-Historic | 1617.55 | 232.04 | 2.8 | 664.03 | 0.31 |
| Main Thames | London | 4292.937 | 250-Wet Scenario | 1893.57 | 232.68 | 2.98 | 738.1 | 0.32 |
| | | | | | | | | |
| Main Thames | London | 4223.858 | 250-Historic | 1617.55 | 232.14 | 1.6 | 1078.12 | 0.17 |
| Main Thames | London | 4223.858 | 250-Wet Scenario | 1893.57 | 232.79 | 1.74 | 1173.53 | 0.18 |
| | | | | | | | | |
| Main Thames | London | 3712.046 | 250-Historic | 1617.55 | 231.59 | 2.93 | 635.08 | 0.34 |
| Main Thames | London | 3712.046 | 250-Wet Scenario | 1893.57 | 232.2 | 3.13 | 721.73 | 0.35 |
| | | | | | | | | |
| Main Thames | London | 3154.553 | 250-Historic | 1615.88 | 231 | 3.07 | 721.66 | 0.35 |
| Main Thames | London | 3154.553 | 250-Wet Scenario | 1892.22 | 231.6 | 3.29 | 798.87 | 0.36 |
| | | | | | | | | |
| Main Thames | London | 2778.377 | 250-Historic | 1615.88 | 230.43 | 2.75 | 787.78 | 0.32 |
| Main Thames | London | 2778.377 | 250-Wet Scenario | 1892.22 | 231.01 | 2.94 | 881.26 | 0.33 |
| | | | | | | | | |
| Main Thames | London | 2310.213 | 250-Historic | 1615.88 | 229.79 | 2.61 | 834.72 | 0.3 |
| Main Thames | London | 2310.213 | 250-Wet Scenario | 1892.22 | 230.36 | 2.79 | 926.83 | 0.31 |

Table 3.1 HEC-RAS results for the Main Thames River-continued

| River | Reach | River Sta | Profile | Q Total | W.S. Elev | Vel Chnl | Flow Area | Froude # Chl |
|---|---|---|---|---|---|---|---|---|
| | | | | (m3/s) | (m) | (m/s) | (m2) | |
| Main Thames | London | 2287.847 | | Bridge | | | | |
| | | | | | | | | |
| Main Thames | London | 2267.38 | 250-Historic | 1615.88 | 229.71 | 2.63 | 822.03 | 0.31 |
| Main Thames | London | 2267.38 | 250-Wet Scenario | 1892.22 | 230.27 | 2.81 | 913.07 | 0.32 |
| | | | | | | | | |
| Main Thames | London | 2213.693 | 250-Historic | 1615.88 | 229.57 | 2.84 | 763.33 | 0.34 |
| Main Thames | London | 2213.693 | 250-Wet Scenario | 1892.22 | 230.13 | 3.02 | 858.28 | 0.35 |
| | | | | | | | | |
| Main Thames | London | 1880.584 | 250-Historic | 1615.88 | 229.09 | 2.89 | 788.25 | 0.36 |
| Main Thames | London | 1880.584 | 250-Wet Scenario | 1892.22 | 229.67 | 3 | 919.92 | 0.35 |
| | | | | | | | | |
| Main Thames | London | 1272.046 | 250-Historic | 1615.88 | 228.25 | 2.58 | 767.8 | 0.33 |
| Main Thames | London | 1272.046 | 250-Wet Scenario | 1892.22 | 228.85 | 2.71 | 876.49 | 0.33 |
| | | | | | | | | |
| Main Thames | London | 837.2055 | 250-Historic | 1618.52 | 227.74 | 2.14 | 1255.88 | 0.27 |
| Main Thames | London | 837.2055 | 250-Wet Scenario | 1895.57 | 228.39 | 2.23 | 1446.68 | 0.26 |
| | | | | | | | | |
| Main Thames | London | 379.1213 | 250-Historic | 1618.52 | 226.71 | 3.68 | 714.27 | 0.45 |
| Main Thames | London | 379.1213 | 250-Wet Scenario | 1895.57 | 227.32 | 3.89 | 804.78 | 0.46 |
| | | | | | | | | |
| Main Thames | London | 66.001 | 250-Historic | 1618.52 | 226.12 | 3.24 | 619.27 | 0.43 |
| Main Thames | London | 66.001 | 250-Wet Scenario | 1895.57 | 226.77 | 3.34 | 723.35 | 0.42 |

Table 3.2 HEC-RAS results for North Thames River

| River | Reach | River Sta | Profile | Q Total | W.S. Elev | Vel Chnl | Flow Area | Froude # Chl |
|---|---|---|---|---|---|---|---|---|
| | | | | (m3/s) | (m) | (m/s) | (m2) | |
| North Thames | London | 14281.62 | 250 Historic | 962.38 | 254.23 | 2.16 | 494.19 | 0.35 |
| North Thames | London | 14281.62 | 250 Wet Scenario | 1209.17 | 254.77 | 2.37 | 571.56 | 0.36 |
| | | | | | | | | |
| North Thames | London | 13878.6 | 250 Historic | 962.38 | 253.33 | 3.21 | 338.29 | 0.54 |
| North Thames | London | 13878.6 | 250 Wet Scenario | 1209.17 | 253.79 | 3.51 | 394.26 | 0.55 |
| | | | | | | | | |
| North Thames | London | 13770.4 | 250 Historic | 962.38 | 253.15 | 3.01 | 435.68 | 0.47 |
| North Thames | London | 13770.4 | 250 Wet Scenario | 1209.17 | 253.62 | 3.28 | 505.26 | 0.49 |
| | | | | | | | | |
| North Thames | London | 13370.82 | 250 Historic | 962.38 | 251.96 | 4.1 | 359.54 | 0.64 |
| North Thames | London | 13370.82 | 250 Wet Scenario | 1209.17 | 252.52 | 4.19 | 465.08 | 0.61 |
| | | | | | | | | |
| North Thames | London | 13357.21 | 250 Historic | 962.38 | 252.05 | 3.04 | 354.42 | 0.47 |
| North Thames | London | 13357.21 | 250 Wet Scenario | 1209.17 | 252.55 | 3.36 | 409.72 | 0.49 |
| | | | | | | | | |
| North Thames | London | 13335.14 | | Bridge | | | | |
| | | | | | | | | |
| North Thames | London | 13318.85 | 250 Historic | 962.38 | 251.83 | 3.22 | 330.04 | 0.51 |
| North Thames | London | 13318.85 | 250 Wet Scenario | 1209.17 | 252.29 | 3.59 | 380.16 | 0.54 |
| | | | | | | | | |
| North Thames | London | 13303.81 | 250 Historic | 962.38 | 251.81 | 2.8 | 442.05 | 0.44 |
| North Thames | London | 13303.81 | 250 Wet Scenario | 1209.17 | 252.3 | 2.98 | 539.43 | 0.45 |
| | | | | | | | | |
| North Thames | London | 12719.86 | 250 Historic | 962.38 | 250.85 | 2.79 | 593.34 | 0.42 |
| North Thames | London | 12719.86 | 250 Wet Scenario | 1209.17 | 251.45 | 2.8 | 750.4 | 0.39 |
| | | | | | | | | |
| North Thames | London | 11789.97 | 250 Historic | 962.38 | 249.31 | 2.82 | 552.66 | 0.4 |
| North Thames | London | 11789.97 | 250 Wet Scenario | 1209.17 | 250.02 | 2.89 | 720.1 | 0.38 |
| | | | | | | | | |
| North Thames | London | 11519.01 | 250 Historic | 962.38 | 249.09 | 2.29 | 760.57 | 0.33 |
| North Thames | London | 11519.01 | 250 Wet Scenario | 1209.17 | 249.85 | 2.33 | 981.06 | 0.31 |
| | | | | | | | | |
| North Thames | London | 10835.59 | 250 Historic | 962.38 | 247.14 | 3.59 | 323.92 | 0.52 |
| North Thames | London | 10835.59 | 250 Wet Scenario | 1209.17 | 247.71 | 3.99 | 374.71 | 0.55 |
| | | | | | | | | |
| North Thames | London | 10804.63 | 250 Historic | 962.38 | 247.13 | 3.09 | 327.52 | 0.44 |
| North Thames | London | 10804.63 | 250 Wet Scenario | 1209.17 | 247.7 | 3.46 | 370.82 | 0.47 |
| | | | | | | | | |
| North Thames | London | 10789.3 | | Bridge | | | | |
| | | | | | | | | |
| North Thames | London | 10774.62 | 250 Historic | 962.38 | 246.96 | 3.06 | 314.53 | 0.48 |
| North Thames | London | 10774.62 | 250 Wet Scenario | 1209.17 | 247.49 | 3.4 | 355.2 | 0.51 |
| | | | | | | | | |
| North Thames | London | 10728.89 | 250 Historic | 980.47 | 246.55 | 3.73 | 276.47 | 0.57 |
| North Thames | London | 10728.89 | 250 Wet Scenario | 1229.68 | 246.93 | 4.28 | 304.25 | 0.62 |
| | | | | | | | | |
| North Thames | London | 9687.471 | 250 Historic | 980.47 | 245.24 | 1.8 | 957.93 | 0.28 |
| North Thames | London | 9687.471 | 250 Wet Scenario | 1229.68 | 245.6 | 1.93 | 1098.19 | 0.29 |
| | | | | | | | | |
| North Thames | London | 8976.408 | 250 Historic | 980.47 | 244.19 | 1.54 | 1269.34 | 0.24 |
| North Thames | London | 8976.408 | 250 Wet Scenario | 1229.68 | 244.46 | 1.6 | 1549.07 | 0.25 |
| | | | | | | | | |
| North Thames | London | 8297.666 | 250 Historic | 980.47 | 243.76 | 1.22 | 1859.67 | 0.19 |
| North Thames | London | 8297.666 | 250 Wet Scenario | 1229.68 | 244.06 | 1.29 | 2156.65 | 0.19 |
| | | | | | | | | |
| North Thames | London | 7604.849 | 250 Historic | 980.47 | 243.62 | 1.06 | 2028.79 | 0.17 |
| North Thames | London | 7604.849 | 250 Wet Scenario | 1229.68 | 243.92 | 1.11 | 2339.31 | 0.17 |

Table 3.2 HEC-RAS results for North Thames River-continued

| River | Reach | River Sta | Profile | Q Total | W.S. Elev | Vel Chnl | Flow Area | Froude # Chl |
|---|---|---|---|---|---|---|---|---|
| | | | | (m3/s) | (m) | (m/s) | (m2) | |
| North Thames | London | 7185.079 | 250 Historic | 980.47 | 243.2 | 1.05 | 2214.08 | 0.16 |
| North Thames | London | 7185.079 | 250 Wet Scenario | 1229.68 | 243.59 | 1.07 | 2678.84 | 0.16 |
| | | | | | | | | |
| North Thames | London | 6605.999 | 250 Historic | 986.38 | 242.83 | 1.83 | 1123.12 | 0.29 |
| North Thames | London | 6605.999 | 250 Wet Scenario | 1218.38 | 243.24 | 1.97 | 1413.83 | 0.3 |
| | | | | | | | | |
| North Thames | London | 6071.981 | 250 Historic | 986.38 | 242.65 | 0.73 | 2696.68 | 0.11 |
| North Thames | London | 6071.981 | 250 Wet Scenario | 1218.38 | 243.04 | 0.79 | 3135.01 | 0.12 |
| | | | | | | | | |
| North Thames | London | 5836.176 | 250 Historic | 986.38 | 242.3 | 2.09 | 916.29 | 0.31 |
| North Thames | London | 5836.176 | 250 Wet Scenario | 1218.38 | 242.68 | 2.15 | 1097.86 | 0.31 |
| | | | | | | | | |
| North Thames | London | 5232.017 | 250 Historic | 986.38 | 241.63 | 1.99 | 1256.94 | 0.29 |
| North Thames | London | 5232.017 | 250 Wet Scenario | 1218.38 | 241.95 | 2.12 | 1464.09 | 0.3 |
| | | | | | | | | |
| North Thames | London | 4713.349 | 250 Historic | 986.38 | 240.87 | 2.02 | 912.44 | 0.28 |
| North Thames | London | 4713.349 | 250 Wet Scenario | 1218.38 | 241.31 | 2.01 | 1249.99 | 0.26 |
| | | | | | | | | |
| North Thames | London | 4685.763 | 250 Historic | 986.38 | 240.58 | 2.78 | 580.74 | 0.38 |
| North Thames | London | 4685.763 | 250 Wet Scenario | 1218.38 | 241.05 | 2.76 | 875.22 | 0.36 |
| | | | | | | | | |
| North Thames | London | 4668.139 | | Bridge | | | | |
| | | | | | | | | |
| North Thames | London | 4651.49 | 250 Historic | 986.38 | 240.2 | 3.24 | 387.92 | 0.46 |
| North Thames | London | 4651.49 | 250 Wet Scenario | 1218.38 | 240.75 | 3.17 | 672.27 | 0.43 |
| | | | | | | | | |
| North Thames | London | 4638.355 | 250 Historic | 986.38 | 240.22 | 2.88 | 564.56 | 0.42 |
| North Thames | London | 4638.355 | 250 Wet Scenario | 1218.38 | 240.78 | 2.58 | 899.58 | 0.35 |
| | | | | | | | | |
| North Thames | London | 4526.357 | 250 Historic | 986.38 | 240.02 | 2.04 | 1105.77 | 0.29 |
| North Thames | London | 4526.357 | 250 Wet Scenario | 1218.38 | 240.59 | 1.9 | 1510.15 | 0.26 |
| | | | | | | | | |
| North Thames | London | 4432.608 | 250 Historic | 986.38 | 239.98 | 1.43 | 1378.09 | 0.19 |
| North Thames | London | 4432.608 | 250 Wet Scenario | 1218.38 | 240.56 | 1.44 | 1763.64 | 0.19 |
| | | | | | | | | |
| North Thames | London | 4364.224 | 250 Historic | 1031.54 | 239.95 | 1.11 | 1530.35 | 0.16 |
| North Thames | London | 4364.224 | 250 Wet Scenario | 1258.11 | 240.53 | 1.12 | 1910.92 | 0.15 |
| | | | | | | | | |
| North Thames | London | 4212.356 | 250 Historic | 1031.54 | 239.83 | 1.62 | 1166.31 | 0.22 |
| North Thames | London | 4212.356 | 250 Wet Scenario | 1258.11 | 240.44 | 1.58 | 1455.75 | 0.2 |
| | | | | | | | | |
| North Thames | London | 3902.892 | 250 Historic | 1031.54 | 239.4 | 2.42 | 654.33 | 0.33 |
| North Thames | London | 3902.892 | 250 Wet Scenario | 1258.11 | 240.05 | 2.45 | 811.11 | 0.31 |
| | | | | | | | | |
| North Thames | London | 3862.952 | 250 Historic | 1031.54 | 239.34 | 2.21 | 467.18 | 0.31 |
| North Thames | London | 3862.952 | 250 Wet Scenario | 1258.11 | 239.91 | 2.44 | 516.45 | 0.32 |
| | | | | | | | | |
| North Thames | London | 3856.491 | | Bridge | | | | |
| | | | | | | | | |
| North Thames | London | 3849.061 | 250 Historic | 1031.54 | 239.22 | 2.26 | 456.37 | 0.32 |
| North Thames | London | 3849.061 | 250 Wet Scenario | 1258.11 | 239.73 | 2.52 | 500.72 | 0.34 |
| | | | | | | | | |
| North Thames | London | 3805.052 | 250 Historic | 1031.54 | 239.18 | 2.46 | 641.65 | 0.33 |
| North Thames | London | 3805.052 | 250 Wet Scenario | 1258.11 | 239.71 | 2.62 | 755.1 | 0.33 |
| | | | | | | | | |
| North Thames | London | 3456.593 | 250 Historic | 1031.54 | 238.85 | 1.79 | 1102.95 | 0.23 |
| North Thames | London | 3456.593 | 250 Wet Scenario | 1258.11 | 239.38 | 1.87 | 1309.75 | 0.23 |

Table 3.2 HEC-RAS results for North Thames River-continued

| River | Reach | River Sta | Profile | Q Total | W.S. Elev | Vel Chnl | Flow Area | Froude # Chl |
|---|---|---|---|---|---|---|---|---|
| | | | | (m3/s) | (m) | (m/s) | (m2) | |
| North Thames | London | 3032.41 | 250 Historic | 1031.54 | 238.31 | 2.43 | 820.49 | 0.31 |
| North Thames | London | 3032.41 | 250 Wet Scenario | 1258.11 | 238.86 | 2.46 | 1042.75 | 0.3 |
| | | | | | | | | |
| North Thames | London | 2990.473 | 250 Historic | 1031.54 | 238.28 | 2.32 | 863.72 | 0.3 |
| North Thames | London | 2990.473 | 250 Wet Scenario | 1258.11 | 238.84 | 2.35 | 1107.05 | 0.29 |
| | | | | | | | | |
| North Thames | London | 2202.025 | 250 Historic | 1031.54 | 237.54 | 1.6 | 1136.81 | 0.23 |
| North Thames | London | 2202.025 | 250 Wet Scenario | 1258.11 | 238.11 | 1.58 | 1453.17 | 0.21 |
| | | | | | | | | |
| North Thames | London | 2190.01 | 250 Historic | 1031.54 | 237.52 | 1.65 | 1067.33 | 0.23 |
| North Thames | London | 2190.01 | 250 Wet Scenario | 1258.11 | 238.1 | 1.63 | 1394.72 | 0.22 |
| | | | | | | | | |
| North Thames | London | 2181.51 | | Bridge | | | | |
| | | | | | | | | |
| North Thames | London | 2172.707 | 250 Historic | 1031.54 | 237.5 | 1.67 | 1053.84 | 0.24 |
| North Thames | London | 2172.707 | 250 Wet Scenario | 1258.11 | 238.06 | 1.65 | 1374.7 | 0.22 |
| | | | | | | | | |
| North Thames | London | 2130.325 | 250 Historic | 1031.54 | 237.51 | 1.24 | 1484.27 | 0.17 |
| North Thames | London | 2130.325 | 250 Wet Scenario | 1258.11 | 238.07 | 1.27 | 1832.54 | 0.16 |
| | | | | | | | | |
| North Thames | London | 1944.315 | 250 Historic | 1031.54 | 237.45 | 1.23 | 1125.55 | 0.16 |
| North Thames | London | 1944.315 | 250 Wet Scenario | 1258.11 | 238 | 1.34 | 1280.49 | 0.16 |
| | | | | | | | | |
| North Thames | London | 1657.939 | 250 Historic | 1031.54 | 237.19 | 1.79 | 748.2 | 0.24 |
| North Thames | London | 1657.939 | 250 Wet Scenario | 1258.11 | 237.72 | 1.92 | 902.29 | 0.25 |
| | | | | | | | | |
| North Thames | London | 1469.137 | 250 Historic | 1031.54 | 237.11 | 1.47 | 1033.23 | 0.2 |
| North Thames | London | 1469.137 | 250 Wet Scenario | 1258.11 | 237.63 | 1.54 | 1382.83 | 0.2 |
| | | | | | | | | |
| North Thames | London | 1464.37 | 250 Historic | 1031.54 | 237.11 | 1.47 | 1031.42 | 0.21 |
| North Thames | London | 1464.37 | 250 Wet Scenario | 1258.11 | 237.62 | 1.53 | 1378.75 | 0.21 |
| | | | | | | | | |
| North Thames | London | 1453.371 | | Bridge | | | | |
| | | | | | | | | |
| North Thames | London | 1437.962 | 250 Historic | 1031.54 | 237.08 | 1.48 | 1012.54 | 0.21 |
| North Thames | London | 1437.962 | 250 Wet Scenario | 1258.11 | 237.6 | 1.54 | 1365.56 | 0.21 |
| | | | | | | | | |
| North Thames | London | 1395.448 | 250 Historic | 1031.54 | 236.89 | 2.17 | 490.27 | 0.3 |
| North Thames | London | 1395.448 | 250 Wet Scenario | 1258.11 | 237.49 | 2.04 | 1228.54 | 0.27 |
| | | | | | | | | |
| North Thames | London | 934.5929 | 250 Historic | 1031.54 | 236.3 | 2.86 | 369.55 | 0.43 |
| North Thames | London | 934.5929 | 250 Wet Scenario | 1258.11 | 237.5 | 0.89 | 3296.37 | 0.12 |
| | | | | | | | | |
| North Thames | London | 897.6954 | 250 Historic | 1031.54 | 236.11 | 3.16 | 326.86 | 0.48 |
| North Thames | London | 897.6954 | 250 Wet Scenario | 1258.11 | 236.77 | 3.34 | 376.3 | 0.48 |
| | | | | | | | | |
| North Thames | London | 890.2701 | | Bridge | | | | |
| | | | | | | | | |
| North Thames | London | 883.0124 | 250 Historic | 1031.54 | 236.06 | 3.18 | 323.89 | 0.49 |
| North Thames | London | 883.0124 | 250 Wet Scenario | 1258.11 | 236.73 | 3.37 | 373.51 | 0.48 |
| | | | | | | | | |
| North Thames | London | 836.2322 | 250 Historic | 1031.54 | 236 | 3 | 360.69 | 0.41 |
| North Thames | London | 836.2322 | 250 Wet Scenario | 1258.11 | 236.99 | 1.09 | 2934.08 | 0.14 |
| | | | | | | | | |
| North Thames | London | 318.2535 | 250 Historic | 1031.54 | 236.12 | 0.88 | 2629.29 | 0.11 |
| North Thames | London | 318.2535 | 250 Wet Scenario | 1258.11 | 236.95 | 0.82 | 3428.04 | 0.1 |
| | | | | | | | | |

Table 3.2 HEC-RAS results for North Thames River-continued

| River | Reach | River Sta | Profile | Q Total | W.S. Elev | Vel Chnl | Flow Area | Froude # Chl |
|---|---|---|---|---|---|---|---|---|
| | | | | (m3/s) | (m) | (m/s) | (m2) | |
| North Thames | London | 144.8874 | 250 Historic | 1031.54 | 235.85 | 1.96 | 526.89 | 0.26 |
| North Thames | London | 144.8874 | 250 Wet Scenario | 1258.11 | 236.62 | 2.11 | 597.41 | 0.27 |
| | | | | | | | | |
| North Thames | London | 34.75945 | 250 Historic | 1031.54 | 235.79 | 1.76 | 637.23 | 0.21 |
| North Thames | London | 34.75945 | 250 Wet Scenario | 1258.11 | 236.59 | 1.22 | 2832.61 | 0.14 |
| | | | | | | | | |
| North Thames | London | 10.38824 | 250 Historic | 1031.54 | 235.79 | 1.69 | 657.91 | 0.22 |
| North Thames | London | 10.38824 | 250 Wet Scenario | 1258.11 | 236.58 | 1.1 | 2952.58 | 0.14 |

Table 3.3 HEC-RAS results for the South Thames River

| River | Reach | River Sta | Profile | Q Total | W.S. Elev | Vel Chnl | Flow Area | Froude # Chl |
|---|---|---|---|---|---|---|---|---|
| | | | | (m3/s) | (m) | (m/s) | (m2) | |
| South Thames | London | 12890.16 | 250 Historic | 637.78 | 245.77 | 1.59 | 604.03 | 0.28 |
| South Thames | London | 12890.16 | 250 Wet Scenario | 734.39 | 246.04 | 1.65 | 690.07 | 0.28 |
| | | | | | | | | |
| South Thames | London | 12801.97 | 250 Historic | 637.78 | 245.45 | 2.51 | 312.73 | 0.47 |
| South Thames | London | 12801.97 | 250 Wet Scenario | 734.39 | 245.74 | 2.55 | 368.2 | 0.45 |
| | | | | | | | | |
| South Thames | London | 12743.45 | 250 Historic | 637.78 | 245.34 | 2.46 | 262 | 0.44 |
| South Thames | London | 12743.45 | 250 Wet Scenario | 734.39 | 245.57 | 2.64 | 282.72 | 0.46 |
| | | | | | | | | |
| South Thames | London | 12725.02 | | Bridge | | | | |
| | | | | | | | | |
| South Thames | London | 12707.53 | 250 Historic | 637.78 | 245.22 | 2.53 | 253.67 | 0.47 |
| South Thames | London | 12707.53 | 250 Wet Scenario | 734.39 | 245.44 | 2.72 | 273.11 | 0.48 |
| | | | | | | | | |
| South Thames | London | 12638.9 | 250 Historic | 637.78 | 245.21 | 1.87 | 414.87 | 0.35 |
| South Thames | London | 12638.9 | 250 Wet Scenario | 734.39 | 245.45 | 1.95 | 464.82 | 0.35 |
| | | | | | | | | |
| South Thames | London | 11716.29 | 250 Historic | 637.78 | 244.59 | 1.7 | 734.52 | 0.3 |
| South Thames | London | 11716.29 | 250 Wet Scenario | 734.39 | 244.91 | 1.62 | 871.02 | 0.27 |
| | | | | | | | | |
| South Thames | London | 10994.08 | 250 Historic | 637.78 | 244.29 | 1.29 | 974.57 | 0.22 |
| South Thames | London | 10994.08 | 250 Wet Scenario | 734.39 | 244.66 | 1.28 | 1138.44 | 0.21 |
| | | | | | | | | |
| South Thames | London | 10666.53 | 250 Historic | 637.78 | 243.99 | 1.98 | 568.79 | 0.34 |
| South Thames | London | 10666.53 | 250 Wet Scenario | 734.39 | 244.44 | 1.85 | 760.22 | 0.3 |
| | | | | | | | | |
| South Thames | London | 10634.24 | 250 Historic | 660.31 | 243.49 | 3.15 | 209.32 | 0.59 |
| South Thames | London | 10634.24 | 250 Wet Scenario | 759.96 | 243.9 | 3.17 | 239.4 | 0.56 |
| | | | | | | | | |
| South Thames | London | 10621.59 | | Bridge | | | | |
| | | | | | | | | |
| South Thames | London | 10608.59 | 250 Historic | 660.31 | 243.4 | 3.26 | 202.42 | 0.62 |
| South Thames | London | 10608.59 | 250 Wet Scenario | 759.96 | 243.66 | 3.44 | 220.81 | 0.63 |
| | | | | | | | | |
| South Thames | London | 10562.31 | 250 Historic | 660.31 | 243.44 | 2.62 | 406.23 | 0.45 |
| South Thames | London | 10562.31 | 250 Wet Scenario | 759.96 | 243.74 | 2.61 | 475.67 | 0.43 |
| | | | | | | | | |
| South Thames | London | 10130.95 | 250 Historic | 660.31 | 243.04 | 2.33 | 439.57 | 0.38 |
| South Thames | London | 10130.95 | 250 Wet Scenario | 759.96 | 243.31 | 2.47 | 495.76 | 0.39 |
| | | | | | | | | |
| South Thames | London | 9560.527 | 250 Historic | 660.31 | 242.9 | 1.74 | 777.89 | 0.26 |
| South Thames | London | 9560.527 | 250 Wet Scenario | 759.96 | 243.2 | 1.76 | 880.76 | 0.26 |
| | | | | | | | | |
| South Thames | London | 8993.381 | 250 Historic | 660.31 | 242.57 | 1.67 | 682.89 | 0.27 |
| South Thames | London | 8993.381 | 250 Wet Scenario | 759.96 | 242.88 | 1.71 | 770.2 | 0.26 |
| | | | | | | | | |
| South Thames | London | 8549.949 | 250 Historic | 660.31 | 242.37 | 1.6 | 672.4 | 0.27 |
| South Thames | London | 8549.949 | 250 Wet Scenario | 759.96 | 242.68 | 1.63 | 764.1 | 0.26 |
| | | | | | | | | |
| South Thames | London | 8166.684 | 250 Historic | 660.31 | 241.97 | 2.13 | 396.04 | 0.35 |
| South Thames | London | 8166.684 | 250 Wet Scenario | 759.96 | 242.32 | 2.15 | 514.85 | 0.34 |
| | | | | | | | | |
| South Thames | London | 8098.739 | 250 Historic | 655.74 | 242.03 | 1.19 | 732.33 | 0.2 |
| South Thames | London | 8098.739 | 250 Wet Scenario | 754.23 | 242.37 | 1.23 | 816.94 | 0.2 |
| | | | | | | | | |
| South Thames | London | 7265.864 | 250 Historic | 655.74 | 241.31 | 2.01 | 326.39 | 0.33 |
| South Thames | London | 7265.864 | 250 Wet Scenario | 754.23 | 241.65 | 2.12 | 356.41 | 0.33 |

Table 3.3 HEC-RAS results for the South Thames River-continued

| River | Reach | River Sta | Profile | Q Total | W.S. Elev | Vel Chnl | Flow Area | Froude # Chl |
|---|---|---|---|---|---|---|---|---|
| | | | | (m3/s) | (m) | (m/s) | (m2) | |
| South Thames | London | 7257.464 | | Bridge | | | | |
| | | | | | | | | |
| South Thames | London | 7250.436 | 250 Historic | 655.74 | 241.29 | 2.02 | 324.07 | 0.34 |
| South Thames | London | 7250.436 | 250 Wet Scenario | 754.23 | 241.63 | 2.13 | 353.87 | 0.34 |
| | | | | | | | | |
| South Thames | London | 6937.855 | 250 Historic | 655.74 | 241.11 | 1.89 | 410.33 | 0.28 |
| South Thames | London | 6937.855 | 250 Wet Scenario | 754.23 | 241.46 | 1.98 | 458.65 | 0.28 |
| | | | | | | | | |
| South Thames | London | 6908.513 | 250 Historic | 655.74 | 240.97 | 2.29 | 286.51 | 0.37 |
| South Thames | London | 6908.513 | 250 Wet Scenario | 754.23 | 241.3 | 2.42 | 311.38 | 0.38 |
| | | | | | | | | |
| South Thames | London | 6888.857 | | Bridge | | | | |
| | | | | | | | | |
| South Thames | London | 6870.035 | 250 Historic | 655.74 | 240.89 | 2.33 | 280.87 | 0.39 |
| South Thames | London | 6870.035 | 250 Wet Scenario | 754.23 | 241.22 | 2.47 | 305.37 | 0.39 |
| | | | | | | | | |
| South Thames | London | 5839.856 | 250 Historic | 655.74 | 240.1 | 1.45 | 614.85 | 0.22 |
| South Thames | London | 5839.856 | 250 Wet Scenario | 754.23 | 240.49 | 1.45 | 713.88 | 0.21 |
| | | | | | | | | |
| South Thames | London | 5185.578 | 250 Historic | 655.74 | 239.4 | 2.38 | 274.96 | 0.38 |
| South Thames | London | 5185.578 | 250 Wet Scenario | 754.23 | 239.82 | 2.49 | 303.07 | 0.38 |
| | | | | | | | | |
| South Thames | London | 5172 | | Bridge | | | | |
| | | | | | | | | |
| South Thames | London | 5155.075 | 250 Historic | 655.74 | 239.31 | 2.45 | 267.97 | 0.39 |
| South Thames | London | 5155.075 | 250 Wet Scenario | 754.23 | 239.73 | 2.55 | 295.9 | 0.39 |
| | | | | | | | | |
| South Thames | London | 4771.336 | 250 Historic | 655.74 | 239.33 | 1.3 | 1009.51 | 0.2 |
| South Thames | London | 4771.336 | 250 Wet Scenario | 754.23 | 239.78 | 1.28 | 1192.68 | 0.19 |
| | | | | | | | | |
| South Thames | London | 4419.571 | 250 Historic | 655.74 | 239.22 | 1.19 | 938.25 | 0.19 |
| South Thames | London | 4419.571 | 250 Wet Scenario | 754.23 | 239.68 | 1.17 | 1120.92 | 0.18 |
| | | | | | | | | |
| South Thames | London | 3766.49 | 250 Historic | 655.74 | 239.04 | 1.59 | 474.24 | 0.26 |
| South Thames | London | 3766.49 | 250 Wet Scenario | 754.23 | 239.51 | 1.57 | 611.49 | 0.25 |
| | | | | | | | | |
| South Thames | London | 3657.717 | 250 Historic | 655.74 | 238.87 | 2.16 | 304.11 | 0.35 |
| South Thames | London | 3657.717 | 250 Wet Scenario | 754.23 | 239.33 | 2.2 | 364.07 | 0.34 |
| | | | | | | | | |
| South Thames | London | 3640.421 | | Bridge | | | | |
| | | | | | | | | |
| South Thames | London | 3628.674 | 250 Historic | 655.74 | 238.81 | 2.2 | 298.49 | 0.36 |
| South Thames | London | 3628.674 | 250 Wet Scenario | 754.23 | 239.26 | 2.24 | 352.54 | 0.35 |
| | | | | | | | | |
| South Thames | London | 3256.484 | 250 Historic | 655.74 | 238.05 | 2.04 | 427.32 | 0.38 |
| South Thames | London | 3256.484 | 250 Wet Scenario | 754.23 | 238.54 | 1.91 | 531.33 | 0.33 |
| | | | | | | | | |
| South Thames | London | 2963.955 | 250 Historic | 655.74 | 238 | 1.89 | 693.05 | 0.29 |
| South Thames | London | 2963.955 | 250 Wet Scenario | 754.23 | 238.5 | 1.79 | 892.06 | 0.26 |
| | | | | | | | | |
| South Thames | London | 2560.836 | 250 Historic | 655.74 | 237.68 | 2.07 | 403.97 | 0.32 |
| South Thames | London | 2560.836 | 250 Wet Scenario | 754.23 | 238.21 | 2.04 | 485.35 | 0.3 |
| | | | | | | | | |
| South Thames | London | 2419.805 | 250 Historic | 655.74 | 237.57 | 2.22 | 317.26 | 0.34 |
| South Thames | London | 2419.805 | 250 Wet Scenario | 754.23 | 238.09 | 2.25 | 389.25 | 0.33 |
| | | | | | | | | |
| South Thames | London | 2388.047 | 250 Historic | 655.74 | 237.56 | 2.21 | 296.41 | 0.34 |

Table 3.3 HEC-RAS results for the South Thames River-continued

| River | Reach | River Sta | Profile | Q Total | W.S. Elev | Vel Chnl | Flow Area | Froude # Chl |
|---|---|---|---|---|---|---|---|---|
| | | | | (m3/s) | (m) | (m/s) | (m2) | |
| South Thames | London | 2388.047 | 250 Wet Scenario | 754.23 | 238.07 | 2.27 | 332.49 | 0.33 |
| | | | | | | | | |
| South Thames | London | 2369.654 | | Bridge | | | | |
| | | | | | | | | |
| South Thames | London | 2355.203 | 250 Historic | 655.74 | 237.55 | 2.21 | 296.18 | 0.34 |
| South Thames | London | 2355.203 | 250 Wet Scenario | 754.23 | 238.06 | 2.27 | 332.24 | 0.33 |
| | | | | | | | | |
| South Thames | London | 2311.574 | 250 Historic | 655.74 | 237.49 | 2.35 | 306.2 | 0.36 |
| South Thames | London | 2311.574 | 250 Wet Scenario | 754.23 | 238.02 | 2.36 | 378.49 | 0.35 |
| | | | | | | | | |
| South Thames | London | 1499.458 | 250 Historic | 655.74 | 236.69 | 2.51 | 265.5 | 0.36 |
| South Thames | London | 1499.458 | 250 Wet Scenario | 754.23 | 237.38 | 2.52 | 313.55 | 0.34 |
| | | | | | | | | |
| South Thames | London | 1498.565 | | Inl Struct | | | | |
| | | | | | | | | |
| South Thames | London | 1497.378 | 250 Historic | 655.74 | 236.6 | 2.57 | 259.1 | 0.37 |
| South Thames | London | 1497.378 | 250 Wet Scenario | 754.23 | 237.3 | 2.56 | 307.04 | 0.35 |
| | | | | | | | | |
| South Thames | London | 990.1878 | 250 Historic | 655.74 | 236.4 | 1.49 | 440.55 | 0.2 |
| South Thames | London | 990.1878 | 250 Wet Scenario | 754.23 | 237.21 | 1.48 | 545.95 | 0.19 |
| | | | | | | | | |
| South Thames | London | 974.1994 | | Bridge | | | | |
| | | | | | | | | |
| South Thames | London | 960.6936 | 250 Historic | 655.74 | 236.39 | 1.5 | 438.91 | 0.2 |
| South Thames | London | 960.6936 | 250 Wet Scenario | 754.23 | 237.11 | 1.52 | 532.2 | 0.19 |
| | | | | | | | | |
| South Thames | London | 510.4154 | 250 Historic | 655.74 | 236 | 2.64 | 378.69 | 0.32 |
| South Thames | London | 510.4154 | 250 Wet Scenario | 754.23 | 236.78 | 2.61 | 597.35 | 0.3 |
| | | | | | | | | |
| South Thames | London | 491.168 | | Bridge | | | | |
| | | | | | | | | |
| South Thames | London | 474.097 | 250 Historic | 655.74 | 236 | 2.27 | 415.32 | 0.28 |
| South Thames | London | 474.097 | 250 Wet Scenario | 754.23 | 236.85 | 2.15 | 650.63 | 0.25 |
| | | | | | | | | |
| South Thames | London | 302.2231 | 250 Historic | 655.74 | 235.68 | 2.99 | 247 | 0.37 |
| South Thames | London | 302.2231 | 250 Wet Scenario | 754.23 | 236.46 | 3.06 | 294.16 | 0.36 |
| | | | | | | | | |
| South Thames | London | 129.4887 | 250 Historic | 655.74 | 235.66 | 2.28 | 319.49 | 0.28 |
| South Thames | London | 129.4887 | 250 Wet Scenario | 754.23 | 236.44 | 2.34 | 367.32 | 0.27 |
| | | | | | | | | |
| South Thames | London | 123.6912 | | Bridge | | | | |
| | | | | | | | | |
| South Thames | London | 117.2749 | 250 Historic | 655.74 | 235.65 | 2.28 | 319.97 | 0.28 |
| South Thames | London | 117.2749 | 250 Wet Scenario | 754.23 | 236.43 | 2.34 | 367.59 | 0.27 |
| | | | | | | | | |
| South Thames | London | 45.02997 | 250 Historic | 655.74 | 235.75 | 1.34 | 781.31 | 0.16 |
| South Thames | London | 45.02997 | 250 Wet Scenario | 754.23 | 236.55 | 1.29 | 1033.21 | 0.15 |
| | | | | | | | | |
| South Thames | London | 1.273638 | 250 Historic | 655.74 | 235.79 | 0.63 | 1319.2 | 0.09 |
| South Thames | London | 1.273638 | 250 Wet Scenario | 754.23 | 236.58 | 0.62 | 1580.46 | 0.08 |

Table 3.4 HEC-RAS results for the Medway Creek

| River | Reach | River Sta | Profile | Q Total | W.S. Elev | Vel Chnl | Flow Area | Froude # Chl |
|---|---|---|---|---|---|---|---|---|
| | | | | (m3/s) | (m) | (m/s) | (m2) | |
| Medway Creek | London | 12534.02 | 250 Historic | 75.56 | 262.6 | 0.24 | 309.18 | 0.04 |
| Medway Creek | London | 12534.02 | 250 Wet Scenario | 78.05 | 262.62 | 0.25 | 310.44 | 0.04 |
| | | | | | | | | |
| Medway Creek | London | 12394 | 250 Historic | 75.56 | 262.6 | 0.23 | 327.19 | 0.04 |
| Medway Creek | London | 12394 | 250 Wet Scenario | 78.05 | 262.61 | 0.24 | 328.45 | 0.04 |
| | | | | | | | | |
| Medway Creek | London | 12337.73 | 250 Historic | 75.56 | 262.5 | 1.07 | 59.95 | 0.69 |
| Medway Creek | London | 12337.73 | 250 Wet Scenario | 78.05 | 262.52 | 1.1 | 62.27 | 0.69 |
| | | | | | | | | |
| Medway Creek | London | 12335.86 | | Inl Struct | | | | |
| | | | | | | | | |
| Medway Creek | London | 12334.68 | 250 Historic | 75.56 | 260.46 | 0.62 | 122.49 | 0.12 |
| Medway Creek | London | 12334.68 | 250 Wet Scenario | 78.05 | 260.5 | 0.63 | 124.29 | 0.12 |
| | | | | | | | | |
| Medway Creek | London | 12270.32 | 250 Historic | 75.56 | 260.45 | 0.59 | 138.06 | 0.11 |
| Medway Creek | London | 12270.32 | 250 Wet Scenario | 78.05 | 260.49 | 0.6 | 140.61 | 0.12 |
| | | | | | | | | |
| Medway Creek | London | 12243.58 | 250 Historic | 75.56 | 260.38 | 1.15 | 65.91 | 0.25 |
| Medway Creek | London | 12243.58 | 250 Wet Scenario | 78.05 | 260.41 | 1.16 | 67.13 | 0.25 |
| | | | | | | | | |
| Medway Creek | London | 12230.78 | | Bridge | | | | |
| | | | | | | | | |
| Medway Creek | London | 12211.96 | 250 Historic | 75.56 | 260.37 | 1.15 | 65.58 | 0.25 |
| Medway Creek | London | 12211.96 | 250 Wet Scenario | 78.05 | 260.4 | 1.17 | 66.79 | 0.26 |
| | | | | | | | | |
| Medway Creek | London | 11928.78 | 250 Historic | 75.56 | 259.85 | 1.97 | 43.17 | 0.42 |
| Medway Creek | London | 11928.78 | 250 Wet Scenario | 78.05 | 259.88 | 2.01 | 43.76 | 0.43 |
| | | | | | | | | |
| Medway Creek | London | 11053.9 | 250 Historic | 75.56 | 258.36 | 0.85 | 88.65 | 0.19 |
| Medway Creek | London | 11053.9 | 250 Wet Scenario | 78.05 | 258.37 | 0.87 | 89.32 | 0.2 |
| | | | | | | | | |
| Medway Creek | London | 11044.33 | | Bridge | | | | |
| | | | | | | | | |
| Medway Creek | London | 11030.45 | 250 Historic | 75.56 | 258.36 | 0.85 | 88.6 | 0.19 |
| Medway Creek | London | 11030.45 | 250 Wet Scenario | 78.05 | 258.37 | 0.87 | 89.25 | 0.2 |
| | | | | | | | | |
| Medway Creek | London | 10579.32 | 250 Historic | 75.56 | 257.91 | 0.83 | 171.56 | 0.23 |
| Medway Creek | London | 10579.32 | 250 Wet Scenario | 78.05 | 257.93 | 0.84 | 175.76 | 0.23 |
| | | | | | | | | |
| Medway Creek | London | 9633.082 | 250 Historic | 75.56 | 257.2 | 0.63 | 258 | 0.14 |
| Medway Creek | London | 9633.082 | 250 Wet Scenario | 78.05 | 257.23 | 0.63 | 264.13 | 0.14 |
| | | | | | | | | |
| Medway Creek | London | 9396.282 | 250 Historic | 75.56 | 256.91 | 1.08 | 97.16 | 0.24 |
| Medway Creek | London | 9396.282 | 250 Wet Scenario | 78.05 | 256.94 | 1.09 | 99.47 | 0.24 |
| | | | | | | | | |
| Medway Creek | London | 9352.544 | 250 Historic | 75.56 | 256.78 | 1.59 | 72.35 | 0.32 |
| Medway Creek | London | 9352.544 | 250 Wet Scenario | 78.05 | 256.81 | 1.61 | 73.94 | 0.32 |
| | | | | | | | | |
| Medway Creek | London | 9157.174 | | Bridge | | | | |
| | | | | | | | | |
| Medway Creek | London | 9156.027 | 250 Historic | 75.56 | 256.51 | 1.51 | 68.52 | 0.34 |
| Medway Creek | London | 9156.027 | 250 Wet Scenario | 78.05 | 256.53 | 1.53 | 70.37 | 0.34 |
| | | | | | | | | |
| Medway Creek | London | 8800.228 | 250 Historic | 75.56 | 256.26 | 0.74 | 176.55 | 0.16 |
| Medway Creek | London | 8800.228 | 250 Wet Scenario | 78.05 | 256.28 | 0.74 | 181.7 | 0.15 |
| | | | | | | | | |
| Medway Creek | London | 8776.636 | 250 Historic | 75.56 | 256.25 | 0.45 | 275.85 | 0.1 |

Table 3.4 HEC-RAS results for the Medway Creek-continued

| River | Reach | River Sta | Profile | Q Total | W.S. Elev | Vel Chnl | Flow Area | Froude # Chl |
|---|---|---|---|---|---|---|---|---|
| | | | | (m3/s) | (m) | (m/s) | (m2) | |
| Medway Creek | London | 8776.636 | 250 Wet Scenario | 78.05 | 256.28 | 0.45 | 283.42 | 0.1 |
| | | | | | | | | |
| Medway Creek | London | 8774.774 | | Bridge | | | | |
| | | | | | | | | |
| Medway Creek | London | 8773.424 | 250 Historic | 75.56 | 256.25 | 0.46 | 274.24 | 0.1 |
| Medway Creek | London | 8773.424 | 250 Wet Scenario | 78.05 | 256.27 | 0.46 | 281.82 | 0.1 |
| | | | | | | | | |
| Medway Creek | London | 8507.261 | 250 Historic | 75.56 | 256.07 | 1.4 | 54.05 | 0.31 |
| Medway Creek | London | 8507.261 | 250 Wet Scenario | 78.05 | 256.09 | 1.43 | 54.63 | 0.31 |
| | | | | | | | | |
| Medway Creek | London | 8496.955 | | Bridge | | | | |
| | | | | | | | | |
| Medway Creek | London | 8487.207 | 250 Historic | 75.56 | 256.06 | 1.41 | 53.85 | 0.31 |
| Medway Creek | London | 8487.207 | 250 Wet Scenario | 78.05 | 256.08 | 1.44 | 54.41 | 0.31 |
| | | | | | | | | |
| Medway Creek | London | 8172.843 | 250 Historic | 77.34 | 255.37 | 0.91 | 154.64 | 0.21 |
| Medway Creek | London | 8172.843 | 250 Wet Scenario | 79.94 | 255.39 | 0.91 | 159.54 | 0.21 |
| | | | | | | | | |
| Medway Creek | London | 7980.011 | 250 Historic | 77.34 | 255.25 | 0.51 | 245.19 | 0.12 |
| Medway Creek | London | 7980.011 | 250 Wet Scenario | 79.94 | 255.28 | 0.51 | 252.85 | 0.12 |
| | | | | | | | | |
| Medway Creek | London | 7429.214 | 250 Historic | 77.34 | 254.97 | 0.75 | 185.55 | 0.16 |
| Medway Creek | London | 7429.214 | 250 Wet Scenario | 79.94 | 255 | 0.76 | 189.93 | 0.16 |
| | | | | | | | | |
| Medway Creek | London | 6743.273 | 250 Historic | 77.34 | 254.11 | 0.72 | 157.7 | 0.18 |
| Medway Creek | London | 6743.273 | 250 Wet Scenario | 79.94 | 254.14 | 0.72 | 161.38 | 0.18 |
| | | | | | | | | |
| Medway Creek | London | 6038.008 | 250 Historic | 77.34 | 253.11 | 0.78 | 179.54 | 0.17 |
| Medway Creek | London | 6038.008 | 250 Wet Scenario | 79.94 | 253.14 | 0.78 | 184.12 | 0.17 |
| | | | | | | | | |
| Medway Creek | London | 5758.905 | 250 Historic | 77.34 | 252.73 | 1.37 | 56.28 | 0.36 |
| Medway Creek | London | 5758.905 | 250 Wet Scenario | 79.94 | 252.76 | 1.39 | 57.42 | 0.36 |
| | | | | | | | | |
| Medway Creek | London | 5738.844 | | Bridge | | | | |
| | | | | | | | | |
| Medway Creek | London | 5720.785 | 250 Historic | 77.34 | 252.71 | 1.39 | 55.69 | 0.36 |
| Medway Creek | London | 5720.785 | 250 Wet Scenario | 79.94 | 252.74 | 1.41 | 56.8 | 0.36 |
| | | | | | | | | |
| Medway Creek | London | 5207.577 | 250 Historic | 77.34 | 251.92 | 1.4 | 80.47 | 0.34 |
| Medway Creek | London | 5207.577 | 250 Wet Scenario | 79.94 | 251.95 | 1.41 | 83 | 0.34 |
| | | | | | | | | |
| Medway Creek | London | 4658.275 | 250 Historic | 77.34 | 250.93 | 1.49 | 109.89 | 0.36 |
| Medway Creek | London | 4658.275 | 250 Wet Scenario | 79.94 | 250.94 | 1.52 | 112.5 | 0.37 |
| | | | | | | | | |
| Medway Creek | London | 4003.46 | 250 Historic | 80.58 | 249.86 | 1.71 | 96.16 | 0.43 |
| Medway Creek | London | 4003.46 | 250 Wet Scenario | 82.34 | 249.88 | 1.71 | 98.37 | 0.43 |
| | | | | | | | | |
| Medway Creek | London | 3593.942 | 250 Historic | 80.58 | 248.68 | 1.23 | 110.44 | 0.32 |
| Medway Creek | London | 3593.942 | 250 Wet Scenario | 82.34 | 248.7 | 1.23 | 113.1 | 0.31 |
| | | | | | | | | |
| Medway Creek | London | 2898.354 | 250 Historic | 80.58 | 246.64 | 1.87 | 47.77 | 0.55 |
| Medway Creek | London | 2898.354 | 250 Wet Scenario | 82.34 | 246.65 | 1.89 | 48.57 | 0.55 |
| | | | | | | | | |
| Medway Creek | London | 2502.589 | 250 Historic | 82.92 | 245.72 | 1.45 | 76.35 | 0.35 |
| Medway Creek | London | 2502.589 | 250 Wet Scenario | 83.96 | 245.73 | 1.46 | 77.13 | 0.35 |
| | | | | | | | | |
| Medway Creek | London | 1866.711 | 250 Historic | 82.92 | 243.16 | 3.1 | 37.49 | 0.87 |

Table 3.4 HEC-RAS results for the Medway Creek-continued

| River | Reach | River Sta | Profile | Q Total | W.S. Elev | Vel Chnl | Flow Area | Froude # Chl |
|---|---|---|---|---|---|---|---|---|
| | | | | (m3/s) | (m) | (m/s) | (m2) | |
| Medway Creek | London | 1866.711 | 250 Wet Scenario | 83.96 | 243.17 | 3.11 | 37.93 | 0.87 |
| | | | | | | | | |
| Medway Creek | London | 1533.288 | 250 Historic | 82.92 | 242.21 | 2.32 | 42.86 | 0.68 |
| Medway Creek | London | 1533.288 | 250 Wet Scenario | 83.96 | 242.22 | 2.35 | 43.29 | 0.69 |
| | | | | | | | | |
| Medway Creek | London | 1071.312 | 250 Historic | 82.92 | 240.78 | 1.59 | 59.71 | 0.36 |
| Medway Creek | London | 1071.312 | 250 Wet Scenario | 83.96 | 240.91 | 1.51 | 64.65 | 0.33 |
| | | | | | | | | |
| Medway Creek | London | 1045.327 | 250 Historic | 82.92 | 240.7 | 1.65 | 50.28 | 0.41 |
| Medway Creek | London | 1045.327 | 250 Wet Scenario | 83.96 | 240.84 | 1.53 | 54.71 | 0.38 |
| | | | | | | | | |
| Medway Creek | London | 1038.507 | | Bridge | | | | |
| | | | | | | | | |
| Medway Creek | London | 1031.45 | 250 Historic | 82.92 | 240.66 | 1.69 | 49 | 0.42 |
| Medway Creek | London | 1031.45 | 250 Wet Scenario | 83.96 | 240.81 | 1.57 | 53.62 | 0.39 |
| | | | | | | | | |
| Medway Creek | London | 956.9636 | 250 Historic | 82.92 | 240.52 | 1.68 | 56.75 | 0.35 |
| Medway Creek | London | 956.9636 | 250 Wet Scenario | 83.96 | 240.7 | 1.53 | 63.35 | 0.31 |
| | | | | | | | | |
| Medway Creek | London | 836.889 | 250 Historic | 82.92 | 240.16 | 1.77 | 48.84 | 0.39 |
| Medway Creek | London | 836.889 | 250 Wet Scenario | 83.96 | 240.45 | 1.56 | 56.58 | 0.32 |
| | | | | | | | | |
| Medway Creek | London | 772.637 | 250 Historic | 82.92 | 240.11 | 1.43 | 63.23 | 0.31 |
| Medway Creek | London | 772.637 | 250 Wet Scenario | 83.96 | 240.43 | 1.24 | 75.3 | 0.25 |
| | | | | | | | | |
| Medway Creek | London | 739.4892 | 250 Historic | 82.92 | 240.1 | 1.16 | 71.5 | 0.24 |
| Medway Creek | London | 739.4892 | 250 Wet Scenario | 83.96 | 240.42 | 1.03 | 81.16 | 0.2 |
| | | | | | | | | |
| Medway Creek | London | 732.3555 | | Bridge | | | | |
| | | | | | | | | |
| Medway Creek | London | 594.7961 | 250 Historic | 82.92 | 239.96 | 1.27 | 65.15 | 0.27 |
| Medway Creek | London | 594.7961 | 250 Wet Scenario | 83.96 | 240.33 | 1.1 | 76.2 | 0.22 |
| | | | | | | | | |
| Medway Creek | London | 584.8447 | | Bridge | | | | |
| | | | | | | | | |
| Medway Creek | London | 573.3849 | 250 Historic | 82.92 | 239.94 | 1.29 | 64.51 | 0.27 |
| Medway Creek | London | 573.3849 | 250 Wet Scenario | 83.96 | 240.32 | 1.11 | 75.78 | 0.22 |
| | | | | | | | | |
| Medway Creek | London | 328.9676 | 250 Historic | 82.92 | 239.8 | 0.89 | 180.47 | 0.15 |
| Medway Creek | London | 328.9676 | 250 Wet Scenario | 83.96 | 240.2 | 0.61 | 261.68 | 0.1 |
| | | | | | | | | |
| Medway Creek | London | 46.51068 | 250 Historic | 82.92 | 239.8 | 0.24 | 580.77 | 0.04 |
| Medway Creek | London | 46.51068 | 250 Wet Scenario | 83.96 | 240.2 | 0.19 | 713.06 | 0.03 |

Table 3.5 HEC-RAS results for the Pottersburg Creek

| River | Reach | River Sta | Profile | Q Total | W.S. Elev | Vel Chnl | Flow Area | Froude # Chl |
|---|---|---|---|---|---|---|---|---|
| | | | | (m3/s) | (m) | (m/s) | (m2) | |
| Pottersburg Cr | London | 14213.43 | 250 Historic | 39.3 | 274.5 | 0.98 | 118.14 | 0.2 |
| Pottersburg Cr | London | 14213.43 | 250 Wet Scenario | 46.63 | 274.56 | 1.01 | 131.58 | 0.2 |
| | | | | | | | | |
| Pottersburg Cr | London | 13917.92 | 250 Historic | 39.3 | 274.17 | 1.72 | 59.66 | 0.35 |
| Pottersburg Cr | London | 13917.92 | 250 Wet Scenario | 46.63 | 274.26 | 1.66 | 77.4 | 0.33 |
| | | | | | | | | |
| Pottersburg Cr | London | 13087 | 250 Historic | 39.3 | 273.52 | 1.13 | 80.31 | 0.23 |
| Pottersburg Cr | London | 13087 | 250 Wet Scenario | 46.63 | 273.63 | 1.12 | 95.5 | 0.22 |
| | | | | | | | | |
| Pottersburg Cr | London | 12845.15 | 250 Historic | 39.3 | 272.83 | 1.43 | 68.34 | 0.28 |
| Pottersburg Cr | London | 12845.15 | 250 Wet Scenario | 46.63 | 272.94 | 1.46 | 81.14 | 0.27 |
| | | | | | | | | |
| Pottersburg Cr | London | 12020.39 | 250 Historic | 39.3 | 271.26 | 2.97 | 22.37 | 0.64 |
| Pottersburg Cr | London | 12020.39 | 250 Wet Scenario | 46.63 | 271.65 | 2.22 | 47.36 | 0.44 |
| | | | | | | | | |
| Pottersburg Cr | London | 11736.32 | 250 Historic | 39.3 | 271.18 | 1.49 | 26.38 | 0.33 |
| Pottersburg Cr | London | 11736.32 | 250 Wet Scenario | 46.63 | 271.51 | 1.53 | 30.47 | 0.31 |
| | | | | | | | | |
| Pottersburg Cr | London | 11562.04 | | Bridge | | | | |
| | | | | | | | | |
| Pottersburg Cr | London | 11390.69 | 250 Historic | 39.3 | 271.17 | 1.29 | 30.52 | 0.28 |
| Pottersburg Cr | London | 11390.69 | 250 Wet Scenario | 46.63 | 271.25 | 1.47 | 31.63 | 0.31 |
| | | | | | | | | |
| Pottersburg Cr | London | 10999.37 | 250 Historic | 39.3 | 271.15 | 0.24 | 415.08 | 0.04 |
| Pottersburg Cr | London | 10999.37 | 250 Wet Scenario | 46.63 | 271.23 | 0.25 | 451.73 | 0.05 |
| | | | | | | | | |
| Pottersburg Cr | London | 10705.16 | 250 Historic | 39.3 | 270.66 | 1.89 | 20.84 | 0.37 |
| Pottersburg Cr | London | 10705.16 | 250 Wet Scenario | 46.63 | 270.73 | 2.18 | 21.4 | 0.42 |
| | | | | | | | | |
| Pottersburg Cr | London | 10403.58 | 250 Historic | 39.3 | 270.3 | 1.73 | 48.7 | 0.35 |
| Pottersburg Cr | London | 10403.58 | 250 Wet Scenario | 46.63 | 270.32 | 1.98 | 51.3 | 0.4 |
| | | | | | | | | |
| Pottersburg Cr | London | 10391.58 | | Culvert | | | | |
| | | | | | | | | |
| Pottersburg Cr | London | 10379.76 | 250 Historic | 39.3 | 270.14 | 1.37 | 46.39 | 0.29 |
| Pottersburg Cr | London | 10379.76 | 250 Wet Scenario | 46.63 | 270.26 | 1.43 | 59.85 | 0.29 |
| | | | | | | | | |
| Pottersburg Cr | London | 9945.8 | 250 Historic | 39.3 | 269.48 | 1.06 | 62.5 | 0.26 |
| Pottersburg Cr | London | 9945.8 | 250 Wet Scenario | 46.63 | 269.59 | 1.11 | 72.24 | 0.27 |
| | | | | | | | | |
| Pottersburg Cr | London | 9600.814 | 250 Historic | 87.22 | 269.48 | 0.51 | 433.86 | 0.1 |
| Pottersburg Cr | London | 9600.814 | 250 Wet Scenario | 101.01 | 269.59 | 0.51 | 492.4 | 0.1 |
| | | | | | | | | |
| Pottersburg Cr | London | 9336.81 | 250 Historic | 87.22 | 269.38 | 0.73 | 348.5 | 0.14 |
| Pottersburg Cr | London | 9336.81 | 250 Wet Scenario | 101.01 | 269.5 | 0.71 | 398.84 | 0.13 |
| | | | | | | | | |
| Pottersburg Cr | London | 9196.486 | 250 Historic | 87.22 | 269.37 | 0.57 | 431.79 | 0.11 |
| Pottersburg Cr | London | 9196.486 | 250 Wet Scenario | 101.01 | 269.49 | 0.56 | 492.1 | 0.1 |
| | | | | | | | | |
| Pottersburg Cr | London | 9179.952 | | Bridge | | | | |
| | | | | | | | | |
| Pottersburg Cr | London | 9169.085 | 250 Historic | 87.22 | 269.31 | 0.62 | 404.33 | 0.12 |
| Pottersburg Cr | London | 9169.085 | 250 Wet Scenario | 101.01 | 269.46 | 0.58 | 478.08 | 0.11 |
| | | | | | | | | |
| Pottersburg Cr | London | 9129.323 | 250 Historic | 87.22 | 269.31 | 0.51 | 366.68 | 0.1 |
| Pottersburg Cr | London | 9129.323 | 250 Wet Scenario | 101.01 | 269.45 | 0.51 | 425.82 | 0.1 |
| | | | | | | | | |

Table 3.5 HEC-RAS results for the Pottersburg Creek-continued

| River | Reach | River Sta | Profile | Q Total | W.S. Elev | Vel Chnl | Flow Area | Froude # Chl |
|---|---|---|---|---|---|---|---|---|
| | | | | (m3/s) | (m) | (m/s) | (m2) | |
| Pottersburg Cr | London | 8787.067 | 250 Historic | 87.22 | 269.06 | 1.13 | 196.74 | 0.23 |
| Pottersburg Cr | London | 8787.067 | 250 Wet Scenario | 101.01 | 269.29 | 0.93 | 267.3 | 0.18 |
| | | | | | | | | |
| Pottersburg Cr | London | 8767.1 | 250 Historic | 87.22 | 269.05 | 1.03 | 259.28 | 0.21 |
| Pottersburg Cr | London | 8767.1 | 250 Wet Scenario | 101.01 | 269.28 | 0.84 | 377.18 | 0.16 |
| | | | | | | | | |
| Pottersburg Cr | London | 8755.028 | | Bridge | | | | |
| | | | | | | | | |
| Pottersburg Cr | London | 8742.553 | 250 Historic | 87.22 | 268.94 | 0.99 | 219.12 | 0.2 |
| Pottersburg Cr | London | 8742.553 | 250 Wet Scenario | 101.01 | 269.21 | 0.93 | 338.81 | 0.18 |
| | | | | | | | | |
| Pottersburg Cr | London | 8719.361 | 250 Historic | 87.22 | 268.89 | 1 | 190.31 | 0.21 |
| Pottersburg Cr | London | 8719.361 | 250 Wet Scenario | 101.01 | 269.17 | 1.12 | 265.69 | 0.22 |
| | | | | | | | | |
| Pottersburg Cr | London | 7820.696 | 250 Historic | 87.22 | 268.41 | 2.22 | 88.76 | 0.39 |
| Pottersburg Cr | London | 7820.696 | 250 Wet Scenario | 101.01 | 268.76 | 2.03 | 119.38 | 0.34 |
| | | | | | | | | |
| Pottersburg Cr | London | 7593.461 | 250 Historic | 87.22 | 265.89 | 0.53 | 307.31 | 0.13 |
| Pottersburg Cr | London | 7593.461 | 250 Wet Scenario | 101.01 | 266.41 | 0.42 | 530.63 | 0.09 |
| | | | | | | | | |
| Potterrsburg Cr | London | 7377.505 | 250 Historic | 87.22 | 265.82 | 0.67 | 201.67 | 0.15 |
| Potterrsburg Cr | London | 7377.505 | 250 Wet Scenario | 101.01 | 266.38 | 0.5 | 315.98 | 0.1 |
| | | | | | | | | |
| Potterrsburg Cr | London | 6789.392 | 250 Historic | 87.22 | 265.05 | 2.37 | 68.2 | 0.43 |
| Potterrsburg Cr | London | 6789.392 | 250 Wet Scenario | 101.01 | 265.98 | 1.89 | 111.71 | 0.3 |
| | | | | | | | | |
| Pottersburg Cr | London | 6780.69 | 250 Historic | 96.94 | 264.58 | 3.32 | 29.24 | 0.67 |
| Pottersburg Cr | London | 6780.69 | 250 Wet Scenario | 111.93 | 265.76 | 2.61 | 42.96 | 0.43 |
| | | | | | | | | |
| Pottersburg Cr | London | 6766.895 | | Bridge | | | | |
| | | | | | | | | |
| Pottersburg Cr | London | 6755.016 | 250 Historic | 96.94 | 264.2 | 3.85 | 25.16 | 0.83 |
| Pottersburg Cr | London | 6755.016 | 250 Wet Scenario | 111.93 | 264.38 | 4.11 | 27.22 | 0.86 |
| | | | | | | | | |
| Pottersburg Cr | London | 6361.93 | 250 Historic | 96.94 | 264.1 | 1.34 | 153.91 | 0.24 |
| Pottersburg Cr | London | 6361.93 | 250 Wet Scenario | 111.93 | 264.26 | 1.4 | 176.27 | 0.24 |
| | | | | | | | | |
| Pottersburg Cr | London | 6348.452 | | Bridge | | | | |
| | | | | | | | | |
| Pottersburg Cr | London | 6335.22 | 250 Historic | 96.94 | 264.03 | 1.43 | 143.94 | 0.26 |
| Pottersburg Cr | London | 6335.22 | 250 Wet Scenario | 111.93 | 264.22 | 1.47 | 170.82 | 0.26 |
| | | | | | | | | |
| Pottersburg Cr | London | 5799.997 | 250 Historic | 99.47 | 263.86 | 0.79 | 234.91 | 0.13 |
| Pottersburg Cr | London | 5799.997 | 250 Wet Scenario | 114.22 | 264.05 | 0.77 | 266.02 | 0.12 |
| | | | | | | | | |
| Pottersburg Cr | London | 5473.485 | 250 Historic | 99.47 | 261.95 | 2.42 | 137.72 | 0.45 |
| Pottersburg Cr | London | 5473.485 | 250 Wet Scenario | 114.22 | 262.17 | 2.32 | 166.19 | 0.42 |
| | | | | | | | | |
| Pottersburg Cr | London | 4961.666 | 250 Historic | 99.47 | 261.62 | 0.97 | 224.02 | 0.16 |
| Pottersburg Cr | London | 4961.666 | 250 Wet Scenario | 114.22 | 261.87 | 0.94 | 266.56 | 0.15 |
| | | | | | | | | |
| Potterrsburg Cr | London | 4953.376 | | Bridge | | | | |
| | | | | | | | | |
| Potterrsburg Cr | London | 4944.249 | 250 Historic | 99.47 | 261.59 | 1.01 | 217.68 | 0.17 |
| Potterrsburg Cr | London | 4944.249 | 250 Wet Scenario | 114.22 | 261.85 | 0.97 | 263.09 | 0.15 |
| | | | | | | | | |
| Pottersburg Cr | London | 4740.563 | 250 Historic | 99.47 | 260.9 | 2.03 | 163.61 | 0.34 |

Table 3.5 HEC-RAS results for the Pottersburg Creek-continued

| River | Reach | River Sta | Profile | Q Total | W.S. Elev | Vel Chnl | Flow Area | Froude # Chl |
|---|---|---|---|---|---|---|---|---|
| | | | | (m3/s) | (m) | (m/s) | (m2) | |
| Pottersburg Cr | London | 4740.563 | 250 Wet Scenario | 114.22 | 261.03 | 1.99 | 191.28 | 0.33 |
| | | | | | | | | |
| Pottersburg Cr | London | 4588.74 | 250 Historic | 99.47 | 260.78 | 2.21 | 137.76 | 0.36 |
| Pottersburg Cr | London | 4588.74 | 250 Wet Scenario | 114.22 | 260.91 | 2.29 | 154.95 | 0.37 |
| | | | | | | | | |
| Pottersburg Cr | London | 4296.229 | 250 Historic | 99.47 | 259.87 | 1.45 | 147.94 | 0.24 |
| Pottersburg Cr | London | 4296.229 | 250 Wet Scenario | 114.22 | 259.97 | 1.5 | 167.92 | 0.24 |
| | | | | | | | | |
| Pottersburg Cr | London | 4028.238 | 250 Historic | 99.47 | 259.58 | 1.43 | 162.41 | 0.21 |
| Potterrsburg Cr | London | 4028.238 | 250 Wet Scenario | 114.22 | 259.67 | 1.45 | 180.11 | 0.21 |
| | | | | | | | | |
| Pottersburg Cr | London | 3383.662 | 250 Historic | 99.47 | 259.58 | 0.72 | 343.09 | 0.1 |
| Pottersburg Cr | London | 3383.662 | 250 Wet Scenario | 114.22 | 259.66 | 0.78 | 373.83 | 0.11 |
| | | | | | | | | |
| Pottersburg Cr | London | 3372.148 | | Bridge | | | | |
| | | | | | | | | |
| Pottersburg Cr | London | 3361.717 | 250 Historic | 99.47 | 259.53 | 0.74 | 328.95 | 0.11 |
| Potterrsburg Cr | London | 3361.717 | 250 Wet Scenario | 114.22 | 259.63 | 0.8 | 360.17 | 0.11 |
| | | | | | | | | |
| Pottersburg Cr | London | 3008.501 | 250 Historic | 99.47 | 259.53 | 0.22 | 1316.91 | 0.03 |
| Pottersburg Cr | London | 3008.501 | 250 Wet Scenario | 114.22 | 259.63 | 0.23 | 1384.27 | 0.03 |
| | | | | | | | | |
| Pottersburg Cr | London | 2631.258 | 250 Historic | 127.42 | 259.53 | 0.19 | 1512.22 | 0.02 |
| Pottersburg Cr | London | 2631.258 | 250 Wet Scenario | 145.77 | 259.62 | 0.21 | 1606.56 | 0.02 |
| | | | | | | | | |
| Pottersburg Cr | London | 2619.492 | | Bridge | | | | |
| | | | | | | | | |
| Pottersburg Cr | London | 2610.263 | 250 Historic | 127.42 | 259.53 | 0.19 | 1511.6 | 0.02 |
| Pottersburg Cr | London | 2610.263 | 250 Wet Scenario | 145.77 | 259.62 | 0.21 | 1605.82 | 0.02 |
| | | | | | | | | |
| Pottersburg Cr | London | 2272.463 | 250 Historic | 127.42 | 259.52 | 0.13 | 2831.07 | 0.01 |
| Potterrsburg Cr | London | 2272.463 | 250 Wet Scenario | 145.77 | 259.62 | 0.15 | 2919.18 | 0.02 |
| | | | | | | | | |
| Pottersburg Cr | London | 1805.415 | 250 Historic | 127.42 | 259.52 | 0.34 | 1288.42 | 0.03 |
| Potterrsburg Cr | London | 1805.415 | 250 Wet Scenario | 145.77 | 259.61 | 0.38 | 1316.83 | 0.04 |
| | | | | | | | | |
| Pottersburg Cr | London | 1787.191 | | Bridge | | | | |
| | | | | | | | | |
| Pottersburg Cr | London | 1771.452 | 250 Historic | 140.12 | 252.69 | 5.96 | 23.52 | 1 |
| Potterrsburg Cr | London | 1771.452 | 250 Wet Scenario | 160.1 | 253.02 | 6.24 | 25.67 | 1 |
| | | | | | | | | |
| Pottersburg Cr | London | 1338.223 | 250 Historic | 140.12 | 248.93 | 3.9 | 73.04 | 0.71 |
| Potterrsburg Cr | London | 1338.223 | 250 Wet Scenario | 160.1 | 248.9 | 4.52 | 71 | 0.83 |
| | | | | | | | | |
| Pottersburg Cr | London | 1002.736 | 250 Historic | 140.12 | 247.48 | 2.93 | 98.92 | 0.49 |
| Potterrsburg Cr | London | 1002.736 | 250 Wet Scenario | 160.1 | 247.59 | 3.12 | 106.29 | 0.52 |
| | | | | | | | | |
| Pottersburg Cr | London | 710.4677 | 250 Historic | 143.3 | 245.76 | 0.71 | 136.3 | 0.13 |
| Pottersburg Cr | London | 710.4677 | 250 Wet Scenario | 163.69 | 246.22 | 0.57 | 175.57 | 0.1 |
| | | | | | | | | |
| Pottersburg Cr | London | 309.3382 | 250 Historic | 143.3 | 242.48 | 3.3 | 102.38 | 0.67 |
| Pottersburg Cr | London | 309.3382 | 250 Wet Scenario | 163.69 | 242.63 | 3.29 | 131.02 | 0.65 |
| | | | | | | | | |
| Pottersburg Cr | London | 64.53727 | 250 Historic | 143.3 | 242.3 | 0.28 | 1443.65 | 0.05 |
| Pottersburg Cr | London | 64.53727 | 250 Wet Scenario | 163.69 | 242.62 | 0.27 | 1700.54 | 0.04 |

Table 3.6 HEC-RAS results for the Stoney Creek

| River | Reach | River Sta | Profile | Q Total | W.S. Elev | Vel Chnl | Flow Area |
|---|---|---|---|---|---|---|---|
| | | | | (m3/s) | (m) | (m/s) | (m2) |
| Stoney Creek | Upper Reach | 10028.42 | 250 Historic | 18.36 | 266.29 | 1.51 | 22.96 |
| Stoney Creek | Upper Reach | 10028.42 | 250 Wet Scenario | 20.47 | 266.34 | 1.54 | 25.38 |
| | | | | | | | |
| Stoney Creek | Upper Reach | 9216.203 | 250 Historic | 18.36 | 262.75 | 1.76 | 10.45 |
| Stoney Creek | Upper Reach | 9216.203 | 250 Wet Scenario | 20.47 | 262.81 | 1.89 | 10.83 |
| | | | | | | | |
| Stoney Creek | Upper Reach | 9206.765 | | Culvert | | | |
| | | | | | | | |
| Stoney Creek | Upper Reach | 9199.002 | 250 Historic | 18.36 | 262.61 | 1.97 | 9.33 |
| Stoney Creek | Upper Reach | 9199.002 | 250 Wet Scenario | 20.47 | 262.61 | 2.18 | 9.38 |
| | | | | | | | |
| Stoney Creek | Upper Reach | 8750.41 | 250 Historic | 19.81 | 260.62 | 1.08 | 26.3 |
| Stoney Creek | Upper Reach | 8750.41 | 250 Wet Scenario | 22.09 | 260.66 | 1.13 | 28.62 |
| | | | | | | | |
| Stoney Creek | Upper Reach | 8469.355 | 250 Historic | 19.81 | 259.74 | 0.83 | 49.38 |
| Stoney Creek | Upper Reach | 8469.355 | 250 Wet Scenario | 22.09 | 259.8 | 0.84 | 54.52 |
| | | | | | | | |
| Stoney Creek | Upper Reach | 7986.903 | 250 Historic | 19.81 | 258.49 | 0.66 | 62.58 |
| Stoney Creek | Upper Reach | 7986.903 | 250 Wet Scenario | 22.09 | 258.52 | 0.69 | 66.32 |
| | | | | | | | |
| Stoney Creek | Upper Reach | 7106.365 | 250 Historic | 19.81 | 257.29 | 1.5 | 23.9 |
| Stoney Creek | Upper Reach | 7106.365 | 250 Wet Scenario | 22.09 | 257.33 | 1.52 | 27 |
| | | | | | | | |
| Stoney Creek | Upper Reach | 6565.449 | 250 Historic | 27.37 | 256.44 | 0.78 | 57.66 |
| Stoney Creek | Upper Reach | 6565.449 | 250 Wet Scenario | 30.56 | 256.54 | 0.72 | 69.39 |
| | | | | | | | |
| Stoney Creek | Upper Reach | 6369.594 | 250 Historic | 27.37 | 256.41 | 0.26 | 156.57 |
| Stoney Creek | Upper Reach | 6369.594 | 250 Wet Scenario | 30.56 | 256.51 | 0.25 | 178.02 |
| | | | | | | | |
| Stoney Creek | Middle Reach | 6242.931 | 250 Historic | 47.72 | 256.34 | 1.02 | 89.3 |
| Stoney Creek | Middle Reach | 6242.931 | 250 Wet Scenario | 52.2 | 256.45 | 1.01 | 101.34 |
| | | | | | | | |
| Stoney Creek | Middle Reach | 6226.208 | 250 Historic | 47.72 | 256.05 | 2.33 | 20.5 |
| Stoney Creek | Middle Reach | 6226.208 | 250 Wet Scenario | 52.2 | 256.13 | 2.42 | 21.59 |
| | | | | | | | |
| Stoney Creek | Middle Reach | 6217.025 | | Bridge | | | |
| | | | | | | | |
| Stoney Creek | Middle Reach | 6209.119 | 250 Historic | 47.72 | 255.65 | 3.2 | 14.89 |
| Stoney Creek | Middle Reach | 6209.119 | 250 Wet Scenario | 52.2 | 255.7 | 3.33 | 15.68 |
| | | | | | | | |
| Stoney Creek | Middle Reach | 5947.052 | 250 Historic | 47.72 | 255.43 | 1.92 | 56.13 |
| Stoney Creek | Middle Reach | 5947.052 | 250 Wet Scenario | 52.2 | 255.48 | 1.94 | 60.78 |
| | | | | | | | |
| Stoney Creek | Middle Reach | 5349.737 | 250 Historic | 47.72 | 254.71 | 0.83 | 98.25 |
| Stoney Creek | Middle Reach | 5349.737 | 250 Wet Scenario | 52.2 | 254.76 | 0.86 | 103.62 |
| | | | | | | | |
| Stoney Creek | Middle Reach | 4736.068 | 250 Historic | 48.73 | 253.36 | 2.24 | 32.56 |
| Stoney Creek | Middle Reach | 4736.068 | 250 Wet Scenario | 53.89 | 253.4 | 2.31 | 35.07 |
| | | | | | | | |
| Stoney Creek | Middle Reach | 4254.917 | 250 Historic | 48.73 | 252.77 | 1.44 | 57.22 |
| Stoney Creek | Middle Reach | 4254.917 | 250 Wet Scenario | 53.89 | 252.74 | 1.66 | 55.07 |
| | | | | | | | |
| Stoney Creek | Middle Reach | 3923.573 | 250 Historic | 48.73 | 250.29 | 2.75 | 18.93 |
| Stoney Creek | Middle Reach | 3923.573 | 250 Wet Scenario | 53.89 | 250.35 | 2.83 | 20.42 |
| | | | | | | | |
| Stoney Creek | Middle Reach | 3782.788 | 250 Historic | 48.73 | 249.32 | 1.03 | 50.66 |
| Stoney Creek | Middle Reach | 3782.788 | 250 Wet Scenario | 53.89 | 249.46 | 1.06 | 54.78 |

Table 3.6 HEC-RAS results for the Stoney Creek-continued

| River | Reach | River Sta | Profile | Q Total | W.S. Elev | Vel Chnl | Flow Area |
|---|---|---|---|---|---|---|---|
| | | | | (m3/s) | (m) | (m/s) | (m2) |
| Stoney Creek | Middle Reach | 3324.718 | 250 Historic | 48.73 | 249.08 | 0.94 | 60.53 |
| Stoney Creek | Middle Reach | 3324.718 | 250 Wet Scenario | 53.89 | 249.22 | 0.98 | 65.88 |
| | | | | | | | |
| Stoney Creek | Middle Reach | 3309.405 | 250 Historic | 48.73 | 249.08 | 0.85 | 57.21 |
| Stoney Creek | Middle Reach | 3309.405 | 250 Wet Scenario | 53.89 | 249.22 | 0.89 | 60.86 |
| | | | | | | | |
| Stoney Creek | Middle Reach | 3306.687 | | Bridge | | | |
| | | | | | | | |
| Stoney Creek | Middle Reach | 3303.389 | 250 Historic | 48.73 | 249.08 | 0.85 | 57.43 |
| Stoney Creek | Middle Reach | 3303.389 | 250 Wet Scenario | 53.89 | 249.21 | 0.88 | 60.99 |
| | | | | | | | |
| Stoney Creek | Middle Reach | 3295.009 | 250 Historic | 48.73 | 249.07 | 0.92 | 62.45 |
| Stoney Creek | Middle Reach | 3295.009 | 250 Wet Scenario | 53.89 | 249.2 | 0.96 | 67.98 |
| | | | | | | | |
| Stoney Creek | Middle Reach | 3019.428 | 250 Historic | 48.73 | 248.99 | 1.01 | 57.01 |
| Stoney Creek | Middle Reach | 3019.428 | 250 Wet Scenario | 53.89 | 249.12 | 1.07 | 77.23 |
| | | | | | | | |
| Stoney Creek | Lower Reach | 2881.127 | 250 Historic | 59.16 | 248.83 | 1.41 | 55.75 |
| Stoney Creek | Lower Reach | 2881.127 | 250 Wet Scenario | 65.65 | 248.95 | 1.47 | 60.38 |
| | | | | | | | |
| Stoney Creek | Lower Reach | 2708.136 | 250 Historic | 59.16 | 248.76 | 1.01 | 58.84 |
| Stoney Creek | Lower Reach | 2708.136 | 250 Wet Scenario | 65.65 | 248.88 | 1.05 | 62.48 |
| | | | | | | | |
| Stoney Creek | Lower Reach | 2694.901 | | Bridge | | | |
| | | | | | | | |
| Stoney Creek | Lower Reach | 2678.896 | 250 Historic | 59.16 | 248.75 | 1.06 | 56.01 |
| Stoney Creek | Lower Reach | 2678.896 | 250 Wet Scenario | 65.65 | 248.87 | 1.1 | 59.7 |
| | | | | | | | |
| Stoney Creek | Lower Reach | 2299.93 | 250 Historic | 59.16 | 248.39 | 1.45 | 59.98 |
| Stoney Creek | Lower Reach | 2299.93 | 250 Wet Scenario | 65.65 | 248.53 | 1.49 | 67.28 |
| | | | | | | | |
| Stoney Creek | Lower Reach | 1703.93 | 250 Historic | 59.16 | 247.97 | 1.1 | 68.36 |
| Stoney Creek | Lower Reach | 1703.93 | 250 Wet Scenario | 65.65 | 248.16 | 1.07 | 80.77 |
| | | | | | | | |
| Stoney Creek | Lower Reach | 1702.212 | | Bridge | | | |
| | | | | | | | |
| Stoney Creek | Lower Reach | 1700.905 | 250 Historic | 59.16 | 247.6 | 1.55 | 45.82 |
| Stoney Creek | Lower Reach | 1700.905 | 250 Wet Scenario | 65.65 | 247.69 | 1.59 | 50.38 |
| | | | | | | | |
| Stoney Creek | Lower Reach | 746.7147 | 250 Historic | 64.5 | 242.97 | 0.62 | 228.05 |
| Stoney Creek | Lower Reach | 746.7147 | 250 Wet Scenario | 71.53 | 243.22 | 0.59 | 266.89 |
| | | | | | | | |
| Stoney Creek | Lower Reach | 578.084 | 250 Historic | 64.5 | 242.91 | 0.22 | 832.3 |
| Stoney Creek | Lower Reach | 578.084 | 250 Wet Scenario | 71.53 | 243.17 | 0.2 | 1001 |
| | | | | | | | |
| Stoney Creek | Lower Reach | 427.6991 | 250 Historic | 64.5 | 242.89 | 0.61 | 232.03 |
| Stoney Creek | Lower Reach | 427.6991 | 250 Wet Scenario | 71.53 | 243.15 | 0.53 | 288.02 |
| | | | | | | | |
| Stoney Creek | Lower Reach | 420.5541 | | Bridge | | | |
| | | | | | | | |
| Stoney Creek | Lower Reach | 412.8342 | 250 Historic | 64.5 | 242.87 | 0.79 | 227.9 |
| Stoney Creek | Lower Reach | 412.8342 | 250 Wet Scenario | 71.53 | 243.14 | 0.71 | 290.21 |
| | | | | | | | |
| Stoney Creek | Lower Reach | 20.46021 | 250 Historic | 64.5 | 242.87 | 0.12 | 874.62 |
| Stoney Creek | Lower Reach | 20.46021 | 250 Wet Scenario | 71.53 | 243.14 | 0.13 | 947.2 |
| | | | | | | | |
| Ballymonte Drain | Reach 1 | 2511.324 | 250 Historic | 13.14 | 267.99 | 2.29 | 11.71 |

Table 3.6 HEC-RAS results for the Stoney Creek-continued

| River | Reach | River Sta | Profile | Q Total | W.S. Elev | Vel Chnl | Flow Area |
|---|---|---|---|---|---|---|---|
| | | | | (m3/s) | (m) | (m/s) | (m2) |
| Ballymonte Drain | Reach 1 | 2511.324 | 250 Wet Scenario | 14.41 | 267.99 | 2.53 | 11.61 |
| | | | | | | | |
| Ballymonte Drain | Reach 1 | 2146.919 | 250 Historic | 13.14 | 265.48 | 1.9 | 15.84 |
| Ballymonte Drain | Reach 1 | 2146.919 | 250 Wet Scenario | 14.41 | 265.51 | 1.84 | 17.8 |
| | | | | | | | |
| Ballymonte Drain | Reach 1 | 1757.441 | 250 Historic | 13.14 | 262.85 | 0.9 | 25.34 |
| Ballymonte Drain | Reach 1 | 1757.441 | 250 Wet Scenario | 14.41 | 262.88 | 0.95 | 26.62 |
| | | | | | | | |
| Ballymonte Drain | Reach 1 | 1412.911 | 250 Historic | 13.14 | 261.5 | 2.77 | 7.82 |
| Ballymonte Drain | Reach 1 | 1412.911 | 250 Wet Scenario | 14.41 | 261.52 | 2.91 | 8.21 |
| | | | | | | | |
| Ballymonte Drain | Reach 1 | 1247.322 | 250 Historic | 13.14 | 260.57 | 1.73 | 7.61 |
| Ballymonte Drain | Reach 1 | 1247.322 | 250 Wet Scenario | 14.41 | 260.7 | 1.75 | 8.25 |
| | | | | | | | |
| Ballymonte Drain | Reach 1 | 1236.629 | | Culvert | | | |
| | | | | | | | |
| Ballymonte Drain | Reach 1 | 1227.42 | 250 Historic | 13.14 | 260.44 | 1.88 | 6.99 |
| Ballymonte Drain | Reach 1 | 1227.42 | 250 Wet Scenario | 14.41 | 260.55 | 1.93 | 7.49 |
| | | | | | | | |
| Ballymonte Drain | Reach 1 | 992.8035 | 250 Historic | 13.14 | 259.72 | 1.91 | 15.17 |
| Ballymonte Drain | Reach 1 | 992.8035 | 250 Wet Scenario | 14.41 | 259.73 | 2.04 | 15.51 |
| | | | | | | | |
| Ballymonte Drain | Reach 1 | 524.5715 | 250 Historic | 18.32 | 258.41 | 2.07 | 15.31 |
| Ballymonte Drain | Reach 1 | 524.5715 | 250 Wet Scenario | 20.1 | 258.62 | 1.69 | 20.68 |
| | | | | | | | |
| Ballymonte Drain | Reach 1 | 281.2261 | 250 Historic | 18.32 | 258.31 | 1.4 | 13.04 |
| Ballymonte Drain | Reach 1 | 281.2261 | 250 Wet Scenario | 20.1 | 258.49 | 1.45 | 13.87 |
| | | | | | | | |
| Ballymonte Drain | Reach 1 | 268.6835 | | Culvert | | | |
| | | | | | | | |
| Ballymonte Drain | Reach 1 | 256.5497 | 250 Historic | 18.32 | 257.96 | 1.61 | 11.36 |
| Ballymonte Drain | Reach 1 | 256.5497 | 250 Wet Scenario | 20.1 | 258.04 | 1.71 | 11.77 |
| | | | | | | | |
| Ballymonte Drain | Reach 1 | 180.6748 | 250 Historic | 18.32 | 257.32 | 0.59 | 40.13 |
| Ballymonte Drain | Reach 1 | 180.6748 | 250 Wet Scenario | 20.1 | 257.39 | 0.59 | 44.46 |
| | | | | | | | |
| Ballymonte Drain | Reach 1 | 27.50741 | 250 Historic | 18.32 | 256.39 | 0.57 | 56.5 |
| Ballymonte Drain | Reach 1 | 27.50741 | 250 Wet Scenario | 20.1 | 256.49 | 0.52 | 67.72 |
| | | | | | | | |
| Powell Drain | Upper Reach | 1355.036 | 250 Historic | 2.96 | 258.31 | 1.55 | 2 |
| Powell Drain | Upper Reach | 1355.036 | 250 Wet Scenario | 3.31 | 258.33 | 1.64 | 2.12 |
| | | | | | | | |
| Powell Drain | Upper Reach | 1136.692 | 250 Historic | 2.96 | 254.22 | 1.87 | 2.63 |
| Powell Drain | Upper Reach | 1136.692 | 250 Wet Scenario | 3.31 | 254.23 | 1.98 | 2.78 |
| | | | | | | | |
| Powell Drain | Upper Reach | 896.1691 | 250 Historic | 2.96 | 252.33 | 0.62 | 9.21 |
| Powell Drain | Upper Reach | 896.1691 | 250 Wet Scenario | 3.31 | 252.35 | 0.64 | 10.01 |
| | | | | | | | |
| Powell Drain | Upper Reach | 687.2398 | 250 Historic | 3.6 | 251.41 | 1.15 | 3.14 |
| Powell Drain | Upper Reach | 687.2398 | 250 Wet Scenario | 4.02 | 251.5 | 1.2 | 3.34 |
| | | | | | | | |
| Powell Drain | Upper Reach | 659.3658 | | Culvert | | | |
| | | | | | | | |
| Powell Drain | Upper Reach | 640.0165 | 250 Historic | 3.6 | 250.71 | 2.64 | 1.36 |
| Powell Drain | Upper Reach | 640.0165 | 250 Wet Scenario | 4.02 | 250.77 | 2.73 | 1.47 |
| | | | | | | | |
| Powell Drain | Upper Reach | 460.996 | 250 Historic | 3.6 | 249.08 | 0.51 | 7.86 |

Table 3.6 HEC-RAS results for the Stoney Creek-continued

| River | Reach | River Sta | Profile | Q Total | W.S. Elev | Vel Chnl | Flow Area |
|---|---|---|---|---|---|---|---|
| | | | | (m3/s) | (m) | (m/s) | (m2) |
| Powell Drain | Upper Reach | 460.996 | 250 Wet Scenario | 4.02 | 249.2 | 0.5 | 8.98 |
| | | | | | | | |
| Powell Drain | Upper Reach | 283.5963 | 250 Historic | 3.6 | 248.97 | 0.14 | 36.51 |
| Powell Drain | Upper Reach | 283.5963 | 250 Wet Scenario | 4.02 | 249.11 | 0.14 | 41.12 |
| | | | | | | | |
| Powell Drain | Upper Reach | 282.5818 | 250 Historic | 3.6 | 248.97 | 0.12 | 42.26 |
| Powell Drain | Upper Reach | 282.5818 | 250 Wet Scenario | 4.02 | 249.11 | 0.12 | 47.11 |
| | | | | | | | |
| Powell Drain | Lower Reach | 269.5363 | 250 Historic | 9.06 | 248.97 | 0.34 | 34.77 |
| Powell Drain | Lower Reach | 269.5363 | 250 Wet Scenario | 10.13 | 249.11 | 0.34 | 38.24 |
| | | | | | | | |
| Powell Drain | Lower Reach | 213.9913 | 250 Historic | 9.06 | 248.96 | 0.39 | 32.13 |
| Powell Drain | Lower Reach | 213.9913 | 250 Wet Scenario | 10.13 | 249.1 | 0.4 | 35.62 |
| | | | | | | | |
| Powell Drain | Lower Reach | 199.4174 | 250 Historic | 9.06 | 248.96 | 0.4 | 22.77 |
| Powell Drain | Lower Reach | 199.4174 | 250 Wet Scenario | 10.13 | 249.1 | 0.41 | 24.43 |
| | | | | | | | |
| Powell Drain | Lower Reach | 192.1507 | | Bridge | | | |
| | | | | | | | |
| Powell Drain | Lower Reach | 184.5587 | 250 Historic | 9.06 | 248.94 | 0.4 | 22.57 |
| Powell Drain | Lower Reach | 184.5587 | 250 Wet Scenario | 10.13 | 249.08 | 0.42 | 24.17 |
| | | | | | | | |
| Powell Drain | Lower Reach | 172.5238 | 250 Historic | 9.06 | 248.94 | 0.5 | 25.82 |
| Powell Drain | Lower Reach | 172.5238 | 250 Wet Scenario | 10.13 | 249.08 | 0.51 | 28.39 |
| | | | | | | | |
| Powell Drain | Lower Reach | 60.04735 | 250 Historic | 9.06 | 248.93 | 0.42 | 32.16 |
| Powell Drain | Lower Reach | 60.04735 | 250 Wet Scenario | 10.13 | 249.07 | 0.47 | 38.94 |
| | | | | | | | |
| Northdale Drain | Reach 1 | 1114.278 | 250 Historic | 1.25 | 257.36 | 1.72 | 0.8 |
| Northdale Drain | Reach 1 | 1114.278 | 250 Wet Scenario | 1.39 | 257.39 | 1.78 | 0.87 |
| | | | | | | | |
| Northdale Drain | Reach 1 | 966.8527 | 250 Historic | 1.25 | 255.64 | 0.38 | 3.74 |
| Northdale Drain | Reach 1 | 966.8527 | 250 Wet Scenario | 1.39 | 255.67 | 0.4 | 3.98 |
| | | | | | | | |
| Northdale Drain | Reach 1 | 931.9177 | 250 Historic | 1.25 | 255.59 | 0.76 | 1.82 |
| Northdale Drain | Reach 1 | 931.9177 | 250 Wet Scenario | 1.39 | 255.61 | 0.8 | 1.92 |
| | | | | | | | |
| Northdale Drain | Reach 1 | 758.9473 | 250 Historic | 1.25 | 254.38 | 0.65 | 4.88 |
| Northdale Drain | Reach 1 | 758.9473 | 250 Wet Scenario | 1.39 | 254.4 | 0.68 | 5.18 |
| | | | | | | | |
| Northdale Drain | Reach 1 | 457.1955 | 250 Historic | 4.09 | 252.14 | 1.79 | 5.97 |
| Northdale Drain | Reach 1 | 457.1955 | 250 Wet Scenario | 4.57 | 252.14 | 1.92 | 6.18 |
| | | | | | | | |
| Northdale Drain | Reach 1 | 265.3042 | 250 Historic | 4.09 | 249.69 | 0.81 | 5.02 |
| Northdale Drain | Reach 1 | 265.3042 | 250 Wet Scenario | 4.57 | 249.75 | 0.86 | 5.29 |
| | | | | | | | |
| Northdale Drain | Reach 1 | 254.4174 | | Bridge | | | |
| | | | | | | | |
| Northdale Drain | Reach 1 | 242.3045 | 250 Historic | 4.09 | 249.47 | 1.01 | 4.03 |
| Northdale Drain | Reach 1 | 242.3045 | 250 Wet Scenario | 4.57 | 249.52 | 1.08 | 4.24 |
| | | | | | | | |
| Northdale Drain | Reach 1 | 174.2316 | 250 Historic | 4.09 | 249.09 | 0.7 | 6.37 |
| Northdale Drain | Reach 1 | 174.2316 | 250 Wet Scenario | 4.57 | 249.19 | 0.65 | 7.74 |
| | | | | | | | |
| Northdale Drain | Reach 1 | 51.28607 | 250 Historic | 4.09 | 248.97 | 0.62 | 7.6 |
| Northdale Drain | Reach 1 | 51.28607 | 250 Wet Scenario | 4.57 | 249.11 | 0.55 | 9.55 |
| | | | | | | | |

Table 3.6 HEC-RAS results for the Stoney Creek-continued

| River | Reach | River Sta | Profile | Q Total | W.S. Elev | Vel Chnl | Flow Area |
|---|---|---|---|---|---|---|---|
| | | | | (m3/s) | (m) | (m/s) | (m2) |
| Northdale Drain | Reach 1 | 51.18607 | 250 Historic | 4.09 | 248.97 | 0.3 | 15.2 |
| Northdale Drain | Reach 1 | 51.18607 | 250 Wet Scenario | 4.57 | 249.11 | 0.3 | 17.13 |
| | | | | | | | |
| Northdale Drain | Reach 1 | 18.44887 | 250 Historic | 4.09 | 248.97 | 0.28 | 22.06 |
| Northdale Drain | Reach 1 | 18.44887 | 250 Wet Scenario | 4.57 | 249.11 | 0.27 | 25.79 |

Table 3.7 HEC-RAS results for the Dingman Creek

| River | Reach | River Sta | Profile | Q Total | W.S. Elev | Vel Chnl | Flow Area |
|---|---|---|---|---|---|---|---|
| | | | | (m3/s) | (m) | (m/s) | (m2) |
| Dingman Creek | Reach 13 | 35235.36 | 250 Historic | 32.31 | 269.8 | 1.84 | 25.52 |
| Dingman Creek | Reach 13 | 35235.36 | 250 Wet Scenario | 36.06 | 269.87 | 1.86 | 29.66 |
| | | | | | | | |
| Dingman Creek | Reach 13 | 33798.37 | 250 Historic | 32.31 | 267.41 | 1.77 | 37.19 |
| Dingman Creek | Reach 13 | 33798.37 | 250 Wet Scenario | 36.06 | 267.48 | 1.8 | 42.72 |
| | | | | | | | |
| Dingman Creek | Reach 13 | 32914.46 | 250 Historic | 32.31 | 265.75 | 1.41 | 25.77 |
| Dingman Creek | Reach 13 | 32914.46 | 250 Wet Scenario | 36.06 | 265.82 | 1.5 | 27.26 |
| | | | | | | | |
| Dingman Creek | Reach 12 | 32757.15 | 250 Historic | 48.48 | 265.72 | 0.78 | 98.8 |
| Dingman Creek | Reach 12 | 32757.15 | 250 Wet Scenario | 54.47 | 265.8 | 0.8 | 108.8 |
| | | | | | | | |
| Dingman Creek | Reach 12 | 31610.83 | 250 Historic | 48.48 | 264.82 | 0.67 | 173.46 |
| Dingman Creek | Reach 12 | 31610.83 | 250 Wet Scenario | 54.47 | 264.93 | 0.66 | 195.78 |
| | | | | | | | |
| Dingman Creek | Reach 11 | 31417.08 | 250 Historic | 72.99 | 264.83 | 0.2 | 753.21 |
| Dingman Creek | Reach 11 | 31417.08 | 250 Wet Scenario | 82.19 | 264.93 | 0.21 | 803.49 |
| | | | | | | | |
| Dingman Creek | Reach 11 | 29624.61 | 250 Historic | 83.28 | 264.54 | 1.67 | 96.06 |
| Dingman Creek | Reach 11 | 29624.61 | 250 Wet Scenario | 93.73 | 264.62 | 1.77 | 104.78 |
| | | | | | | | |
| Dingman Creek | Reach 11 | 29619.85 | | Bridge | | | |
| | | | | | | | |
| Dingman Creek | Reach 11 | 29615.87 | 250 Historic | 83.28 | 264.22 | 2.53 | 32.95 |
| Dingman Creek | Reach 11 | 29615.87 | 250 Wet Scenario | 93.73 | 264.29 | 2.79 | 33.59 |
| | | | | | | | |
| Dingman Creek | Reach 11 | 29179.73 | 250 Historic | 83.53 | 263.58 | 1.98 | 66.86 |
| Dingman Creek | Reach 11 | 29179.73 | 250 Wet Scenario | 94.02 | 263.71 | 2.02 | 75.65 |
| | | | | | | | |
| Dingman Creek | Reach 10 | 29098.12 | 250 Historic | 77.24 | 263.59 | 1.25 | 104.94 |
| Dingman Creek | Reach 10 | 29098.12 | 250 Wet Scenario | 87.04 | 263.73 | 1.26 | 115.92 |
| | | | | | | | |
| Dingman Creek | Reach 10 | 28323.04 | 250 Historic | 83.09 | 262.88 | 1.61 | 96.51 |
| Dingman Creek | Reach 10 | 28323.04 | 250 Wet Scenario | 93.73 | 263 | 1.6 | 108.71 |
| | | | | | | | |
| Dingman Creek | Reach 10 | 26350.68 | 250 Historic | 87 | 261.87 | 0.87 | 190.82 |
| Dingman Creek | Reach 10 | 26350.68 | 250 Wet Scenario | 97.92 | 262.18 | 0.78 | 259.57 |
| | | | | | | | |
| Dingman Creek | Reach 10 | 26342.14 | | Bridge | | | |
| | | | | | | | |
| Dingman Creek | Reach 10 | 26335.16 | 250 Historic | 87 | 261.79 | 1.03 | 176.72 |
| Dingman Creek | Reach 10 | 26335.16 | 250 Wet Scenario | 97.92 | 262.13 | 0.91 | 247.32 |
| | | | | | | | |
| Dingman Creek | Reach 10 | 25735.1 | 250 Historic | 87 | 260.48 | 2.75 | 54.18 |
| Dingman Creek | Reach 10 | 25735.1 | 250 Wet Scenario | 97.92 | 260.65 | 2.81 | 61.57 |
| | | | | | | | |
| Dingman Creek | Reach 10 | 23276.36 | 250 Historic | 101.78 | 258 | 0.83 | 281.68 |
| Dingman Creek | Reach 10 | 23276.36 | 250 Wet Scenario | 113.75 | 258.13 | 0.83 | 344.97 |
| | | | | | | | |
| Dingman Creek | Reach 10 | 22693.54 | 250 Historic | 101.78 | 257.58 | 1.57 | 136.56 |
| Dingman Creek | Reach 10 | 22693.54 | 250 Wet Scenario | 113.75 | 257.66 | 1.64 | 147.8 |
| | | | | | | | |
| Dingman Creek | Reach 8 | 18900.88 | 250 Historic | 123.29 | 254.21 | 1.51 | 211.38 |
| Dingman Creek | Reach 8 | 18900.88 | 250 Wet Scenario | 137.91 | 254.3 | 1.54 | 233.58 |
| | | | | | | | |
| Dingman Creek | Reach 8 | 18398.32 | 250 Historic | 123.29 | 253.88 | 0.91 | 462.58 |
| Dingman Creek | Reach 8 | 18398.32 | 250 Wet Scenario | 137.91 | 254.1 | 0.79 | 597.78 |

Table 3.7 HEC-RAS results for the Dingman Creek-continued

| River | Reach | River Sta | Profile | Q Total | W.S. Elev | Vel Chnl | Flow Area |
|---|---|---|---|---|---|---|---|
| | | | | (m3/s) | (m) | (m/s) | (m2) |
| Dingman Creek | Reach 7 | 18147.96 | 250 Historic | 130.98 | 253.87 | 0.32 | 837.82 |
| Dingman Creek | Reach 7 | 18147.96 | 250 Wet Scenario | 146.09 | 254.1 | 0.3 | 991.16 |
| | | | | | | | |
| Dingman Creek | Reach 7 | 17883.05 | 250 Historic | 130.98 | 253.87 | 0.33 | 814.18 |
| Dingman Creek | Reach 7 | 17883.05 | 250 Wet Scenario | 146.09 | 254.09 | 0.3 | 973.1 |
| | | | | | | | |
| Dingman Creek | Reach 6 | 17717.42 | 250 Historic | 131.45 | 253.86 | 0.35 | 740.19 |
| Dingman Creek | Reach 6 | 17717.42 | 250 Wet Scenario | 146.59 | 254.08 | 0.31 | 869.57 |
| | | | | | | | |
| Dingman Creek | Reach 6 | 16691.8 | 250 Historic | 131.45 | 253.21 | 1.48 | 305.04 |
| Dingman Creek | Reach 6 | 16691.8 | 250 Wet Scenario | 146.59 | 253.47 | 1.2 | 411.12 |
| | | | | | | | |
| Dingman Creek | Reach 5 | 16598.71 | 250 Historic | 130.6 | 253.2 | 0.96 | 413.52 |
| Dingman Creek | Reach 5 | 16598.71 | 250 Wet Scenario | 145.66 | 253.45 | 0.88 | 493.26 |
| | | | | | | | |
| Dingman Creek | Reach 5 | 16565.42 | 250 Historic | 130.6 | 253.19 | 1.01 | 421.01 |
| Dingman Creek | Reach 5 | 16565.42 | 250 Wet Scenario | 145.66 | 253.44 | 0.94 | 498.85 |
| | | | | | | | |
| Dingman Creek | Reach 4 | 16328.61 | 250 Historic | 129.34 | 253.06 | 1.78 | 248.5 |
| Dingman Creek | Reach 4 | 16328.61 | 250 Wet Scenario | 144.26 | 253.35 | 1.6 | 314.13 |
| | | | | | | | |
| Dingman Creek | Reach 4 | 14539.36 | 250 Historic | 128.45 | 252.58 | 1.79 | 71.67 |
| Dingman Creek | Reach 4 | 14539.36 | 250 Wet Scenario | 143.28 | 252.93 | 1.82 | 78.65 |
| | | | | | | | |
| Dingman Creek | Reach 4 | 14526.73 | | Bridge | | | |
| | | | | | | | |
| Dingman Creek | Reach 4 | 14515.18 | 250 Historic | 128.45 | 252.3 | 1.78 | 72.07 |
| Dingman Creek | Reach 4 | 14515.18 | 250 Wet Scenario | 143.28 | 252.54 | 1.86 | 76.98 |
| | | | | | | | |
| Dingman Creek | Reach 4 | 12864.36 | 250 Historic | 128.01 | 252.21 | 0.62 | 562.27 |
| Dingman Creek | Reach 4 | 12864.36 | 250 Wet Scenario | 142.8 | 252.47 | 0.59 | 665.48 |
| | | | | | | | |
| Dingman Creek | Reach 4 | 11725.65 | 250 Historic | 128.01 | 251.67 | 1.24 | 389.95 |
| Dingman Creek | Reach 4 | 11725.65 | 250 Wet Scenario | 142.8 | 251.94 | 1.25 | 430.16 |
| | | | | | | | |
| Dingman Creek | Reach 3 | 11556.95 | 250 Historic | 127.46 | 251.63 | 1.29 | 372.81 |
| Dingman Creek | Reach 3 | 11556.95 | 250 Wet Scenario | 142.19 | 251.89 | 1.29 | 413.65 |
| | | | | | | | |
| Dingman Creek | Reach 3 | 10250.11 | 250 Historic | 127.4 | 250.75 | 1.56 | 154.99 |
| Dingman Creek | Reach 3 | 10250.11 | 250 Wet Scenario | 142.12 | 250.94 | 1.61 | 168.35 |
| | | | | | | | |
| Dingman Creek | Reach 2 | 10155.01 | 250 Historic | 130.52 | 250.61 | 1.98 | 148.62 |
| Dingman Creek | Reach 2 | 10155.01 | 250 Wet Scenario | 145.65 | 250.8 | 2.05 | 163.56 |
| | | | | | | | |
| Dingman Creek | Reach 2 | 9415.808 | 250 Historic | 130.52 | 249.81 | 2.15 | 100.37 |
| Dingman Creek | Reach 2 | 9415.808 | 250 Wet Scenario | 145.65 | 249.97 | 2.24 | 110.81 |
| | | | | | | | |
| Dingman Creek | Reach 1 | 9249.62 | 250 Historic | 134.1 | 249.79 | 1.49 | 198.01 |
| Dingman Creek | Reach 1 | 9249.62 | 250 Wet Scenario | 149.71 | 249.95 | 1.53 | 217.14 |
| | | | | | | | |
| Dingman Creek | Reach 1 | 8018.647 | 250 Historic | 134.1 | 248.73 | 2.25 | 122.04 |
| Dingman Creek | Reach 1 | 8018.647 | 250 Wet Scenario | 149.71 | 248.85 | 2.31 | 135.14 |
| | | | | | | | |
| Dingman Creek | Reach 1 | 7170.537 | 250 Historic | 134.1 | 247.91 | 2.11 | 146.82 |
| Dingman Creek | Reach 1 | 7170.537 | 250 Wet Scenario | 149.71 | 248.03 | 2.14 | 163.16 |
| | | | | | | | |
| Dingman Creek | Reach 1 | 5726.107 | 250 Historic | 134.1 | 246.14 | 2.38 | 56.44 |

Table 3.7 HEC-RAS results for the Dingman Creek-continued

| River | Reach | River Sta | Profile | Q Total | W.S. Elev | Vel Chnl | Flow Area |
|---|---|---|---|---|---|---|---|
| | | | | (m3/s) | (m) | (m/s) | (m2) |
| Dingman Creek | Reach 1 | 5726.107 | 250 Wet Scenario | 149.71 | 246.28 | 2.54 | 59.04 |
| | | | | | | | |
| Dingman Creek | Reach 1 | 5718.255 | | Bridge | | | |
| | | | | | | | |
| Dingman Creek | Reach 1 | 5712.288 | 250 Historic | 138.2 | 246.11 | 2.48 | 55.79 |
| Dingman Creek | Reach 1 | 5712.288 | 250 Wet Scenario | 154.36 | 246.25 | 2.65 | 58.32 |
| | | | | | | | |
| Dingman Creek | Reach 1 | 4146.032 | 250 Historic | 138.2 | 243.6 | 1.98 | 209.53 |
| Dingman Creek | Reach 1 | 4146.032 | 250 Wet Scenario | 154.36 | 243.71 | 2.04 | 229.61 |
| | | | | | | | |
| Dingman Creek | Reach 1 | 3104.552 | 250 Historic | 140.73 | 241.69 | 2.29 | 140.15 |
| Dingman Creek | Reach 1 | 3104.552 | 250 Wet Scenario | 157.22 | 241.81 | 2.38 | 158.39 |
| | | | | | | | |
| Dingman Creek | Reach 1 | 2137.112 | 250 Historic | 140.73 | 239.28 | 2.93 | 110.08 |
| Dingman Creek | Reach 1 | 2137.112 | 250 Wet Scenario | 157.22 | 239.38 | 3.04 | 122.1 |
| | | | | | | | |
| Dingman Creek | Reach 1 | 1458.81 | 250 Historic | 140.73 | 236.92 | 3.52 | 41.97 |
| Dingman Creek | Reach 1 | 1458.81 | 250 Wet Scenario | 157.22 | 236.96 | 3.83 | 43.17 |
| | | | | | | | |
| Dingman Creek | Reach 1 | 800.6564 | 250 Historic | 140.73 | 234.99 | 3.11 | 78.49 |
| Dingman Creek | Reach 1 | 800.6564 | 250 Wet Scenario | 157.22 | 235.09 | 3.26 | 94.38 |
| | | | | | | | |
| Dingman Creek | Reach 1 | 275.0753 | 250 Historic | 140.73 | 234.2 | 1.51 | 192.4 |
| Dingman Creek | Reach 1 | 275.0753 | 250 Wet Scenario | 157.22 | 234.31 | 1.57 | 210.55 |
| | | | | | | | |
| Tributary 13 (K) | Reach 1 | 3457.278 | 250 Historic | 3.29 | 269.56 | 0.15 | 44.39 |
| Tributary 13 (K) | Reach 1 | 3457.278 | 250 Wet Scenario | 3.75 | 269.64 | 0.14 | 55.74 |
| | | | | | | | |
| Tributary 13 (K) | Reach 1 | 3154.85 | 250 Historic | 3.29 | 268.55 | 1.01 | 3.25 |
| Tributary 13 (K) | Reach 1 | 3154.85 | 250 Wet Scenario | 3.75 | 268.62 | 1.08 | 3.46 |
| | | | | | | | |
| Tributary 13 (K) | Reach 1 | 3133.654 | | Culvert | | | |
| | | | | | | | |
| Tributary 13 (K) | Reach 1 | 3110.776 | 250 Historic | 3.29 | 268.47 | 1.09 | 3.01 |
| Tributary 13 (K) | Reach 1 | 3110.776 | 250 Wet Scenario | 3.75 | 268.53 | 1.18 | 3.19 |
| | | | | | | | |
| Tributary 13 (K) | Reach 1 | 2339.263 | 250 Historic | 3.29 | 268.22 | 0.42 | 19.3 |
| Tributary 13 (K) | Reach 1 | 2339.263 | 250 Wet Scenario | 3.75 | 268.28 | 0.39 | 27.84 |
| | | | | | | | |
| Tributary 13 (K) | Reach 1 | 1499.36 | 250 Historic | 3.29 | 267.53 | 0.52 | 9.7 |
| Tributary 13 (K) | Reach 1 | 1499.36 | 250 Wet Scenario | 3.75 | 267.62 | 0.52 | 11.87 |
| | | | | | | | |
| Tributary 13 (K) | Reach 1 | 211.7297 | 250 Historic | 3.29 | 265.77 | 1.29 | 3.92 |
| Tributary 13 (K) | Reach 1 | 211.7297 | 250 Wet Scenario | 3.75 | 265.85 | 1.3 | 4.53 |
| | | | | | | | |
| Tributary 12 (J) | Reach 1 | 3098.65 | 250 Historic | 4.2 | 273.67 | 0.05 | 233.9 |
| Tributary 12 (J) | Reach 1 | 3098.65 | 250 Wet Scenario | 4.7 | 273.68 | 0.06 | 235.3 |
| | | | | | | | |
| Tributary 12 (J) | Reach 1 | 2316.435 | 250 Historic | 4.2 | 268.39 | 0.44 | 14.18 |
| Tributary 12 (J) | Reach 1 | 2316.435 | 250 Wet Scenario | 4.7 | 268.48 | 0.44 | 18.61 |
| | | | | | | | |
| Tributary 12 (J) | Reach 2 | 1080.846 | 250 Historic | 11.29 | 269.7 | 1.96 | 5.78 |
| Tributary 12 (J) | Reach 2 | 1080.846 | 250 Wet Scenario | 12.63 | 269.79 | 2.1 | 6.03 |
| | | | | | | | |
| Tributary 12 (J) | Reach 2 | 178.4853 | 250 Historic | 11.29 | 268.47 | 0.87 | 15.89 |
| Tributary 12 (J) | Reach 2 | 178.4853 | 250 Wet Scenario | 12.63 | 268.56 | 0.89 | 18.23 |
| | | | | | | | |

Table 3.7 HEC-RAS results for the Dingman Creek-continued

| River | Reach | River Sta | Profile | Q Total | W.S. Elev | Vel Chnl | Flow Area |
|---|---|---|---|---|---|---|---|
| | | | | (m3/s) | (m) | (m/s) | (m2) |
| Tributary 12 (J) | Reach 3 | 2213.149 | 250 Historic | 19.86 | 268.08 | 2.01 | 13.75 |
| Tributary 12 (J) | Reach 3 | 2213.149 | 250 Wet Scenario | 22.23 | 268.17 | 2.05 | 17.75 |
| | | | | | | | |
| Tributary 12 (J) | Reach 3 | 621.3592 | 250 Historic | 28.49 | 267.1 | 2.24 | 12.72 |
| Tributary 12 (J) | Reach 3 | 621.3592 | 250 Wet Scenario | 31.87 | 267.44 | 0.98 | 79.28 |
| | | | | | | | |
| Tributary 12 (J) | Reach 3 | 610.4087 | | Culvert | | | |
| | | | | | | | |
| Tributary 12 (J) | Reach 3 | 601.6315 | 250 Historic | 28.49 | 265.71 | 3.52 | 8.09 |
| Tributary 12 (J) | Reach 3 | 601.6315 | 250 Wet Scenario | 31.87 | 265.79 | 3.83 | 8.33 |
| | | | | | | | |
| Tributary 12 (J) | Reach 3 | 252.1656 | 250 Historic | 28.49 | 264.74 | 2.75 | 26.65 |
| Tributary 12 (J) | Reach 3 | 252.1656 | 250 Wet Scenario | 31.87 | 264.85 | 2.41 | 36.52 |
| | | | | | | | |
| Tributary 11 (P) | Reach 1 | 3514.93 | 250 Historic | 6 | 263.13 | 2.06 | 2.96 |
| Tributary 11 (P) | Reach 1 | 3514.93 | 250 Wet Scenario | 6.31 | 263.25 | 1.79 | 3.64 |
| | | | | | | | |
| Tributary 11 (P) | Reach 1 | 2610.112 | 250 Historic | 7.05 | 259.36 | 2.26 | 3.13 |
| Tributary 11 (P) | Reach 1 | 2610.112 | 250 Wet Scenario | 7.41 | 259.42 | 2.3 | 3.23 |
| | | | | | | | |
| Tributary 11 (P) | Reach 1 | 851.6322 | 250 Historic | 7.05 | 254.04 | 0.05 | 337.18 |
| Tributary 11 (P) | Reach 1 | 851.6322 | 250 Wet Scenario | 7.41 | 254.27 | 0.04 | 432.17 |
| | | | | | | | |
| Tributary 11 (P) | Reach 2 | 311.5762 | 250 Historic | 14.1 | 254.04 | 0.13 | 274.54 |
| Tributary 11 (P) | Reach 2 | 311.5762 | 250 Wet Scenario | 14.8 | 254.27 | 0.1 | 370.56 |
| | | | | | | | |
| Tributary 11 (P) | Reach 2 | 88.10411 | 250 Historic | 14.1 | 254.04 | 0.09 | 378.33 |
| Tributary 11 (P) | Reach 2 | 88.10411 | 250 Wet Scenario | 14.8 | 254.27 | 0.07 | 495.3 |
| | | | | | | | |
| Tributary 11 (P) | Reach 3 | 610.848 | 250 Historic | 14.09 | 254.04 | 0.06 | 662.89 |
| Tributary 11 (P) | Reach 3 | 610.848 | 250 Wet Scenario | 14.8 | 254.27 | 0.04 | 866.33 |
| | | | | | | | |
| Tributary 11 (P) | Reach 3 | 181.0659 | 250 Historic | 14.09 | 253.88 | 0.12 | 344.92 |
| Tributary 11 (P) | Reach 3 | 181.0659 | 250 Wet Scenario | 14.8 | 254.1 | 0.1 | 435.37 |
| | | | | | | | |
| Tributary 10 (R) | Reach 1 | 784.3457 | 250 Historic | 6.32 | 253.53 | 0.1 | 232.84 |
| Tributary 10 (R) | Reach 1 | 784.3457 | 250 Wet Scenario | 6.74 | 253.81 | 0.06 | 364.25 |
| | | | | | | | |
| Tributary 10 (R) | Reach 1 | 336.6994 | 250 Historic | 6.32 | 253.53 | 0.11 | 217.82 |
| Tributary 10 (R) | Reach 1 | 336.6994 | 250 Wet Scenario | 6.74 | 253.81 | 0.07 | 360.03 |
| | | | | | | | |
| Tributary 10 (R) | Reach 1 | 46.67747 | 250 Historic | 6.32 | 253.22 | 0.07 | 235.47 |
| Tributary 10 (R) | Reach 1 | 46.67747 | 250 Wet Scenario | 6.74 | 253.46 | 0.06 | 286.1 |
| | | | | | | | |
| Tributary9(C-30) | Reach 1 | 1649.276 | 250 Historic | 0.91 | 262.83 | 1.14 | 1.12 |
| Tributary9(C-30) | Reach 1 | 1649.276 | 250 Wet Scenario | 0.97 | 262.84 | 1.18 | 1.17 |
| | | | | | | | |
| Tributary9(C-30) | Reach 1 | 800.777 | 250 Historic | 0.91 | 255.39 | 1.74 | 0.52 |
| Tributary9(C-30) | Reach 1 | 800.777 | 250 Wet Scenario | 0.97 | 255.4 | 1.77 | 0.55 |
| | | | | | | | |
| Tributary9(C-30) | Reach 1 | 752.6324 | 250 Historic | 0.91 | 255.09 | 1.12 | 0.81 |
| Tributary9(C-30) | Reach 1 | 752.6324 | 250 Wet Scenario | 0.97 | 255.11 | 1.14 | 0.85 |
| | | | | | | | |
| Tributary9(C-30) | Reach 1 | 743.3839 | | Culvert | | | |
| | | | | | | | |
| Tributary9(C-30) | Reach 1 | 734.0452 | 250 Historic | 0.91 | 254.91 | 1.39 | 0.66 |
| Tributary9(C-30) | Reach 1 | 734.0452 | 250 Wet Scenario | 0.97 | 254.92 | 1.43 | 0.68 |

Table 3.7 HEC-RAS results for the Dingman Creek-continued

| River | Reach | River Sta | Profile | Q Total | W.S. Elev | Vel Chnl | Flow Area |
|---|---|---|---|---|---|---|---|
| | | | | (m3/s) | (m) | (m/s) | (m2) |
| Tributary9(C-30) | Reach 1 | 72.17505 | 250 Historic | 0.91 | 251.67 | 0.01 | 147.56 |
| Tributary9(C-30) | Reach 1 | 72.17505 | 250 Wet Scenario | 0.97 | 251.93 | 0.01 | 162.9 |
| | | | | | | | |
| Tributary8(B-62) | Reach 1 | 1354.271 | 250 Historic | 3.8 | 262.7 | 1.78 | 3.4 |
| Tributary8(B-62) | Reach 1 | 1354.271 | 250 Wet Scenario | 4.08 | 262.71 | 1.81 | 3.61 |
| | | | | | | | |
| Tributary8(B-62) | Reach 1 | 1190.894 | 250 Historic | 3.8 | 262.22 | 0.46 | 15.38 |
| Tributary8(B-62) | Reach 1 | 1190.894 | 250 Wet Scenario | 4.08 | 262.3 | 0.41 | 18.85 |
| | | | | | | | |
| Tributary8(B-62) | Reach 1 | 999.0443 | 250 Historic | 3.8 | 261.92 | 1.92 | 1.98 |
| Tributary8(B-62) | Reach 1 | 999.0443 | 250 Wet Scenario | 4.08 | 261.98 | 1.97 | 2.08 |
| | | | | | | | |
| Tributary8(B-62) | Reach 1 | 985.5711 | | Culvert | | | |
| | | | | | | | |
| Tributary8(B-62) | Reach 1 | 969.8938 | 250 Historic | 3.8 | 261.37 | 2.91 | 1.31 |
| Tributary8(B-62) | Reach 1 | 969.8938 | 250 Wet Scenario | 4.08 | 261.41 | 3.01 | 1.36 |
| | | | | | | | |
| Tributary8(B-62) | Reach 1 | 442.3338 | 250 Historic | 3.8 | 255.03 | 1.26 | 3.13 |
| Tributary8(B-62) | Reach 1 | 442.3338 | 250 Wet Scenario | 4.08 | 255.1 | 1.26 | 3.39 |
| | | | | | | | |
| Tributary8(B-62) | Reach 1 | 239.1602 | 250 Historic | 3.8 | 252 | 2.5 | 1.7 |
| Tributary8(B-62) | Reach 1 | 239.1602 | 250 Wet Scenario | 4.08 | 252.04 | 2.53 | 1.82 |
| | | | | | | | |
| Tributary8(B-62) | Reach 1 | 60.5166 | 250 Historic | 3.8 | 250.87 | 0.44 | 11.91 |
| Tributary8(B-62) | Reach 1 | 60.5166 | 250 Wet Scenario | 4.08 | 251.07 | 0.39 | 14.85 |
| | | | | | | | |
| Tributary7(B-64) | Reach 1 | 2297.615 | 250 Historic | 6.18 | 265.56 | 0.07 | 133.72 |
| Tributary7(B-64) | Reach 1 | 2297.615 | 250 Wet Scenario | 6.64 | 265.61 | 0.07 | 139.2 |
| | | | | | | | |
| Tributary7(B-64) | Reach 1 | 2006.106 | 250 Historic | 6.18 | 265.56 | 0.09 | 125.5 |
| Tributary7(B-64) | Reach 1 | 2006.106 | 250 Wet Scenario | 6.64 | 265.61 | 0.09 | 130.16 |
| | | | | | | | |
| Tributary7(B-64) | Reach 1 | 1973.936 | | Culvert | | | |
| | | | | | | | |
| Tributary7(B-64) | Reach 1 | 1960.685 | 250 Historic | 6.18 | 264.81 | 0.56 | 19.28 |
| Tributary7(B-64) | Reach 1 | 1960.685 | 250 Wet Scenario | 6.64 | 264.82 | 0.59 | 19.67 |
| | | | | | | | |
| Tributary7(B-64) | Reach 1 | 655.4799 | 250 Historic | 6.18 | 252.17 | 1.51 | 5.99 |
| Tributary7(B-64) | Reach 1 | 655.4799 | 250 Wet Scenario | 6.64 | 252.19 | 1.48 | 6.45 |
| | | | | | | | |
| Tributary7(B-64) | Reach 1 | 80.94641 | 250 Historic | 6.18 | 249.89 | 0.08 | 114.18 |
| Tributary7(B-64) | Reach 1 | 80.94641 | 250 Wet Scenario | 6.64 | 250.06 | 0.07 | 135.74 |
| | | | | | | | |
| Tributary 6 (I) | Reach 1 | 2622.822 | 250 Historic | 7.48 | 267.74 | 2.5 | 2.99 |
| Tributary 6 (I) | Reach 1 | 2622.822 | 250 Wet Scenario | 8.39 | 267.8 | 2.56 | 3.27 |
| | | | | | | | |
| Tributary 6 (I) | Reach 1 | 2057.843 | 250 Historic | 7.48 | 265.43 | 0.88 | 8.48 |
| Tributary 6 (I) | Reach 1 | 2057.843 | 250 Wet Scenario | 8.39 | 265.56 | 0.88 | 9.52 |
| | | | | | | | |
| Tributary 6 (I) | Reach 1 | 2011.807 | 250 Historic | 7.48 | 265.34 | 1.17 | 6.37 |
| Tributary 6 (I) | Reach 1 | 2011.807 | 250 Wet Scenario | 8.39 | 265.45 | 1.24 | 6.79 |
| | | | | | | | |
| Tributary 6 (I) | Reach 1 | 1982.81 | | Bridge | | | |
| | | | | | | | |
| Tributary 6 (I) | Reach 1 | 1969.807 | 250 Historic | 7.48 | 265.3 | 1.2 | 6.23 |
| Tributary 6 (I) | Reach 1 | 1969.807 | 250 Wet Scenario | 8.39 | 265.41 | 1.26 | 6.64 |
| | | | | | | | |

Table 3.7 HEC-RAS results for the Dingman Creek-continued

| River | Reach | River Sta | Profile | Q Total | W.S. Elev | Vel Chnl | Flow Area |
|---|---|---|---|---|---|---|---|
| | | | | (m3/s) | (m) | (m/s) | (m2) |
| Tributary 6 (I) | Reach 1 | 1962.426 | 250 Historic | 7.48 | 265.31 | 0.47 | 16.21 |
| Tributary 6 (I) | Reach 1 | 1962.426 | 250 Wet Scenario | 8.39 | 265.42 | 0.49 | 17.42 |
| | | | | | | | |
| Tributary 6 (I) | Reach 1 | 1687.523 | 250 Historic | 7.48 | 264.58 | 2 | 3.73 |
| Tributary 6 (I) | Reach 1 | 1687.523 | 250 Wet Scenario | 8.39 | 264.65 | 2.07 | 4.05 |
| | | | | | | | |
| Tributary 6 (I) | Reach 1 | 1140.616 | 250 Historic | 7.48 | 263.74 | 0.04 | 353.5 |
| Tributary 6 (I) | Reach 1 | 1140.616 | 250 Wet Scenario | 8.39 | 263.89 | 0.03 | 401.69 |
| | | | | | | | |
| Tributary 6 (I) | Reach 1 | 58.44173 | 250 Historic | 7.48 | 263.68 | 0.18 | 87.67 |
| Tributary 6 (I) | Reach 1 | 58.44173 | 250 Wet Scenario | 8.39 | 263.81 | 0.18 | 97.41 |
| | | | | | | | |
| Tributary 5 (G) | Reach 1 | 2181.574 | 250 Historic | 14.12 | 261.38 | 0.4 | 59.92 |
| Tributary 5 (G) | Reach 1 | 2181.574 | 250 Wet Scenario | 15.69 | 261.55 | 0.38 | 79.26 |
| | | | | | | | |
| Tributary 5 (G) | Reach 1 | 2019.322 | 250 Historic | 14.12 | 260.92 | 2.37 | 5.96 |
| Tributary 5 (G) | Reach 1 | 2019.322 | 250 Wet Scenario | 15.69 | 261.05 | 2.46 | 6.37 |
| | | | | | | | |
| Tributary 5 (G) | Reach 1 | 1989.496 | | Culvert | | | |
| | | | | | | | |
| Tributary 5 (G) | Reach 1 | 1970.787 | 250 Historic | 14.12 | 260.29 | 3.54 | 3.98 |
| Tributary 5 (G) | Reach 1 | 1970.787 | 250 Wet Scenario | 15.69 | 260.38 | 3.67 | 4.28 |
| | | | | | | | |
| Tributary 5 (G) | Reach 1 | 1148.506 | 250 Historic | 14.12 | 258.27 | 1.19 | 20.6 |
| Tributary 5 (G) | Reach 1 | 1148.506 | 250 Wet Scenario | 15.69 | 258.32 | 1.19 | 23.78 |
| | | | | | | | |
| Tributary 5 (G) | Reach 1 | 279.0797 | 250 Historic | 14.12 | 257.59 | 0.27 | 95.42 |
| Tributary 5 (G) | Reach 1 | 279.0797 | 250 Wet Scenario | 15.69 | 257.68 | 0.28 | 102.57 |
| | | | | | | | |
| Tributary 5 (G) | Reach 2 | 1429.644 | 250 Historic | 9 | 257.69 | 0.66 | 16.02 |
| Tributary 5 (G) | Reach 2 | 1429.644 | 250 Wet Scenario | 10 | 257.78 | 0.68 | 17.42 |
| | | | | | | | |
| Tributary 5 (G) | Reach 2 | 864.2008 | 250 Historic | 9 | 257.62 | 0.31 | 30.09 |
| Tributary 5 (G) | Reach 2 | 864.2008 | 250 Wet Scenario | 10 | 257.71 | 0.32 | 32.06 |
| | | | | | | | |
| Tributary 5 (G) | Reach 2 | 41.99506 | 250 Historic | 9 | 257.59 | 0.16 | 179.02 |
| Tributary 5 (G) | Reach 2 | 41.99506 | 250 Wet Scenario | 10 | 257.68 | 0.15 | 207.42 |
| | | | | | | | |
| Tributary 5 (G) | Reach 3 | 179.6919 | 250 Historic | 34.07 | 257.59 | 0.35 | 228.58 |
| Tributary 5 (G) | Reach 3 | 179.6919 | 250 Wet Scenario | 37.86 | 257.68 | 0.34 | 260.33 |
| | | | | | | | |
| Tributary 5 (G) | Reach 3 | 99.05259 | 250 Historic | 34.07 | 257.55 | 0.72 | 47.57 |
| Tributary 5 (G) | Reach 3 | 99.05259 | 250 Wet Scenario | 37.86 | 257.63 | 0.78 | 48.61 |
| | | | | | | | |
| Tributary 4 (F) | Reach 1 | 2394.624 | 250 Historic | 13.48 | 259.42 | 0.29 | 51.71 |
| Tributary 4 (F) | Reach 1 | 2394.624 | 250 Wet Scenario | 14.64 | 259.46 | 0.3 | 53.46 |
| | | | | | | | |
| Tributary 4 (F) | Reach 1 | 2372.165 | 250 Historic | 13.48 | 259.41 | 0.48 | 51.59 |
| Tributary 4 (F) | Reach 1 | 2372.165 | 250 Wet Scenario | 14.64 | 259.46 | 0.51 | 53.19 |
| | | | | | | | |
| Tributary 4 (F) | Reach 1 | 2362.02 | | Culvert | | | |
| | | | | | | | |
| Tributary 4 (F) | Reach 1 | 2355.249 | 250 Historic | 13.48 | 258.29 | 0.98 | 21.49 |
| Tributary 4 (F) | Reach 1 | 2355.249 | 250 Wet Scenario | 14.64 | 258.36 | 1 | 23.01 |
| | | | | | | | |
| Tributary 4 (F) | Reach 1 | 2171.989 | 250 Historic | 13.48 | 258.1 | 1 | 13.6 |
| Tributary 4 (F) | Reach 1 | 2171.989 | 250 Wet Scenario | 14.64 | 258.16 | 1.02 | 14.68 |

Table 3.7 HEC-RAS results for the Dingman Creek-continued

| River | Reach | River Sta | Profile | Q Total | W.S. Elev | Vel Chnl | Flow Area |
|---|---|---|---|---|---|---|---|
| | | | | (m3/s) | (m) | (m/s) | (m2) |
| Tributary 4 (F) | Reach 1 | 1741.343 | 250 Historic | 14.1 | 256.58 | 1.1 | 12.79 |
| Tributary 4 (F) | Reach 1 | 1741.343 | 250 Wet Scenario | 15.32 | 256.65 | 1.11 | 13.82 |
| | | | | | | | |
| Tributary 4 (F) | Reach 1 | 751.819 | 250 Historic | 15.76 | 254.79 | 1.48 | 15.12 |
| Tributary 4 (F) | Reach 1 | 751.819 | 250 Wet Scenario | 17.12 | 254.85 | 1.5 | 16.55 |
| | | | | | | | |
| Tributary 4 (F) | Reach 2 | 895.0485 | 250 Historic | 2.86 | 258.68 | 1.3 | 2.2 |
| Tributary 4 (F) | Reach 2 | 895.0485 | 250 Wet Scenario | 3.1 | 258.71 | 1.36 | 2.29 |
| | | | | | | | |
| Tributary 4 (F) | Reach 2 | 145.6887 | 250 Historic | 2.86 | 254.79 | 1.68 | 1.71 |
| Tributary 4 (F) | Reach 2 | 145.6887 | 250 Wet Scenario | 3.1 | 254.85 | 1.66 | 1.87 |
| | | | | | | | |
| Tributary 4 (F) | Reach 3 | 588.1453 | 250 Historic | 21.35 | 254.5 | 1.57 | 18.92 |
| Tributary 4 (F) | Reach 3 | 588.1453 | 250 Wet Scenario | 23.18 | 254.59 | 1.55 | 21.98 |
| | | | | | | | |
| Tributary 4 (F) | Reach 3 | 127.2696 | 250 Historic | 21.35 | 254.32 | 0.53 | 79.57 |
| Tributary 4 (F) | Reach 3 | 127.2696 | 250 Wet Scenario | 23.18 | 254.41 | 0.51 | 90.43 |
| | | | | | | | |
| Tributary 3 (E) | Reach 1 | 4832.017 | 250 Historic | 2.54 | 268.9 | 0.89 | 2.84 |
| Tributary 3 (E) | Reach 1 | 4832.017 | 250 Wet Scenario | 2.75 | 268.92 | 0.92 | 2.99 |
| | | | | | | | |
| Tributary 3 (E) | Reach 1 | 3273.808 | 250 Historic | 2.54 | 263.01 | 0.64 | 3.96 |
| Tributary 3 (E) | Reach 1 | 3273.808 | 250 Wet Scenario | 2.75 | 263.06 | 0.66 | 4.14 |
| | | | | | | | |
| Tributary 3 (E) | Reach 1 | 3267.409 | | Bridge | | | |
| | | | | | | | |
| Tributary 3 (E) | Reach 1 | 3261.207 | 250 Historic | 2.54 | 263.01 | 0.64 | 3.96 |
| Tributary 3 (E) | Reach 1 | 3261.207 | 250 Wet Scenario | 2.75 | 263.06 | 0.67 | 4.13 |
| | | | | | | | |
| Tributary 3 (E) | Reach 1 | 1560.724 | 250 Historic | 8.27 | 257.02 | 0.91 | 11.64 |
| Tributary 3 (E) | Reach 1 | 1560.724 | 250 Wet Scenario | 8.93 | 257.04 | 0.92 | 13.68 |
| | | | | | | | |
| Tributary 3 (E) | Reach 1 | 85.37607 | 250 Historic | 12.45 | 253.86 | 0.05 | 364.94 |
| Tributary 3 (E) | Reach 1 | 85.37607 | 250 Wet Scenario | 13.44 | 254.09 | 0.05 | 419.48 |
| | | | | | | | |
| Tributary 2 (D) | Reach 1 | 5183.482 | 250 Historic | 3.88 | 269.72 | 0.81 | 11.75 |
| Tributary 2 (D) | Reach 1 | 5183.482 | 250 Wet Scenario | 4.14 | 269.75 | 0.85 | 12.11 |
| | | | | | | | |
| Tributary 2 (D) | Reach 1 | 4399.641 | 250 Historic | 3.88 | 267.86 | 1.43 | 2.72 |
| Tributary 2 (D) | Reach 1 | 4399.641 | 250 Wet Scenario | 4.14 | 267.88 | 1.47 | 2.82 |
| | | | | | | | |
| Tributary 2 (D) | Reach 1 | 3359.25 | 250 Historic | 6.71 | 263.42 | 1.3 | 5.15 |
| Tributary 2 (D) | Reach 1 | 3359.25 | 250 Wet Scenario | 7.16 | 263.46 | 1.31 | 5.47 |
| | | | | | | | |
| Tributary 2 (D) | Reach 1 | 2686.215 | 250 Historic | 6.71 | 260.08 | 1.94 | 3.46 |
| Tributary 2 (D) | Reach 1 | 2686.215 | 250 Wet Scenario | 7.16 | 260.12 | 1.99 | 3.61 |
| | | | | | | | |
| Tributary 2 (D) | Reach 1 | 2668.427 | | Bridge | | | |
| | | | | | | | |
| Tributary 2 (D) | Reach 1 | 2651.819 | 250 Historic | 6.71 | 259.78 | 2.55 | 2.63 |
| Tributary 2 (D) | Reach 1 | 2651.819 | 250 Wet Scenario | 7.16 | 259.81 | 2.6 | 2.75 |
| | | | | | | | |
| Tributary 2 (D) | Reach 1 | 2042.215 | 250 Historic | 6.71 | 256.84 | 0.78 | 8.65 |
| Tributary 2 (D) | Reach 1 | 2042.215 | 250 Wet Scenario | 7.16 | 256.87 | 0.79 | 9.01 |
| | | | | | | | |
| Tributary 2 (D) | Reach 1 | 1094.016 | 250 Historic | 9.75 | 254.35 | 0.79 | 15.6 |
| Tributary 2 (D) | Reach 1 | 1094.016 | 250 Wet Scenario | 10.41 | 254.38 | 0.8 | 16.67 |

Table 3.7 HEC-RAS results for the Dingman Creek-continued

| River | Reach | River Sta | Profile | Q Total | W.S. Elev | Vel Chnl | Flow Area |
|---|---|---|---|---|---|---|---|
| | | | | (m3/s) | (m) | (m/s) | (m2) |
| Tributary 2 (D) | Reach 1 | 71.18511 | 250 Historic | 9.75 | 253.17 | 0.21 | 169.32 |
| Tributary 2 (D) | Reach 1 | 71.18511 | 250 Wet Scenario | 10.41 | 253.42 | 0.18 | 208.63 |

Table 3.8 HEC-RAS results for the Mud Creek

| River | Reach | River Sta | Profile | Q Total | W.S. Elev | Vel Chnl | Flow Area |
|---|---|---|---|---|---|---|---|
| | | | | (m3/s) | (m) | (m/s) | (m2) |
| Mud Creek | London | 2397.303 | 250 Historic | 0.88 | 238.06 | 0.96 | 1.73 |
| Mud Creek | London | 2397.303 | 250 Wet Scenario | 0.96 | 238.07 | 0.94 | 1.96 |
| | | | | | | | |
| Mud Creek | London | 2090.643 | 250 Historic | 0.88 | 236.6 | 1.24 | 0.95 |
| Mud Creek | London | 2090.643 | 250 Wet Scenario | 0.96 | 236.61 | 1.24 | 1.11 |
| | | | | | | | |
| Mud Creek | London | 1823.279 | 250 Historic | 0.88 | 234.76 | 0.4 | 2.19 |
| Mud Creek | London | 1823.279 | 250 Wet Scenario | 0.96 | 235.58 | 0.11 | 17.26 |
| | | | | | | | |
| Mud Creek | London | 1820.875 | | Bridge | | | |
| | | | | | | | |
| Mud Creek | London | 1818.822 | 250 Historic | 0.88 | 234.76 | 0.4 | 2.19 |
| Mud Creek | London | 1818.822 | 250 Wet Scenario | 0.96 | 235.58 | 0.11 | 17.21 |
| | | | | | | | |
| Mud Creek | London | 1601.478 | 250 Historic | 0.88 | 234.76 | 0.21 | 4.1 |
| Mud Creek | London | 1601.478 | 250 Wet Scenario | 0.96 | 235.58 | 0.03 | 53.62 |
| | | | | | | | |
| Mud Creek | London | 1598.02 | | Bridge | | | |
| | | | | | | | |
| Mud Creek | London | 1595.472 | 250 Historic | 0.88 | 234.75 | 0.21 | 4.15 |
| Mud Creek | London | 1595.472 | 250 Wet Scenario | 0.96 | 235.58 | 0.03 | 53.67 |
| | | | | | | | |
| Mud Creek | London | 1384.955 | 250 Historic | 4.51 | 234.74 | 0.31 | 14.46 |
| Mud Creek | London | 1384.955 | 250 Wet Scenario | 4.9 | 235.58 | 0.26 | 18.52 |
| | | | | | | | |
| Mud Creek | London | 1370.456 | | Bridge | | | |
| | | | | | | | |
| Mud Creek | London | 1357.1 | 250 Historic | 4.51 | 234.74 | 0.31 | 14.59 |
| Mud Creek | London | 1357.1 | 250 Wet Scenario | 4.9 | 235.57 | 0.26 | 18.63 |
| | | | | | | | |
| Mud Creek | London | 1340.192 | 250 Historic | 4.51 | 234.74 | 0.22 | 22.93 |
| Mud Creek | London | 1340.192 | 250 Wet Scenario | 4.9 | 235.57 | 0.1 | 105.67 |
| | | | | | | | |
| Mud Creek | London | 1160.276 | 250 Historic | 4.51 | 234.74 | 0.21 | 21.45 |
| Mud Creek | London | 1160.276 | 250 Wet Scenario | 4.9 | 235.57 | 0.19 | 26.44 |
| | | | | | | | |
| Mud Creek | London | 1144.729 | | Bridge | | | |
| | | | | | | | |
| Mud Creek | London | 1125.822 | 250 Historic | 4.51 | 234.74 | 0.21 | 21.44 |
| Mud Creek | London | 1125.822 | 250 Wet Scenario | 4.9 | 235.57 | 0.19 | 26.43 |
| | | | | | | | |
| Mud Creek | London | 814.0285 | 250 Historic | 4.51 | 234.73 | 0.16 | 49.76 |
| Mud Creek | London | 814.0285 | 250 Wet Scenario | 4.9 | 235.57 | 0.1 | 123.7 |
| | | | | | | | |
| Mud Creek | London | 527.7888 | 250 Historic | 7.27 | 234.6 | 0.28 | 63.58 |
| Mud Creek | London | 527.7888 | 250 Wet Scenario | 7.89 | 235.41 | 0.12 | 166.26 |
| | | | | | | | |
| Mud Creek | London | 263.5877 | 250 Historic | 10.81 | 234.59 | 0.34 | 125.48 |
| Mud Creek | London | 263.5877 | 250 Wet Scenario | 11.72 | 235.41 | 0.24 | 224.14 |
| | | | | | | | |
| Mud Creek | London | 163.5299 | | Culvert | | | |
| | | | | | | | |
| Mud Creek | London | 63.27246 | 250 Historic | 10.81 | 234.59 | 0.15 | 472.02 |
| Mud Creek | London | 63.27246 | 250 Wet Scenario | 11.72 | 235.41 | 0.11 | 692.91 |
| | | | | | | | |
| Mud Creek | London | 54.52624 | 250 Historic | 10.81 | 234.59 | 0.02 | 1336.17 |
| Mud Creek | London | 54.52624 | 250 Wet Scenario | 11.72 | 235.41 | 0.02 | 1708.87 |

## 3.2 Floodplain mapping results

Floodplain mapping results are shown using floodplain boundary lines. Floodplain lines are shown for two climate scenarios: 250-year flood historic climate scenario and 250-year flood wet climate scenario.

### *3.2.1. Floodplain results for selected locations*

The locations that show a larger difference between the historic and wet climate scenarios are presented in Figures 3.1 to 3.13. Every figure with floodplain results is supported with HEC-RAS results. It is important to emphasize that the presentation of the floodplain results on the map is highly dependent on the terrain characteristics. If the terrain is steep (distance between contour lines is small), then the difference between the floodplain lines cannot be clearly visible. For example, Figure 3.1 shows floodplain mapping results for one section of the Main Thames River. On the map it looks as there is no significant difference between 250 year historic climate scenario floodplain line and 250 year wet climate scenario floodplain line. However, according to the HEC-RAS results, there is a difference in water surface elevations of about 40 - 50 cm between the two. The difference in water depth between historic and wet climate scenario will be considered in the Risk Assessment Phase of the Project.

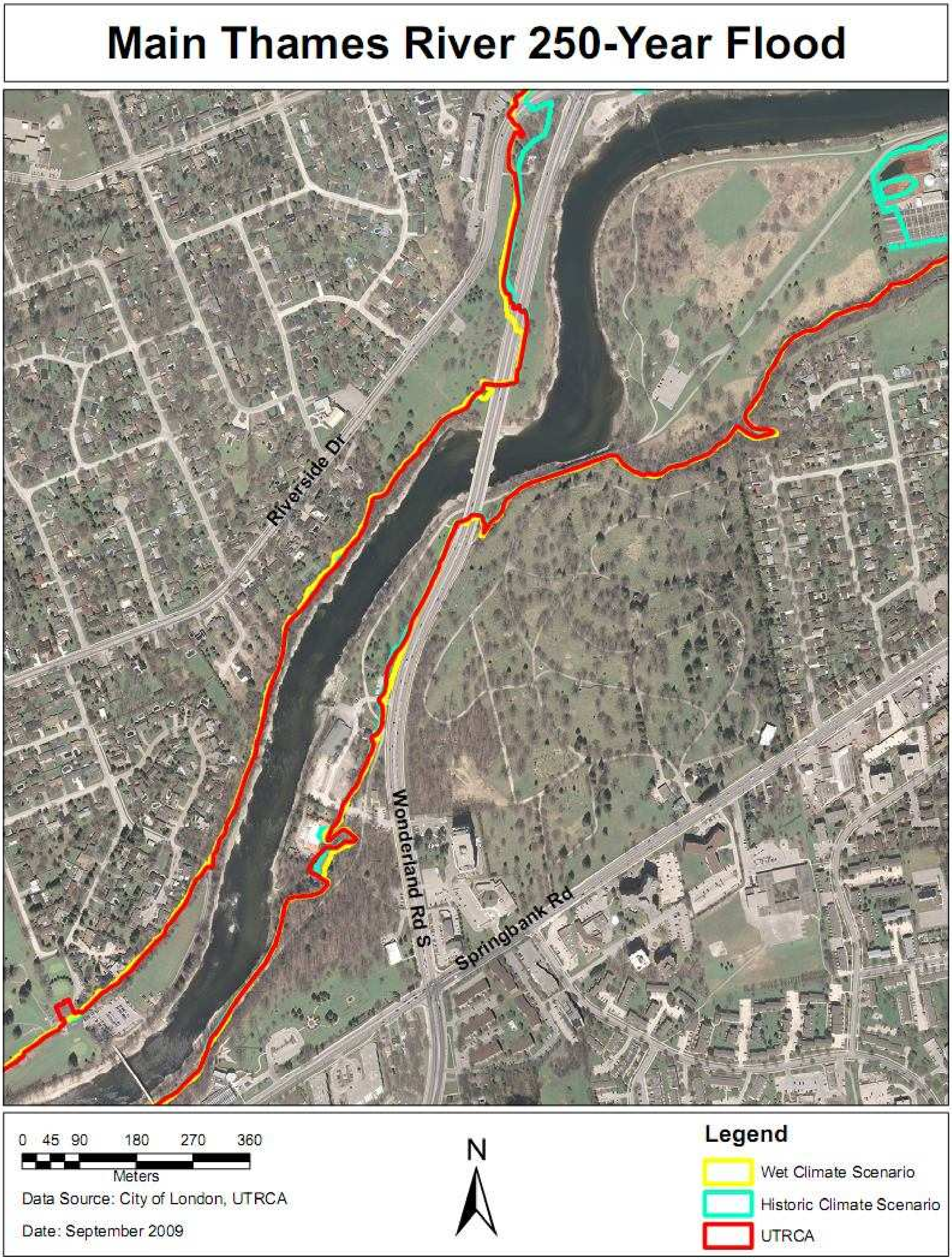


Figure 3.1 Floodplain results for a location at the Main Thames River

Table 3.9 HEC-RAS results for a location at the Main Thames River

| River | Reach | River Sta | Profile | Q Total | W.S. Elev | Vel Chnl | Flow Area | Froude # Chl |
|---|---|---|---|---|---|---|---|---|
| | | | | (m3/s) | (m) | (m/s) | (m2) | |
| Main Thames | London | 8999.401 | 250-Historic | 1616.25 | 234.99 | 2.26 | 795.86 | 0.27 |
| Main Thames | London | 8999.401 | 250-Wet Scenario | 1892.72 | 235.56 | 2.41 | 907.79 | 0.28 |
| | | | | | | | | |
| Main Thames | London | 8733.405 | 250-Historic | 1616.25 | 234.98 | 1.65 | 1452.93 | 0.2 |
| Main Thames | London | 8733.405 | 250-Wet Scenario | 1892.72 | 235.58 | 1.68 | 1706.46 | 0.19 |
| | | | | | | | | |
| Main Thames | London | 8597.229 | 250-Historic | 1616.25 | 234.98 | 1.38 | 1952.69 | 0.16 |
| Main Thames | London | 8597.229 | 250-Wet Scenario | 1892.72 | 235.58 | 1.4 | 2294.01 | 0.16 |
| | | | | | | | | |
| Main Thames | London | 8465.656 | 250-Historic | 1617.55 | 234.97 | 1.26 | 2149.59 | 0.15 |
| Main Thames | London | 8465.656 | 250-Wet Scenario | 1893.57 | 235.58 | 1.25 | 2579.85 | 0.14 |
| | | | | | | | | |
| Main Thames | London | 8359.158 | 250-Historic | 1617.55 | 234.94 | 1.43 | 1945.72 | 0.17 |
| Main Thames | London | 8359.158 | 250-Wet Scenario | 1893.57 | 235.54 | 1.45 | 2271.6 | 0.17 |
| | | | | | | | | |
| Main Thames | London | 8266.557 | 250-Historic | 1617.55 | 234.93 | 1.37 | 1943.83 | 0.16 |
| Main Thames | London | 8266.557 | 250-Wet Scenario | 1893.57 | 235.53 | 1.4 | 2239.92 | 0.16 |
| | | | | | | | | |
| Main Thames | London | 8216.348 | 250-Historic | 1617.55 | 234.88 | 1.61 | 1748.93 | 0.19 |
| Main Thames | London | 8216.348 | 250-Wet Scenario | 1893.57 | 235.49 | 1.62 | 2054.87 | 0.18 |
| | | | | | | | | |
| Main Thames | London | 8078.313 | 250-Historic | 1617.55 | 234.86 | 1.39 | 1648.14 | 0.16 |
| Main Thames | London | 8078.313 | 250-Wet Scenario | 1893.57 | 235.46 | 1.45 | 1857.92 | 0.16 |
| | | | | | | | | |
| Main Thames | London | 7991.973 | 250-Historic | 1617.55 | 234.84 | 1.28 | 1377.6 | 0.15 |
| Main Thames | London | 7991.973 | 250-Wet Scenario | 1893.57 | 235.44 | 1.38 | 1525.46 | 0.15 |
| | | | | | | | | |
| Main Thames | London | 7936.935 | 250-Historic | 1617.55 | 234.76 | 1.74 | 1016.87 | 0.2 |
| Main Thames | London | 7936.935 | 250-Wet Scenario | 1893.57 | 235.34 | 1.87 | 1120.7 | 0.21 |
| | | | | | | | | |
| Main Thames | London | 7845.231 | 250-Historic | 1617.55 | 234.73 | 1.77 | 1116.42 | 0.21 |
| Main Thames | London | 7845.231 | 250-Wet Scenario | 1893.57 | 235.32 | 1.88 | 1255.86 | 0.21 |
| | | | | | | | | |
| Main Thames | London | 7831.712 | 250-Historic | 1617.55 | 234.74 | 1.67 | 1134.44 | 0.2 |
| Main Thames | London | 7831.712 | 250-Wet Scenario | 1893.57 | 235.33 | 1.77 | 1263.61 | 0.2 |
| | | | | | | | | |
| Main Thames | London | 7809.424 | | Bridge | | | | |
| | | | | | | | | |
| Main Thames | London | 7793.904 | 250-Historic | 1617.55 | 234.72 | 1.67 | 1129.49 | 0.2 |
| Main Thames | London | 7793.904 | 250-Wet Scenario | 1893.57 | 235.31 | 1.77 | 1258.59 | 0.2 |
| | | | | | | | | |
| Main Thames | London | 7743.635 | 250-Historic | 1617.55 | 234.67 | 1.77 | 1012.67 | 0.21 |
| Main Thames | London | 7743.635 | 250-Wet Scenario | 1893.57 | 235.25 | 1.91 | 1110.9 | 0.21 |
| | | | | | | | | |
| Main Thames | London | 7635.993 | 250-Historic | 1617.55 | 234.5 | 2.36 | 752.87 | 0.28 |
| Main Thames | London | 7635.993 | 250-Wet Scenario | 1893.57 | 235.05 | 2.54 | 829.03 | 0.29 |
| | | | | | | | | |
| Main Thames | London | 7524.016 | 250-Historic | 1617.55 | 234.4 | 2.49 | 754.83 | 0.3 |
| Main Thames | London | 7524.016 | 250-Wet Scenario | 1893.57 | 234.95 | 2.67 | 838.54 | 0.31 |
| | | | | | | | | |
| Main Thames | London | 7369.606 | 250-Historic | 1617.55 | 234.39 | 2 | 873.66 | 0.24 |
| Main Thames | London | 7369.606 | 250-Wet Scenario | 1893.57 | 234.95 | 2.16 | 969.82 | 0.24 |
| | | | | | | | | |
| Main Thames | London | 7258.678 | 250-Historic | 1617.55 | 234.3 | 2.19 | 843.26 | 0.25 |
| Main Thames | London | 7258.678 | 250-Wet Scenario | 1893.57 | 234.85 | 2.36 | 943.07 | 0.26 |
| | | | | | | | | |
| Main Thames | London | 7066.157 | 250-Historic | 1617.55 | 234.21 | 2.17 | 847.81 | 0.25 |

Table 3.9 HEC-RAS results for a location at the Main Thames River-continued

| River | Reach | River Sta | Profile | Q Total | W.S. Elev | Vel Chnl | Flow Area | Froude # Chl |
|---|---|---|---|---|---|---|---|---|
| | | | | (m3/s) | (m) | (m/s) | (m2) | |
| Main Thames | London | 7066.157 | 250-Wet Scenario | 1893.57 | 234.76 | 2.35 | 940.24 | 0.26 |
| | | | | | | | | |
| Main Thames | London | 6991.004 | 250-Historic | 1617.55 | 234.21 | 1.95 | 871.16 | 0.23 |
| Main Thames | London | 6991.004 | 250-Wet Scenario | 1893.57 | 234.75 | 2.12 | 948.51 | 0.24 |
| | | | | | | | | |
| Main Thames | London | 6908.691 | 250-Historic | 1617.55 | 234.18 | 1.93 | 931.89 | 0.22 |
| Main Thames | London | 6908.691 | 250-Wet Scenario | 1893.57 | 234.73 | 2.08 | 1023.65 | 0.23 |
| | | | | | | | | |
| Main Thames | London | 6836.473 | 250-Historic | 1617.55 | 234.06 | 2.38 | 802.71 | 0.27 |
| Main Thames | London | 6836.473 | 250-Wet Scenario | 1893.57 | 234.59 | 2.55 | 889.3 | 0.28 |
| | | | | | | | | |
| Main Thames | London | 6779.345 | 250-Historic | 1617.55 | 234.04 | 2.32 | 835.67 | 0.27 |
| Main Thames | London | 6779.345 | 250-Wet Scenario | 1893.57 | 234.57 | 2.49 | 926.96 | 0.28 |
| | | | | | | | | |
| Main Thames | London | 6703.037 | 250-Historic | 1617.55 | 234.03 | 2.11 | 931.3 | 0.24 |
| Main Thames | London | 6703.037 | 250-Wet Scenario | 1893.57 | 234.57 | 2.26 | 1038.32 | 0.25 |
| | | | | | | | | |
| Main Thames | London | 6661.459 | 250-Historic | 1617.55 | 234.01 | 2.14 | 934.04 | 0.24 |
| Main Thames | London | 6661.459 | 250-Wet Scenario | 1893.57 | 234.55 | 2.29 | 1037.79 | 0.25 |
| | | | | | | | | |
| Main Thames | London | 6649.045 | 250-Historic | 1617.55 | 234 | 2.17 | 918.43 | 0.25 |
| Main Thames | London | 6649.045 | 250-Wet Scenario | 1893.57 | 234.54 | 2.32 | 1019.21 | 0.26 |
| | | | | | | | | |
| Main Thames | London | 6644.485 | | Bridge | | | | |
| | | | | | | | | |
| Main Thames | London | 6640.114 | 250-Historic | 1617.55 | 233.98 | 2.17 | 914.81 | 0.25 |
| Main Thames | London | 6640.114 | 250-Wet Scenario | 1893.57 | 234.52 | 2.33 | 1014.48 | 0.26 |
| | | | | | | | | |
| Main Thames | London | 6613.312 | 250-Historic | 1617.55 | 233.97 | 2.13 | 918.57 | 0.25 |
| Main Thames | London | 6613.312 | 250-Wet Scenario | 1893.57 | 234.51 | 2.28 | 1022.58 | 0.26 |
| | | | | | | | | |
| Main Thames | London | 6534.023 | 250-Historic | 1617.55 | 233.96 | 1.99 | 941.26 | 0.23 |
| Main Thames | London | 6534.023 | 250-Wet Scenario | 1893.57 | 234.49 | 2.14 | 1037.07 | 0.24 |


Figure 3.2 Floodplain results for a location at the North Thames River

Table 3.10 HEC-RAS results for a location at the North Thames River

| River | Reach | River Sta | Profile | Q Total | W.S. Elev | Vel Chnl | Flow Area | Froude # Chl |
|---|---|---|---|---|---|---|---|---|
| | | | | (m3/s) | (m) | (m/s) | (m2) | |
| North Thames | London | 3662.343 | 250 Historic | 1031.54 | 238.95 | 2.56 | 612.51 | 0.33 |
| North Thames | London | 3662.343 | 250 Wet Scenario | 1258.11 | 239.45 | 2.78 | 715.54 | 0.35 |
| | | | | | | | | |
| North Thames | London | 3552.279 | 250 Historic | 1031.54 | 238.9 | 2.19 | 841.93 | 0.29 |
| North Thames | London | 3552.279 | 250 Wet Scenario | 1258.11 | 239.41 | 2.31 | 1011.9 | 0.3 |
| | | | | | | | | |
| North Thames | London | 3456.593 | 250 Historic | 1031.54 | 238.85 | 1.79 | 1102.95 | 0.23 |
| North Thames | London | 3456.593 | 250 Wet Scenario | 1258.11 | 239.38 | 1.87 | 1309.75 | 0.23 |
| | | | | | | | | |
| North Thames | London | 3352.649 | 250 Historic | 1031.54 | 238.73 | 1.99 | 987.22 | 0.26 |
| North Thames | London | 3352.649 | 250 Wet Scenario | 1258.11 | 239.25 | 2.08 | 1204.96 | 0.26 |
| | | | | | | | | |
| North Thames | London | 3247.213 | 250 Historic | 1031.54 | 238.67 | 1.81 | 1042.66 | 0.23 |
| North Thames | London | 3247.213 | 250 Wet Scenario | 1258.11 | 239.2 | 1.88 | 1270.01 | 0.23 |
| | | | | | | | | |
| North Thames | London | 3137.104 | 250 Historic | 1031.54 | 238.48 | 2.52 | 824.99 | 0.32 |
| North Thames | London | 3137.104 | 250 Wet Scenario | 1258.11 | 239.01 | 2.61 | 1046.88 | 0.32 |
| | | | | | | | | |
| North Thames | London | 3032.41 | 250 Historic | 1031.54 | 238.31 | 2.43 | 820.49 | 0.31 |
| North Thames | London | 3032.41 | 250 Wet Scenario | 1258.11 | 238.86 | 2.46 | 1042.75 | 0.3 |
| | | | | | | | | |
| North Thames | London | 2990.473 | 250 Historic | 1031.54 | 238.28 | 2.32 | 863.72 | 0.3 |
| North Thames | London | 2990.473 | 250 Wet Scenario | 1258.11 | 238.84 | 2.35 | 1107.05 | 0.29 |
| | | | | | | | | |
| North Thames | London | 2940.241 | 250 Historic | 1031.54 | 238.29 | 2.01 | 1034.64 | 0.26 |
| North Thames | London | 2940.241 | 250 Wet Scenario | 1258.11 | 238.84 | 2.03 | 1286.86 | 0.25 |
| | | | | | | | | |
| North Thames | London | 2866.759 | 250 Historic | 1031.54 | 238.25 | 2.04 | 1198.15 | 0.26 |
| North Thames | London | 2866.759 | 250 Wet Scenario | 1258.11 | 238.81 | 2.02 | 1486.83 | 0.25 |
| | | | | | | | | |
| North Thames | London | 2862.548 | 250 Historic | 1031.54 | 238.22 | 1.86 | 1480.76 | 0.24 |
| North Thames | London | 2862.548 | 250 Wet Scenario | 1258.11 | 238.78 | 1.83 | 1824.64 | 0.23 |
| | | | | | | | | |
| North Thames | London | 2754.405 | 250 Historic | 1031.54 | 238.08 | 2.17 | 1272.64 | 0.28 |
| North Thames | London | 2754.405 | 250 Wet Scenario | 1258.11 | 238.64 | 2.22 | 1525.68 | 0.28 |
| | | | | | | | | |
| North Thames | London | 2673.227 | 250 Historic | 1031.54 | 238 | 2.26 | 1006.5 | 0.3 |
| North Thames | London | 2673.227 | 250 Wet Scenario | 1258.11 | 238.52 | 2.49 | 1177.87 | 0.31 |
| | | | | | | | | |
| North Thames | London | 2544.147 | 250 Historic | 1031.54 | 237.57 | 3.48 | 565.56 | 0.48 |
| North Thames | London | 2544.147 | 250 Wet Scenario | 1258.11 | 238.09 | 3.64 | 673.19 | 0.48 |
| | | | | | | | | |
| North Thames | London | 2361.037 | 250 Historic | 1031.54 | 237.56 | 2.09 | 847.18 | 0.29 |
| North Thames | London | 2361.037 | 250 Wet Scenario | 1258.11 | 238.12 | 2.13 | 1063.3 | 0.28 |
| | | | | | | | | |
| North Thames | London | 2308.115 | 250 Historic | 1031.54 | 237.58 | 1.74 | 1116.32 | 0.24 |
| North Thames | London | 2308.115 | 250 Wet Scenario | 1258.11 | 238.14 | 1.76 | 1360.04 | 0.23 |
| | | | | | | | | |
| North Thames | London | 2202.025 | 250 Historic | 1031.54 | 237.54 | 1.6 | 1136.81 | 0.23 |
| North Thames | London | 2202.025 | 250 Wet Scenario | 1258.11 | 238.11 | 1.58 | 1453.17 | 0.21 |
| | | | | | | | | |
| North Thames | London | 2190.01 | 250 Historic | 1031.54 | 237.52 | 1.65 | 1067.33 | 0.23 |
| North Thames | London | 2190.01 | 250 Wet Scenario | 1258.11 | 238.1 | 1.63 | 1394.72 | 0.22 |
| | | | | | | | | |
| North Thames | London | 2181.51 | | Bridge | | | | |
| | | | | | | | | |
| North Thames | London | 2172.707 | 250 Historic | 1031.54 | 237.5 | 1.67 | 1053.84 | 0.24 |

Table 3.10 HEC-RAS results for a location at the North Thames River-continued

| River | Reach | River Sta | Profile | Q Total | W.S. Elev | Vel Chnl | Flow Area | Froude # Chl |
|---|---|---|---|---|---|---|---|---|
| | | | | (m3/s) | (m) | (m/s) | (m2) | |
| North Thames | London | 2172.707 | 250 Wet Scenario | 1258.11 | 238.06 | 1.65 | 1374.7 | 0.22 |
| | | | | | | | | |
| North Thames | London | 2130.325 | 250 Historic | 1031.54 | 237.51 | 1.24 | 1484.27 | 0.17 |
| North Thames | London | 2130.325 | 250 Wet Scenario | 1258.11 | 238.07 | 1.27 | 1832.54 | 0.16 |
| | | | | | | | | |
| North Thames | London | 2040.504 | 250 Historic | 1031.54 | 237.51 | 0.99 | 1805.86 | 0.13 |
| North Thames | London | 2040.504 | 250 Wet Scenario | 1258.11 | 238.07 | 1.03 | 2158.83 | 0.13 |
| | | | | | | | | |
| North Thames | London | 1995.466 | 250 Historic | 1031.54 | 237.49 | 1.03 | 1670.65 | 0.13 |
| North Thames | London | 1995.466 | 250 Wet Scenario | 1258.11 | 238.05 | 1.1 | 1902.21 | 0.13 |
| | | | | | | | | |
| North Thames | London | 1944.315 | 250 Historic | 1031.54 | 237.45 | 1.23 | 1125.55 | 0.16 |
| North Thames | London | 1944.315 | 250 Wet Scenario | 1258.11 | 238 | 1.34 | 1280.49 | 0.16 |
| | | | | | | | | |
| North Thames | London | 1858.895 | 250 Historic | 1031.54 | 237.29 | 1.94 | 650.74 | 0.26 |
| North Thames | London | 1858.895 | 250 Wet Scenario | 1258.11 | 237.81 | 2.13 | 737.09 | 0.27 |
| | | | | | | | | |
| North Thames | London | 1733.633 | 250 Historic | 1031.54 | 237.19 | 2.04 | 607.2 | 0.28 |
| North Thames | London | 1733.633 | 250 Wet Scenario | 1258.11 | 237.71 | 2.21 | 737.15 | 0.29 |
| | | | | | | | | |
| North Thames | London | 1657.939 | 250 Historic | 1031.54 | 237.19 | 1.79 | 748.2 | 0.24 |
| North Thames | London | 1657.939 | 250 Wet Scenario | 1258.11 | 237.72 | 1.92 | 902.29 | 0.25 |
| | | | | | | | | |
| North Thames | London | 1627.085 | 250 Historic | 1031.54 | 237.19 | 1.68 | 765.52 | 0.24 |
| North Thames | London | 1627.085 | 250 Wet Scenario | 1258.11 | 237.73 | 1.79 | 937.03 | 0.24 |
| | | | | | | | | |
| North Thames | London | 1560.961 | 250 Historic | 1031.54 | 237.16 | 1.7 | 1013.51 | 0.23 |
| North Thames | London | 1560.961 | 250 Wet Scenario | 1258.11 | 237.7 | 1.74 | 1395.58 | 0.23 |
| | | | | | | | | |
| North Thames | London | 1515.005 | 250 Historic | 1031.54 | 237.14 | 1.54 | 671.63 | 0.26 |
| North Thames | London | 1515.005 | 250 Wet Scenario | 1258.11 | 237.65 | 1.63 | 769.5 | 0.26 |

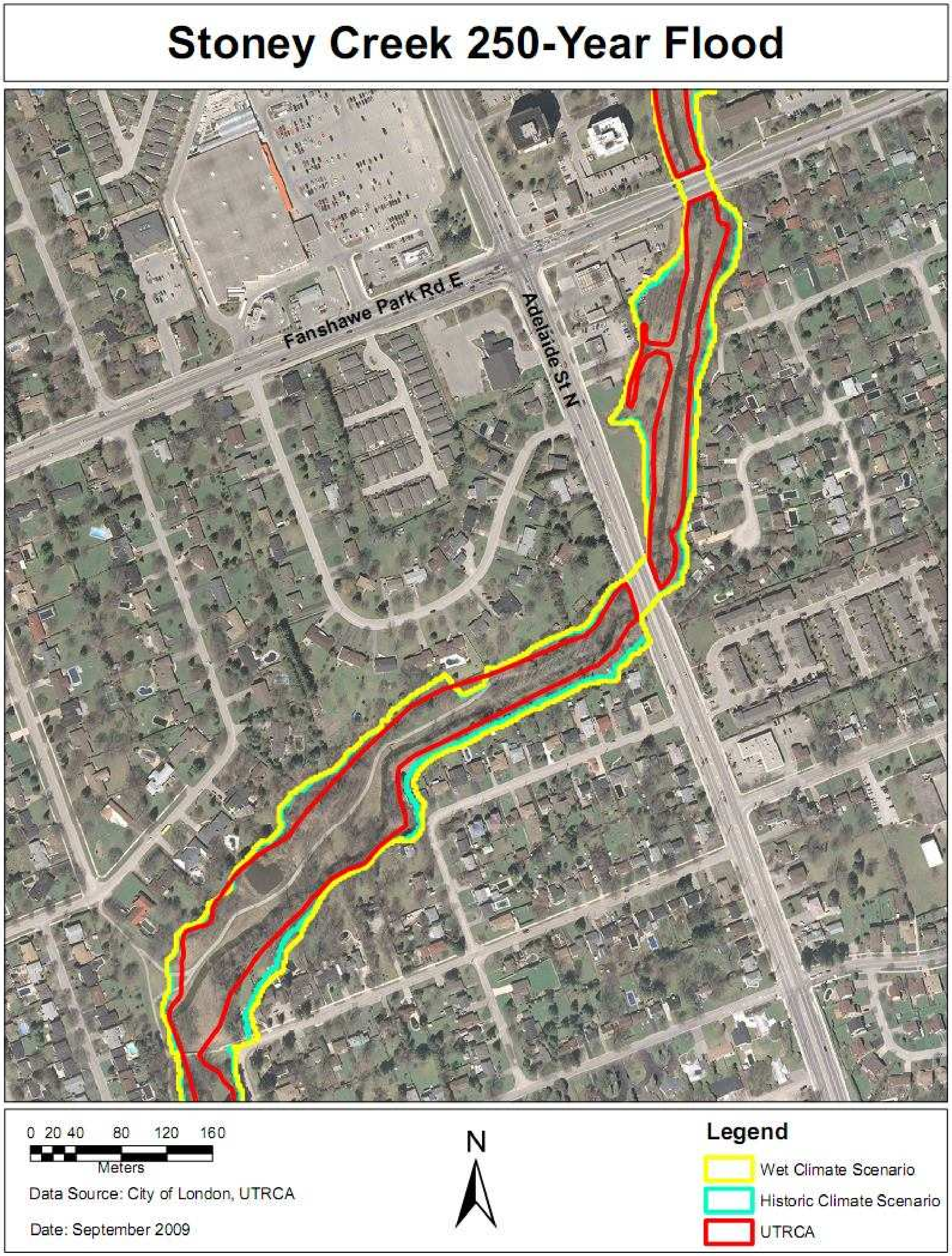


Figure 3.3 Floodplain results for a location at the Stoney Creek

Table 3.11 HEC-RAS results for a location at the Stoney Creek

| River | Reach | River Sta | Profile | Q Total | W.S. Elev | Vel Chnl | Flow Area | Froude # Chl |
|---|---|---|---|---|---|---|---|---|
| | | | | (m3/s) | (m) | (m/s) | (m2) | |
| Stoney Creek | Lower Reach | 2881.127 | 250 Historic | 59.16 | 248.83 | 1.41 | 55.75 | 0.29 |
| Stoney Creek | Lower Reach | 2881.127 | 250 Wet Scenario | 65.65 | 248.95 | 1.47 | 60.38 | 0.3 |
| | | | | | | | | |
| Stoney Creek | Lower Reach | 2721.468 | 250 Historic | 59.16 | 248.75 | 1.49 | 57 | 0.29 |
| Stoney Creek | Lower Reach | 2721.468 | 250 Wet Scenario | 65.65 | 248.87 | 1.57 | 60.77 | 0.3 |
| | | | | | | | | |
| Stoney Creek | Lower Reach | 2708.136 | 250 Historic | 59.16 | 248.76 | 1.01 | 58.84 | 0.23 |
| Stoney Creek | Lower Reach | 2708.136 | 250 Wet Scenario | 65.65 | 248.88 | 1.05 | 62.48 | 0.23 |
| | | | | | | | | |
| Stoney Creek | Lower Reach | 2694.901 | | Bridge | | | | |
| | | | | | | | | |
| Stoney Creek | Lower Reach | 2678.896 | 250 Historic | 59.16 | 248.75 | 1.06 | 56.01 | 0.25 |
| Stoney Creek | Lower Reach | 2678.896 | 250 Wet Scenario | 65.65 | 248.87 | 1.1 | 59.7 | 0.25 |
| | | | | | | | | |
| Stoney Creek | Lower Reach | 2621.681 | 250 Historic | 59.16 | 248.67 | 1.66 | 60.82 | 0.33 |
| Stoney Creek | Lower Reach | 2621.681 | 250 Wet Scenario | 65.65 | 248.8 | 1.71 | 67.76 | 0.33 |
| | | | | | | | | |
| Stoney Creek | Lower Reach | 2471 | 250 Historic | 59.16 | 248.48 | 1.92 | 51.73 | 0.4 |
| Stoney Creek | Lower Reach | 2471 | 250 Wet Scenario | 65.65 | 248.6 | 1.96 | 58.02 | 0.39 |
| | | | | | | | | |
| Stoney Creek | Lower Reach | 2408.007 | 250 Historic | 59.16 | 248.44 | 1.8 | 51.29 | 0.37 |
| Stoney Creek | Lower Reach | 2408.007 | 250 Wet Scenario | 65.65 | 248.57 | 1.82 | 57.23 | 0.37 |
| | | | | | | | | |
| Stoney Creek | Lower Reach | 2357.588 | 250 Historic | 59.16 | 248.45 | 1.47 | 69.35 | 0.3 |
| Stoney Creek | Lower Reach | 2357.588 | 250 Wet Scenario | 65.65 | 248.58 | 1.5 | 76.62 | 0.29 |
| | | | | | | | | |
| Stoney Creek | Lower Reach | 2346.78 | 250 Historic | 59.16 | 248.46 | 0.89 | 66.13 | 0.21 |
| Stoney Creek | Lower Reach | 2346.78 | 250 Wet Scenario | 65.65 | 248.59 | 0.93 | 70.91 | 0.21 |
| | | | | | | | | |
| Stoney Creek | Lower Reach | 2328.596 | | Bridge | | | | |
| | | | | | | | | |
| Stoney Creek | Lower Reach | 2311.613 | 250 Historic | 59.16 | 248.45 | 0.9 | 66.02 | 0.21 |
| Stoney Creek | Lower Reach | 2311.613 | 250 Wet Scenario | 65.65 | 248.58 | 0.93 | 70.75 | 0.21 |
| | | | | | | | | |
| Stoney Creek | Lower Reach | 2299.93 | 250 Historic | 59.16 | 248.39 | 1.45 | 59.98 | 0.3 |
| Stoney Creek | Lower Reach | 2299.93 | 250 Wet Scenario | 65.65 | 248.53 | 1.49 | 67.28 | 0.3 |
| | | | | | | | | |
| Stoney Creek | Lower Reach | 2245.418 | 250 Historic | 59.16 | 248.27 | 2.05 | 46.56 | 0.43 |
| Stoney Creek | Lower Reach | 2245.418 | 250 Wet Scenario | 65.65 | 248.41 | 2.07 | 53.28 | 0.42 |
| | | | | | | | | |
| Stoney Creek | Lower Reach | 2085.312 | 250 Historic | 59.16 | 248.16 | 1.53 | 60.08 | 0.32 |
| Stoney Creek | Lower Reach | 2085.312 | 250 Wet Scenario | 65.65 | 248.32 | 1.5 | 68.33 | 0.3 |
| | | | | | | | | |
| Stoney Creek | Lower Reach | 2024.432 | 250 Historic | 59.16 | 248.14 | 1.19 | 80.82 | 0.24 |
| Stoney Creek | Lower Reach | 2024.432 | 250 Wet Scenario | 65.65 | 248.3 | 1.16 | 93.09 | 0.23 |
| | | | | | | | | |
| Stoney Creek | Lower Reach | 1826.422 | 250 Historic | 59.16 | 248.04 | 1.22 | 91.33 | 0.25 |
| Stoney Creek | Lower Reach | 1826.422 | 250 Wet Scenario | 65.65 | 248.21 | 1.2 | 105.32 | 0.24 |
| | | | | | | | | |
| Stoney Creek | Lower Reach | 1753.131 | 250 Historic | 59.16 | 248.02 | 0.94 | 103.6 | 0.19 |
| Stoney Creek | Lower Reach | 1753.131 | 250 Wet Scenario | 65.65 | 248.2 | 0.93 | 118.61 | 0.18 |
| | | | | | | | | |
| Stoney Creek | Lower Reach | 1714.154 | 250 Historic | 59.16 | 247.99 | 1.16 | 78.46 | 0.25 |
| Stoney Creek | Lower Reach | 1714.154 | 250 Wet Scenario | 65.65 | 248.17 | 1.13 | 91.67 | 0.23 |
| | | | | | | | | |
| Stoney Creek | Lower Reach | 1703.93 | 250 Historic | 59.16 | 247.97 | 1.1 | 68.36 | 0.25 |
| Stoney Creek | Lower Reach | 1703.93 | 250 Wet Scenario | 65.65 | 248.16 | 1.07 | 80.77 | 0.23 |

Table 3.11 HEC-RAS results for a location at the Stoney Creek-continued

| River | Reach | River Sta | Profile | Q Total | W.S. Elev | Vel Chnl | Flow Area | Froude # Chl |
|---|---|---|---|---|---|---|---|---|
| | | | | (m3/s) | (m) | (m/s) | (m2) | |
| Stoney Creek | Lower Reach | 1702.212 | | Bridge | | | | |
| | | | | | | | | |
| Stoney Creek | Lower Reach | 1700.905 | 250 Historic | 59.16 | 247.6 | 1.55 | 45.82 | 0.38 |
| Stoney Creek | Lower Reach | 1700.905 | 250 Wet Scenario | 65.65 | 247.69 | 1.59 | 50.38 | 0.38 |
| | | | | | | | | |
| Stoney Creek | Lower Reach | 1678.303 | 250 Historic | 59.16 | 247.56 | 1.77 | 53.92 | 0.37 |
| Stoney Creek | Lower Reach | 1678.303 | 250 Wet Scenario | 65.65 | 247.65 | 1.83 | 58.48 | 0.37 |

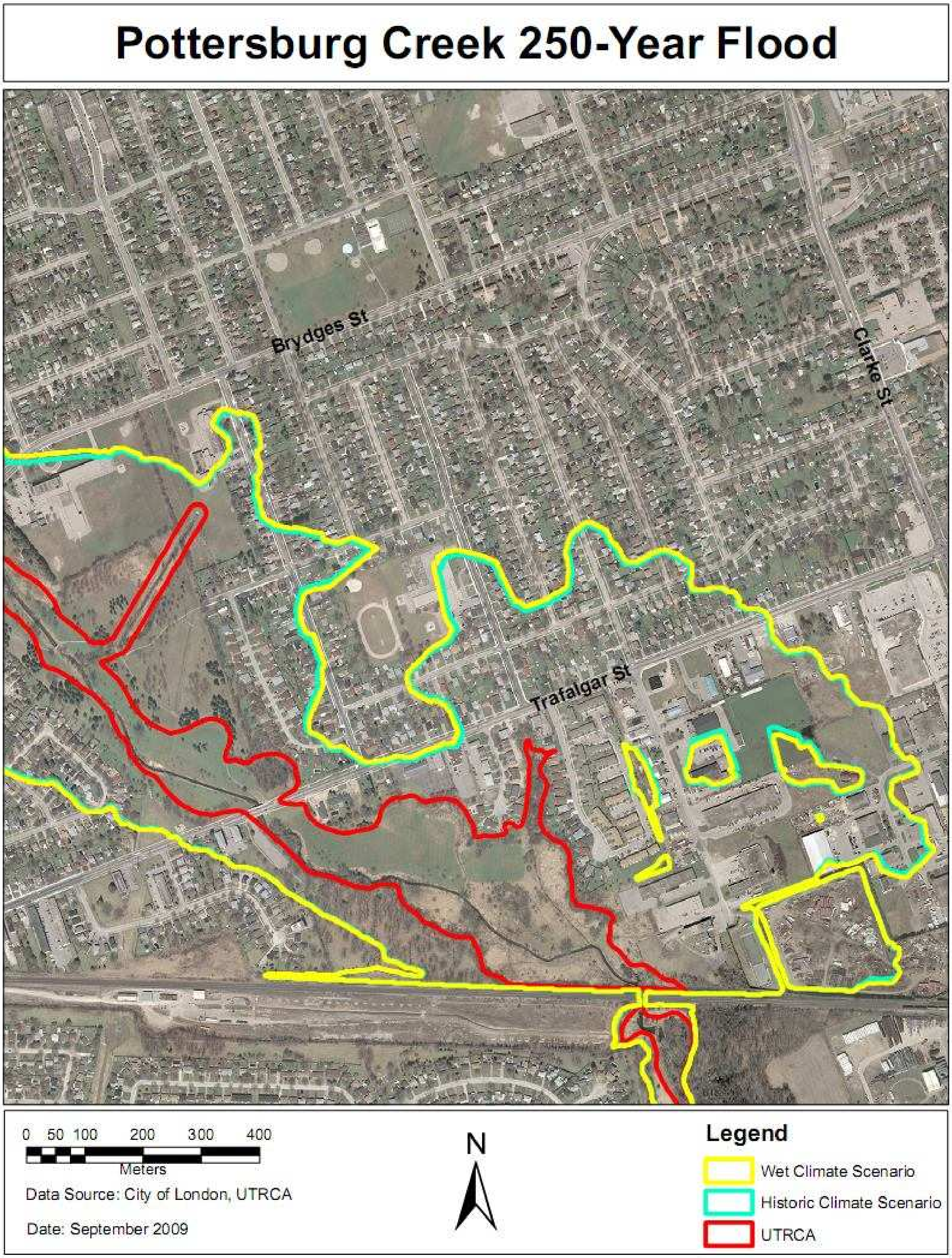


Figure 3.4 Floodplain results for a location at the Pottersburg Creek

Table 3.12 HEC-RAS results for a location at the Pottersburg Creek

| River | Reach | River Sta | Profile | Q Total | W.S. Elev | Vel Chnl | Flow Area | Froude # Chl |
|---|---|---|---|---|---|---|---|---|
| | | | | (m3/s) | (m) | (m/s) | (m2) | |
| Pottersburg Cr | London | 3320.489 | 250 Historic | 99.47 | 259.54 | 0.41 | 588.1 | 0.06 |
| Pottersburg Cr | London | 3320.489 | 250 Wet Scenario | 114.22 | 259.63 | 0.44 | 632.45 | 0.06 |
| | | | | | | | | |
| Pottersburg Cr | London | 3124.122 | 250 Historic | 99.47 | 259.53 | 0.27 | 1014.62 | 0.04 |
| Pottersburg Cr | London | 3124.122 | 250 Wet Scenario | 114.22 | 259.63 | 0.29 | 1073.12 | 0.04 |
| | | | | | | | | |
| Pottersburg Cr | London | 3008.501 | 250 Historic | 99.47 | 259.53 | 0.22 | 1316.91 | 0.03 |
| Pottersburg Cr | London | 3008.501 | 250 Wet Scenario | 114.22 | 259.63 | 0.23 | 1384.27 | 0.03 |
| | | | | | | | | |
| Pottersburg Cr | London | 2859.465 | 250 Historic | 99.47 | 259.53 | 0.29 | 1049.78 | 0.04 |
| Pottersburg Cr | London | 2859.465 | 250 Wet Scenario | 114.22 | 259.63 | 0.31 | 1109.7 | 0.04 |
| | | | | | | | | |
| Pottersburg Cr | London | 2696.997 | 250 Historic | 127.42 | 259.53 | 0.21 | 1066.83 | 0.02 |
| Pottersburg Cr | London | 2696.997 | 250 Wet Scenario | 145.77 | 259.63 | 0.24 | 1107.01 | 0.03 |
| | | | | | | | | |
| Pottersburg Cr | London | 2646.932 | 250 Historic | 127.42 | 259.53 | 0.49 | 1243.26 | 0.06 |
| Pottersburg Cr | London | 2646.932 | 250 Wet Scenario | 145.77 | 259.62 | 0.56 | 1293.63 | 0.06 |
| | | | | | | | | |
| Pottersburg Cr | London | 2631.258 | 250 Historic | 127.42 | 259.53 | 0.19 | 1512.22 | 0.02 |
| Pottersburg Cr | London | 2631.258 | 250 Wet Scenario | 145.77 | 259.62 | 0.21 | 1606.56 | 0.02 |
| | | | | | | | | |
| Pottersburg Cr | London | 2619.492 | | Bridge | | | | |
| | | | | | | | | |
| Pottersburg Cr | London | 2610.263 | 250 Historic | 127.42 | 259.53 | 0.19 | 1511.6 | 0.02 |
| Pottersburg Cr | London | 2610.263 | 250 Wet Scenario | 145.77 | 259.62 | 0.21 | 1605.82 | 0.02 |
| | | | | | | | | |
| Potterrsburg Cr | London | 2565.58 | 250 Historic | 127.42 | 259.52 | 0.42 | 1504.67 | 0.05 |
| Pottrsburg Cr | London | 2565.58 | 250 Wet Scenario | 145.77 | 259.62 | 0.45 | 1598.65 | 0.05 |
| | | | | | | | | |
| Pottersburg Cr | London | 2527.268 | 250 Historic | 127.42 | 259.52 | 0.21 | 1539.47 | 0.02 |
| Pottersburg Cr | London | 2527.268 | 250 Wet Scenario | 145.77 | 259.62 | 0.22 | 1630.88 | 0.02 |
| | | | | | | | | |
| Pottersburg Cr | London | 2457.719 | 250 Historic | 127.42 | 259.52 | 0.3 | 1681.07 | 0.03 |
| Pottersburg Cr | London | 2457.719 | 250 Wet Scenario | 145.77 | 259.62 | 0.32 | 1774.79 | 0.03 |
| | | | | | | | | |
| Pottersburg Cr | London | 2272.463 | 250 Historic | 127.42 | 259.52 | 0.13 | 2831.07 | 0.01 |
| Pottersburg Cr | London | 2272.463 | 250 Wet Scenario | 145.77 | 259.62 | 0.15 | 2919.18 | 0.02 |
| | | | | | | | | |
| Pottersburg Cr | London | 2169.292 | 250 Historic | 127.42 | 259.52 | 0.12 | 2619.31 | 0.01 |
| Pottersburg Cr | London | 2169.292 | 250 Wet Scenario | 145.77 | 259.62 | 0.14 | 2694.15 | 0.01 |
| | | | | | | | | |
| Pottersburg Cr | London | 2059.38 | 250 Historic | 127.42 | 259.52 | 0.07 | 2947.99 | 0.01 |
| Pottersburg Cr | London | 2059.38 | 250 Wet Scenario | 145.77 | 259.62 | 0.07 | 3033.96 | 0.01 |
| | | | | | | | | |
| Pottersburg Cr | London | 1883.751 | 250 Historic | 127.42 | 259.52 | 0.07 | 2930.62 | 0.01 |
| Pottersburg Cr | London | 1883.751 | 250 Wet Scenario | 145.77 | 259.62 | 0.07 | 3010.11 | 0.01 |
| | | | | | | | | |
| Pottersburg Cr | London | 1814.873 | 250 Historic | 127.42 | 259.52 | 0.06 | 3350.51 | 0.01 |
| Pottersburg Cr | London | 1814.873 | 250 Wet Scenario | 145.77 | 259.62 | 0.07 | 3435.73 | 0.01 |
| | | | | | | | | |
| Pottersburg Cr | London | 1805.415 | 250 Historic | 127.42 | 259.52 | 0.34 | 1288.42 | 0.03 |
| Pottersburg Cr | London | 1805.415 | 250 Wet Scenario | 145.77 | 259.61 | 0.38 | 1316.83 | 0.04 |
| | | | | | | | | |
| Pottersburg Cr | London | 1787.191 | | Bridge | | | | |
| | | | | | | | | |
| Pottersburg Cr | London | 1771.452 | 250 Historic | 140.12 | 252.69 | 5.96 | 23.52 | 1 |
| Pottersburg Cr | London | 1771.452 | 250 Wet Scenario | 160.1 | 253.02 | 6.24 | 25.67 | 1 |

Table 3.12 HEC-RAS results for a location at the Pottersburg Creek-continued

| River | Reach | River Sta | Profile | Q Total | W.S. Elev | Vel Chnl | Flow Area | Froude # Chl |
|---|---|---|---|---|---|---|---|---|
| | | | | (m3/s) | (m) | (m/s) | (m2) | |
| Pottersburg Cr | London | 1734.825 | 250 Historic | 140.12 | 251.14 | 1.81 | 187.79 | 0.33 |
| Pottersburg Cr | London | 1734.825 | 250 Wet Scenario | 160.1 | 251.26 | 1.9 | 203.71 | 0.34 |

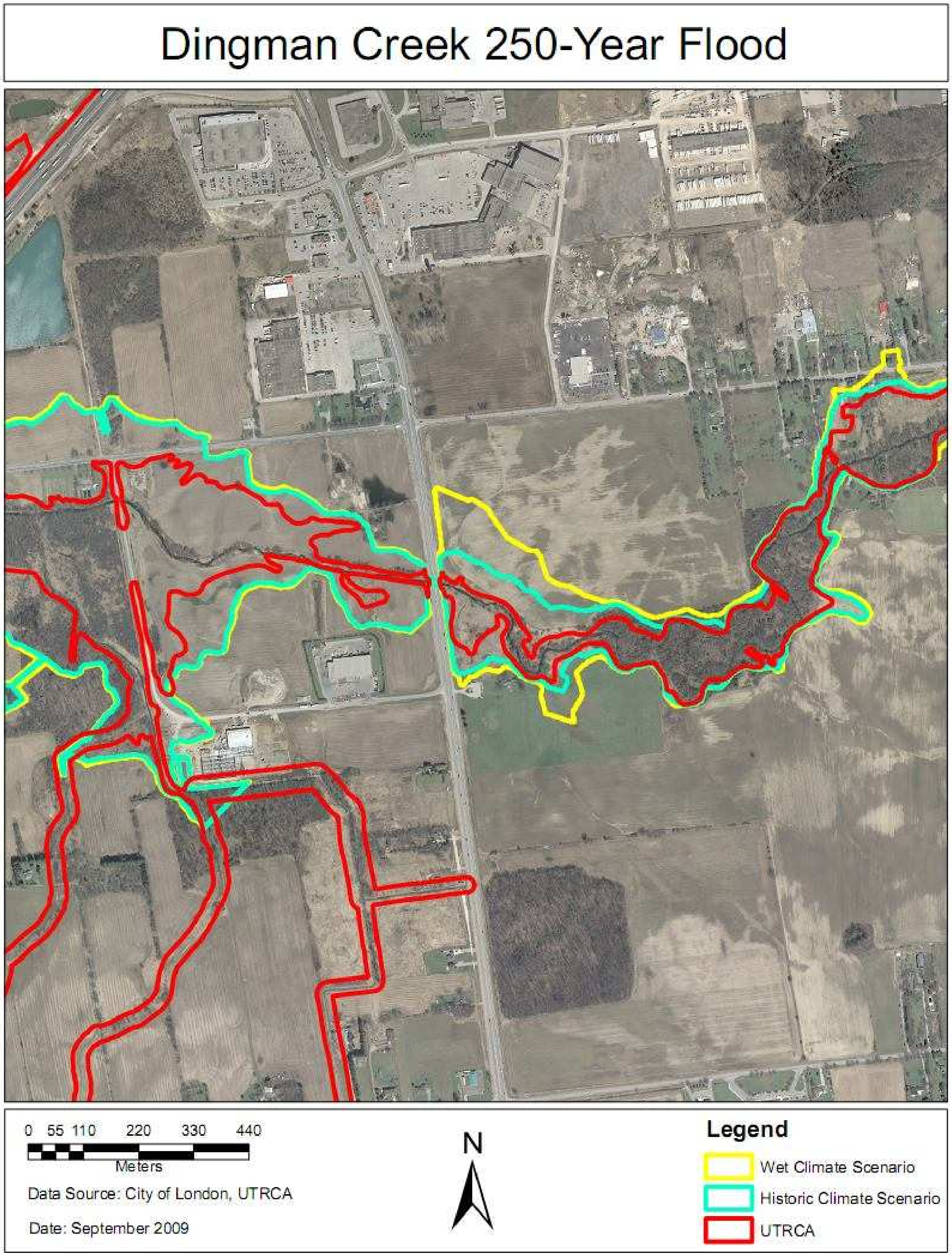


Figure 3.5 Floodplain results for a location at the Dingman Creek

Table 3.13 HEC-RAS results for a location at the Dingman Creek

| River | Reach | River Sta | Profile | Q Total | W.S. Elev | Vel Chnl | Flow Area | Froude # Chl |
|---|---|---|---|---|---|---|---|---|
| | | | | (m3/s) | (m) | (m/s) | (m2) | |
| Dingman Creek | Reach 10 | 26102.15 | 250 Historic | 87 | 260.93 | 2.93 | 104.36 | 0.55 |
| Dingman Creek | Reach 10 | 26102.15 | 250 Wet Scenario | 97.92 | 261.11 | 2.88 | 123.48 | 0.52 |
| | | | | | | | | |
| Dingman Creek | Reach 10 | 25904.62 | 250 Historic | 87 | 260.97 | 1.07 | 268.33 | 0.2 |
| Dingman Creek | Reach 10 | 25904.62 | 250 Wet Scenario | 97.92 | 261.14 | 1.09 | 303.27 | 0.2 |
| | | | | | | | | |
| Dingman Creek | Reach 10 | 25735.1 | 250 Historic | 87 | 260.48 | 2.75 | 54.18 | 0.57 |
| Dingman Creek | Reach 10 | 25735.1 | 250 Wet Scenario | 97.92 | 260.65 | 2.81 | 61.57 | 0.56 |
| | | | | | | | | |
| Dingman Creek | Reach 10 | 25563.7 | 250 Historic | 87 | 260.33 | 1.84 | 140.18 | 0.37 |
| Dingman Creek | Reach 10 | 25563.7 | 250 Wet Scenario | 97.92 | 260.58 | 1.69 | 171.07 | 0.33 |
| | | | | | | | | |
| Dingman Creek | Reach 10 | 25283.32 | 250 Historic | 87 | 260.07 | 1.36 | 153.94 | 0.31 |
| Dingman Creek | Reach 10 | 25283.32 | 250 Wet Scenario | 97.92 | 260.4 | 1.21 | 202.07 | 0.25 |
| | | | | | | | | |
| Dingman Creek | Reach 10 | 25005.04 | 250 Historic | 87 | 259.9 | 1.36 | 215.06 | 0.27 |
| Dingman Creek | Reach 10 | 25005.04 | 250 Wet Scenario | 97.92 | 260.3 | 1.15 | 285.3 | 0.21 |
| | | | | | | | | |
| Dingman Creek | Reach 10 | 24761.7 | 250 Historic | 87 | 259.64 | 1.66 | 90.78 | 0.34 |
| Dingman Creek | Reach 10 | 24761.7 | 250 Wet Scenario | 97.92 | 260.17 | 1.34 | 140.86 | 0.25 |
| | | | | | | | | |
| Dingman Creek | Reach 10 | 24509.31 | 250 Historic | 87 | 259.52 | 1.21 | 132.17 | 0.25 |
| Dingman Creek | Reach 10 | 24509.31 | 250 Wet Scenario | 97.92 | 260.13 | 0.84 | 254.13 | 0.15 |
| | | | | | | | | |
| Dingman Creek | Reach 10 | 24311.37 | 250 Historic | 87 | 259.5 | 0.74 | 242.91 | 0.15 |
| Dingman Creek | Reach 10 | 24311.37 | 250 Wet Scenario | 97.92 | 260.13 | 0.51 | 415.63 | 0.09 |
| | | | | | | | | |
| Dingman Creek | Reach 10 | 24296.22 | 250 Historic | 87 | 258.99 | 2.52 | 34.59 | 0.5 |
| Dingman Creek | Reach 10 | 24296.22 | 250 Wet Scenario | 97.92 | 259.74 | 2.2 | 44.47 | 0.38 |
| | | | | | | | | |
| Dingman Creek | Reach 10 | 24282.59 | | Bridge | | | | |
| | | | | | | | | |
| Dingman Creek | Reach 10 | 24269.29 | 250 Historic | 101.78 | 258.89 | 3.07 | 33.2 | 0.62 |
| Dingman Creek | Reach 10 | 24269.29 | 250 Wet Scenario | 113.75 | 258.95 | 3.35 | 34 | 0.67 |
| | | | | | | | | |
| Dingman Creek | Reach 10 | 24254.15 | 250 Historic | 101.78 | 258.88 | 2.61 | 68.47 | 0.57 |
| Dingman Creek | Reach 10 | 24254.15 | 250 Wet Scenario | 113.75 | 258.95 | 2.73 | 76.22 | 0.59 |
| | | | | | | | | |
| Dingman Creek | Reach 10 | 24208.61 | 250 Historic | 101.78 | 258.88 | 1.91 | 119.91 | 0.4 |
| Dingman Creek | Reach 10 | 24208.61 | 250 Wet Scenario | 113.75 | 258.96 | 1.97 | 131.7 | 0.41 |
| | | | | | | | | |
| Dingman Creek | Reach 10 | 24075.93 | 250 Historic | 101.78 | 258.43 | 2.73 | 79.49 | 0.51 |
| Dingman Creek | Reach 10 | 24075.93 | 250 Wet Scenario | 113.75 | 258.5 | 2.81 | 88.9 | 0.52 |
| | | | | | | | | |
| Dingman Creek | Reach 10 | 23923.71 | 250 Historic | 101.78 | 258.11 | 2.36 | 99.14 | 0.48 |
| Dingman Creek | Reach 10 | 23923.71 | 250 Wet Scenario | 113.75 | 258.22 | 2.29 | 119.49 | 0.46 |
| | | | | | | | | |
| Dingman Creek | Reach 10 | 23737.45 | 250 Historic | 101.78 | 258.15 | 0.85 | 417.53 | 0.16 |
| Dingman Creek | Reach 10 | 23737.45 | 250 Wet Scenario | 113.75 | 258.25 | 0.81 | 486.17 | 0.15 |
| | | | | | | | | |
| Dingman Creek | Reach 10 | 23602.88 | 250 Historic | 101.78 | 258.12 | 0.9 | 429.02 | 0.17 |
| Dingman Creek | Reach 10 | 23602.88 | 250 Wet Scenario | 113.75 | 258.23 | 0.83 | 506.97 | 0.15 |
| | | | | | | | | |
| Dingman Creek | Reach 10 | 23580.06 | 250 Historic | 101.78 | 258.11 | 0.95 | 378.14 | 0.17 |
| Dingman Creek | Reach 10 | 23580.06 | 250 Wet Scenario | 113.75 | 258.23 | 0.85 | 467.3 | 0.15 |
| | | | | | | | | |
| Dingman Creek | Reach 10 | 23572.33 | | Culvert | | | | |

Table 3.13 HEC-RAS results for a location at the Dingman Creek-continued

| River | Reach | River Sta | Profile | Q Total | W.S. Elev | Vel Chnl | Flow Area | Froude # Chl |
|---|---|---|---|---|---|---|---|---|
| | | | | (m3/s) | (m) | (m/s) | (m2) | |
| Dingman Creek | Reach 10 | 23565.27 | 250 Historic | 101.78 | 258.11 | 0.97 | 372.78 | 0.17 |
| Dingman Creek | Reach 10 | 23565.27 | 250 Wet Scenario | 113.75 | 258.22 | 0.85 | 463.93 | 0.15 |
| | | | | | | | | |
| Dingman Creek | Reach 10 | 23527.47 | 250 Historic | 101.78 | 258.1 | 0.65 | 456.5 | 0.12 |
| Dingman Creek | Reach 10 | 23527.47 | 250 Wet Scenario | 113.75 | 258.22 | 0.61 | 538.08 | 0.11 |
| | | | | | | | | |
| Dingman Creek | Reach 10 | 23389.79 | 250 Historic | 101.78 | 258.02 | 1.2 | 269.57 | 0.22 |
| Dingman Creek | Reach 10 | 23389.79 | 250 Wet Scenario | 113.75 | 258.16 | 1.07 | 335.11 | 0.19 |
| | | | | | | | | |
| Dingman Creek | Reach 10 | 23276.36 | 250 Historic | 101.78 | 258 | 0.83 | 281.68 | 0.17 |
| Dingman Creek | Reach 10 | 23276.36 | 250 Wet Scenario | 113.75 | 258.13 | 0.83 | 344.97 | 0.17 |

### *3.2.2. Floodplain results for locations of special concern*

The results requiring special attention are discussed here. Results for some of these locations do not adhere to a desirable level, most likely due to imprecision of the contour lines. Some of the areas where the existing UTRCA 250-year floodplain line is overestimated are also identified.

Figure 3.6 shows results for the North Thames River around the intersection of Oxford St W and Wharncliffe Rd N. The blue floodplain line representing the 250-year flood for historic climate scenario shows as straight line. In spite of the fact that the area has high elevations, the blue line around the Oxford St should not be straight line. This error is the consequence of inaccurate contour lines in that area.

Figure 3.7 shows floodplain results for the North Thames River around the intersection of Richmond St and University Dr. The yellow floodplain line, which represents 250-year flood for wet climate scenario, is closer to the river (lower flooding extent) then the existing UTRCA 250-year floodplain line (red line). According to the HEC-RAS results, however, it should be the opposite. The yellow floodplain line should have higher extent of flooding than the UTRCA red line, because the water surface elevations are higher (about 40 cm on average) for the 250 year wet climate scenario profiles when compared with the existing 250 year UTRCA profiles. Again, the reason for this is the inaccuracy of contour lines. Also, it appears that the UTRCA floodplain line (which is entered manually) is overestimated at some cross sections.

Figures 3.8a and 3.8.b show floodplain results at the South Thames River around the intersection of York St and Ridout St N, as well as the area upstream. Since both contour lines have a value of 237 m, the red floodplain line (UTRCA) should not cross York St at that location. The water surface elevation at the corresponding cross section is 236.4 m. Again, the existing UTRCA floodplain line is overestimated for that area.

Figure 3.9 shows the upstream area (close to the east city boundary) of the Dingman Creek around tributaries 12 and 13. There is no existing UTRCA HEC-RAS model for that area, and the delineation of the existing UTRCA 250-year floodplain line (red) is most likely a rough estimate of water elevation. This is probably the reason why the floodplain results are different for that area.

Figure 3.10 shows the floodplain mapping results for the Stoney Creek, around Fanshawe Park Rd E. The inaccuracy of contour lines resulted in sections of both floodplain lines (250-year historic and wet climate scenario) showing as straight lines, instead of following the contour line.

Figure 3.11 shows the floodplain mapping results for the Stoney Creek, between Adelaide St N and Blackwater Rd. This is another area where the existing UTRCA 250-year floodplain line is highly overestimated.

Figure 3.12 shows floodplain mapping results at the Northdale Drain (tributary of the Stoney Creek). The part of the Northdale Drain (pointed with arrow on the map modeled by both the existing UTRCA and DELCAN HEC-RAS models no longer exist in reality. The extensive residential development can be seen by comparing the more recent (London 2007) with the older aerial photographs (Figure 3.13) taken from the UTRCA HEC-RAS model. Also, it appears (from the aerial photos) that some regulation work has been done in the channel and its surrounding area. The inaccuracy of contour lines (especially around two ponds) affected the accuracy of floodplain mapping. This area requires special attention and probably more field investigation.

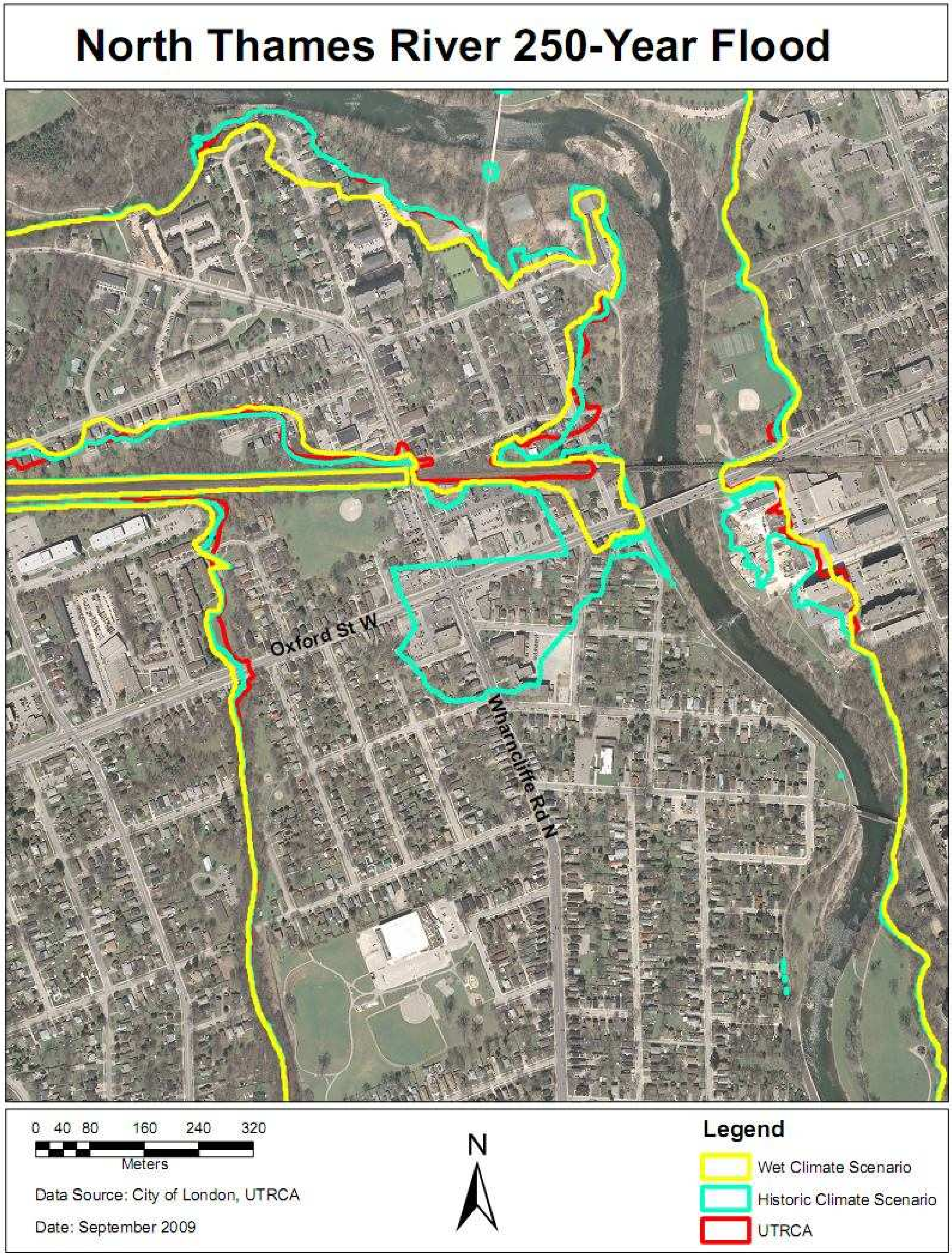


Figure 3.6 Location of special concern at the North Thames River

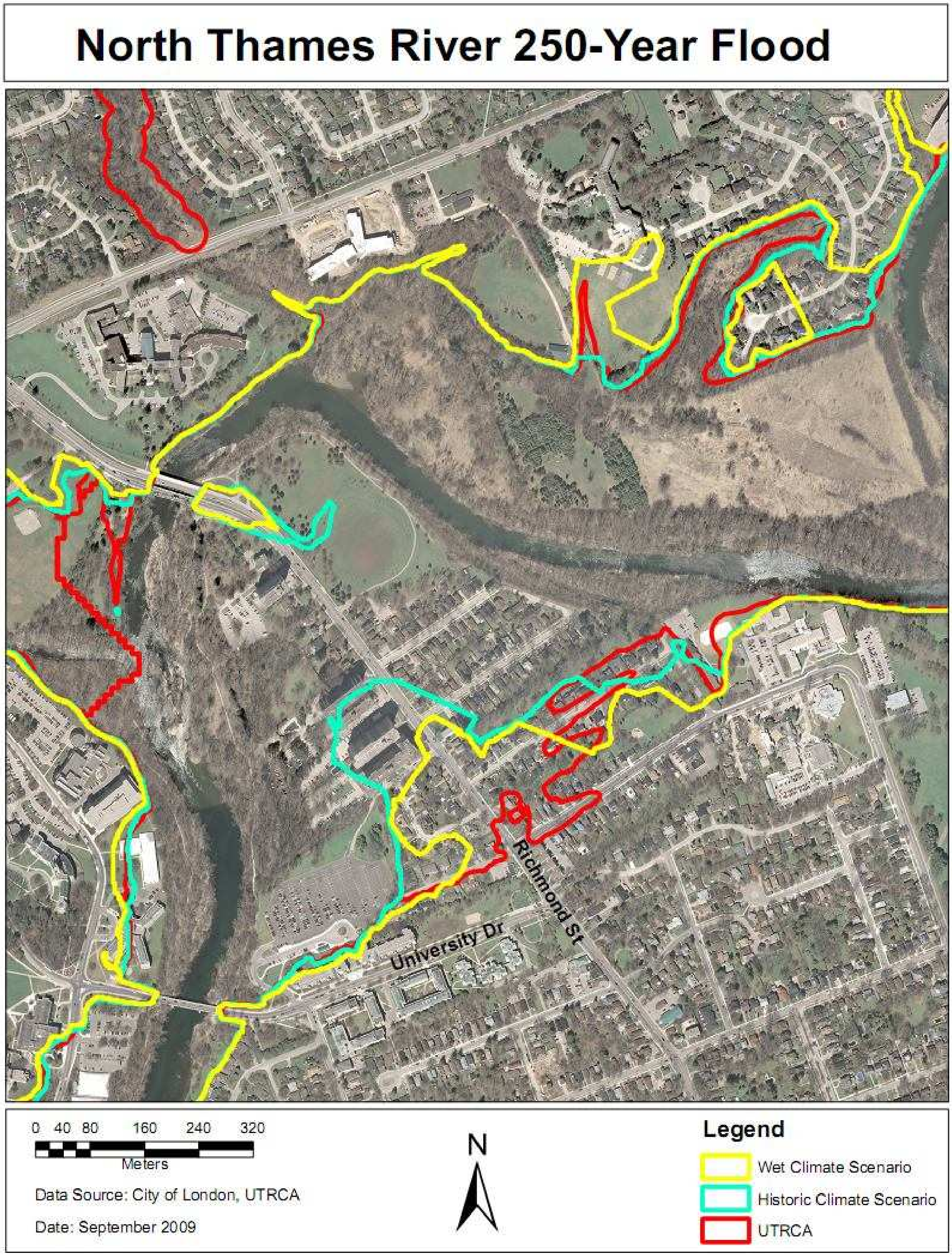


Figure 3.7 Location of special concern at the North Thames River

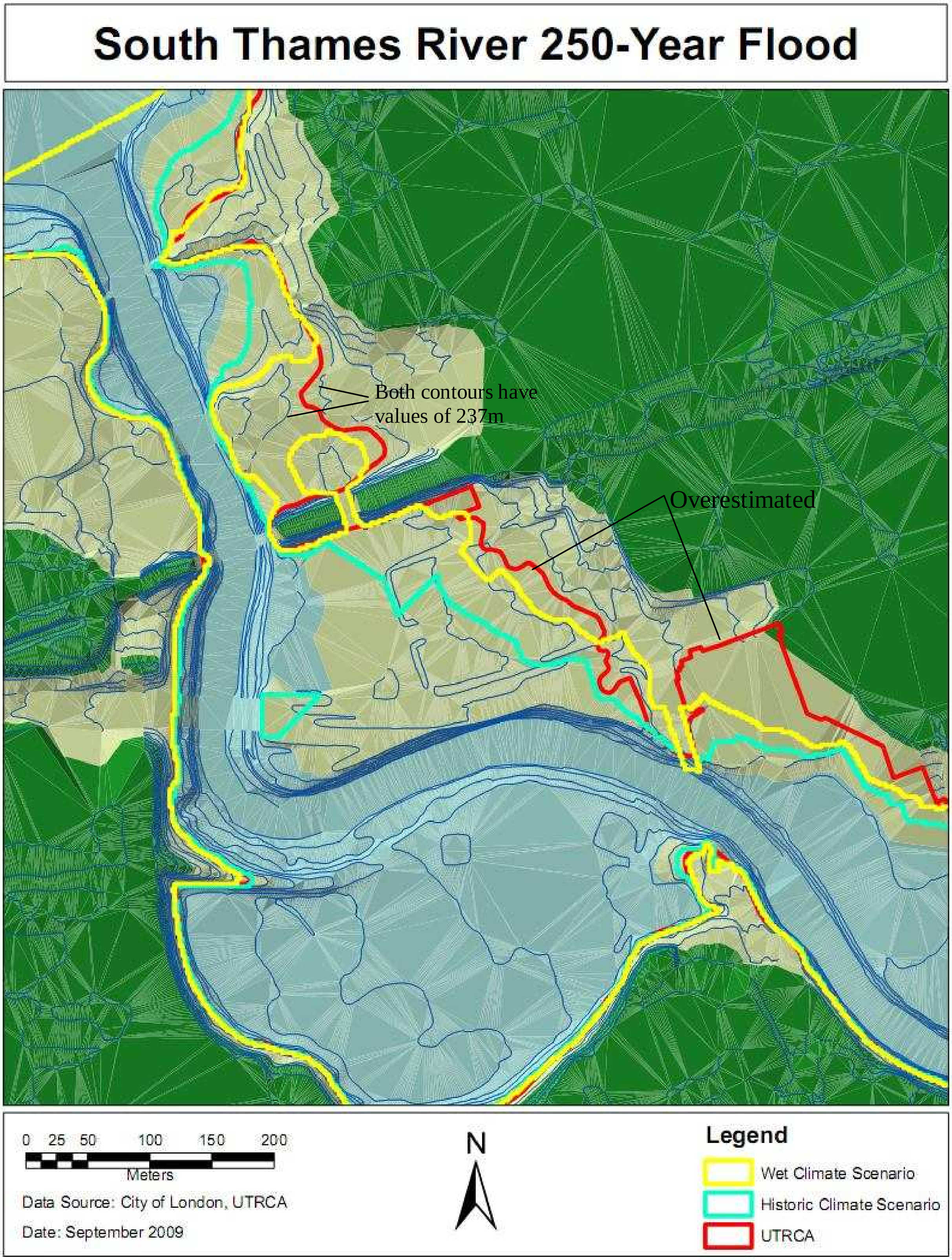


Figure 3.8 (a) Location of special concern at the South Thames River

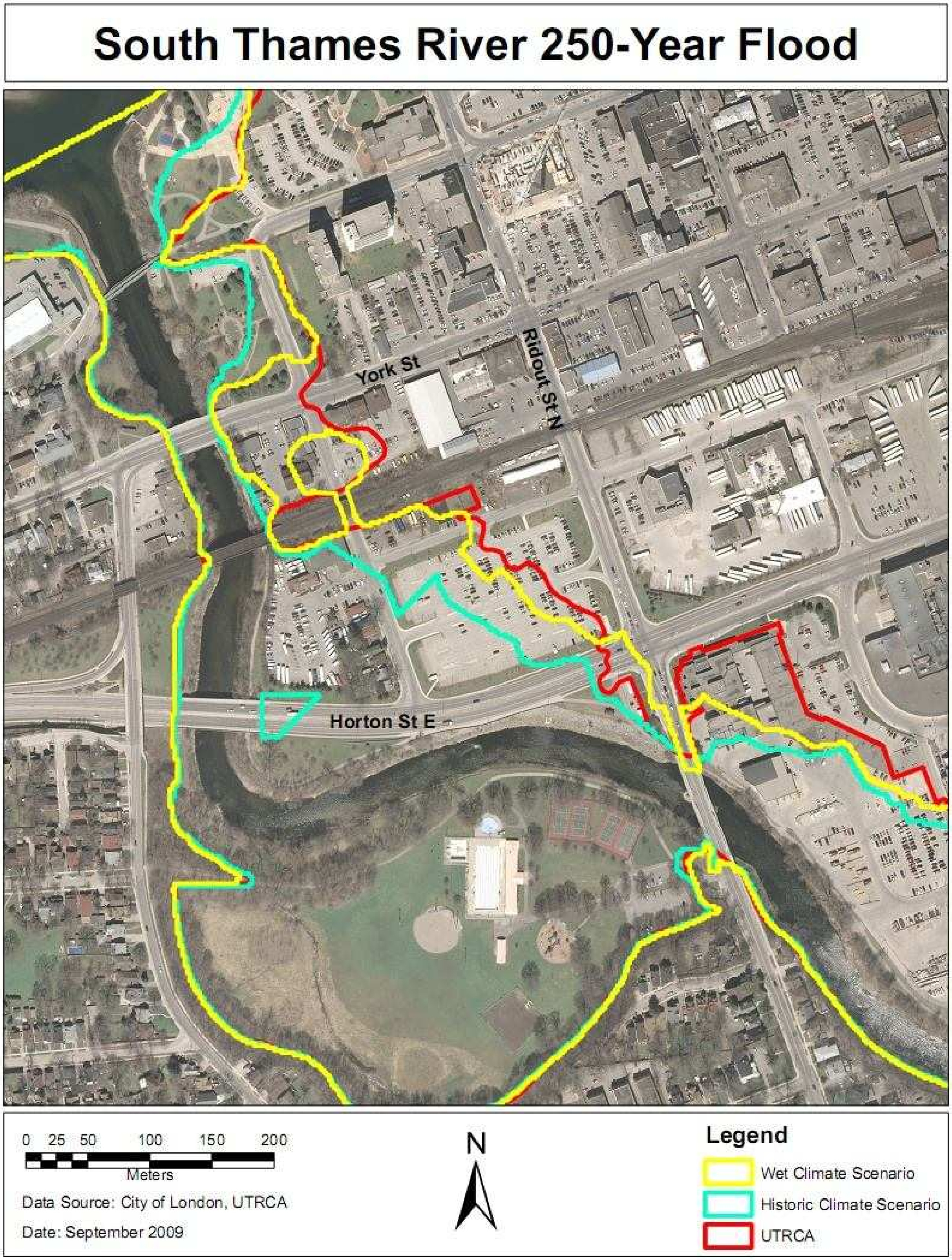


Figure 3.8 (b) Location of special concern at the South Thames River

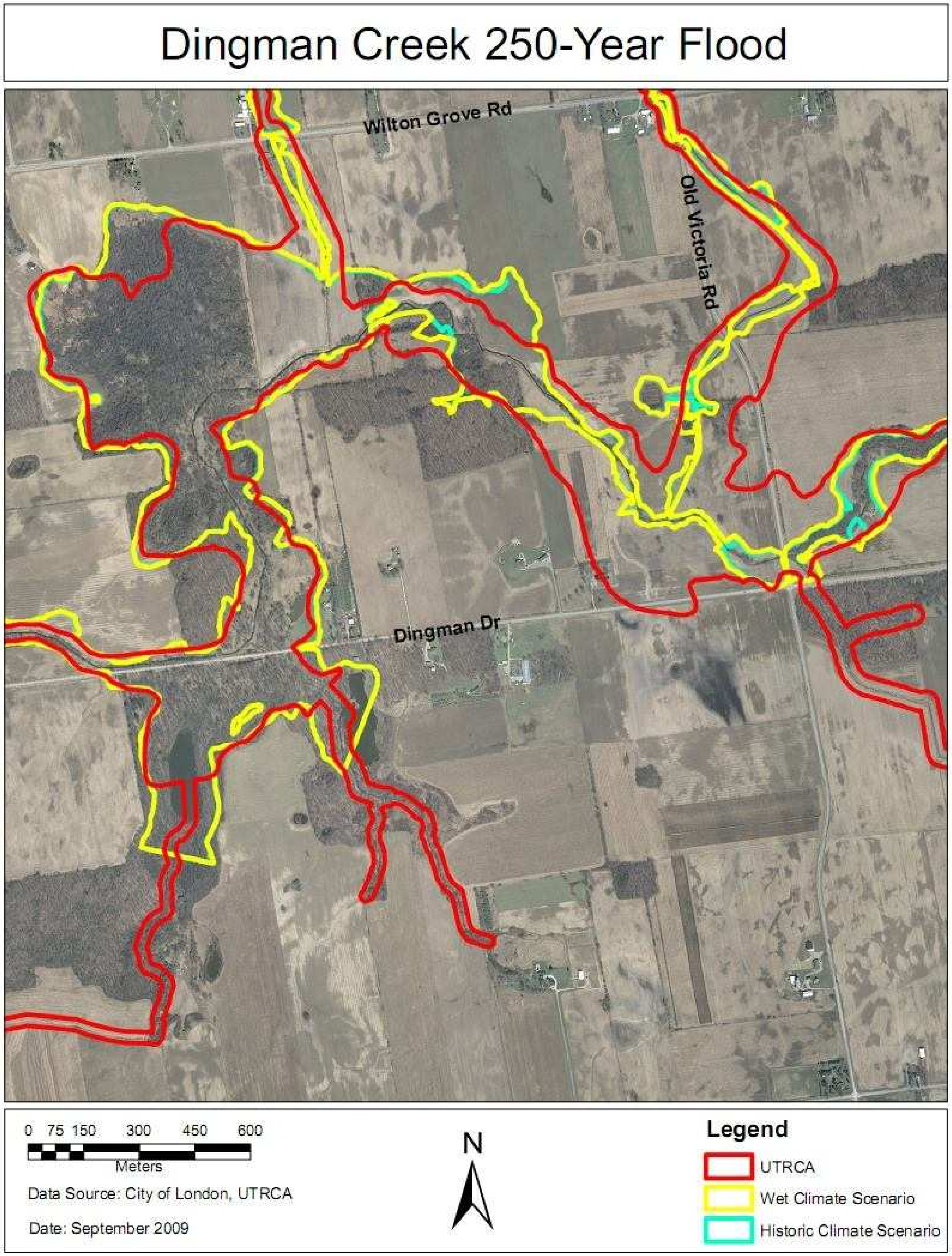


Figure 3.9 Location of special concern at the Dingman Creek

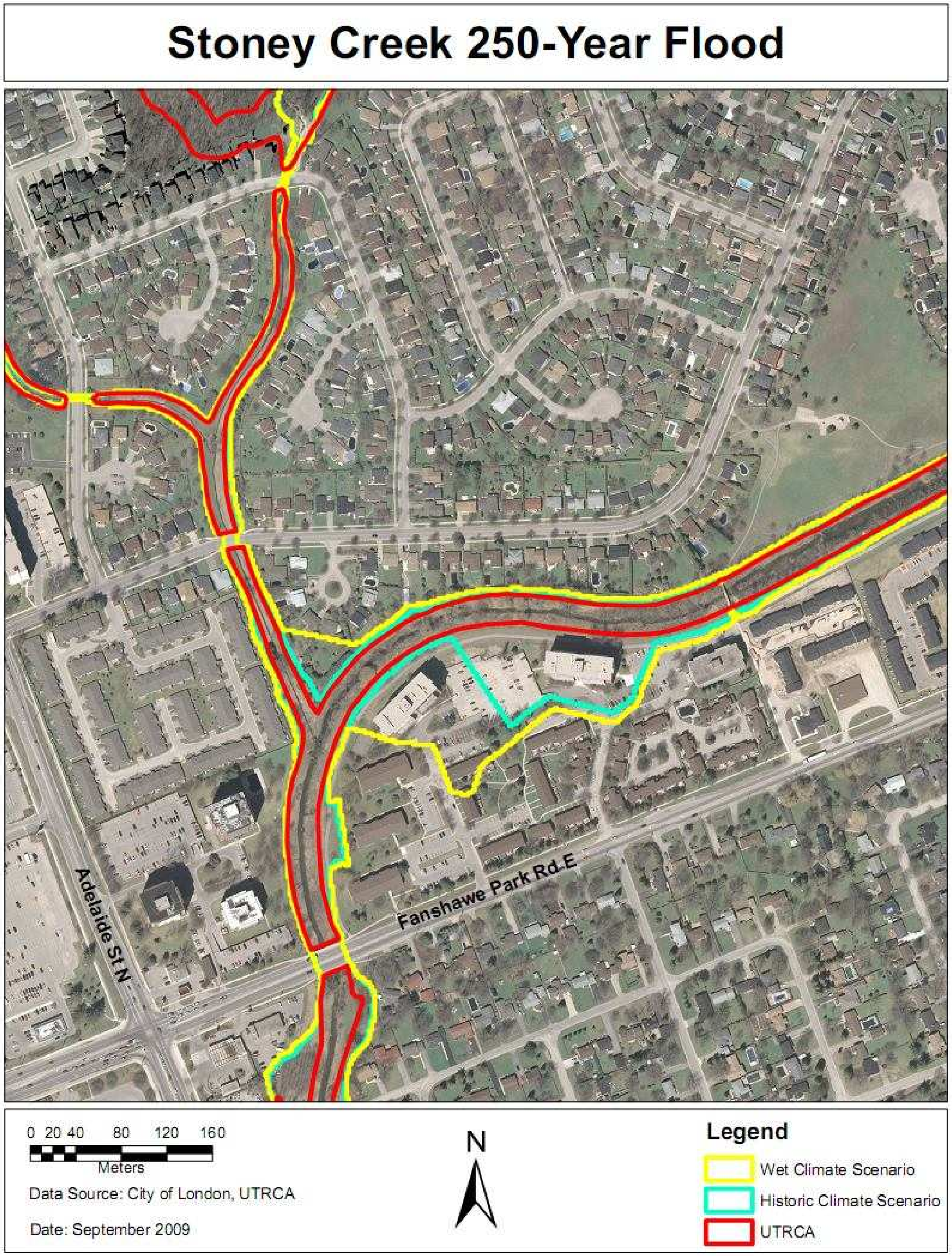


Figure 3.10 Location of special concern at the Stoney Creek

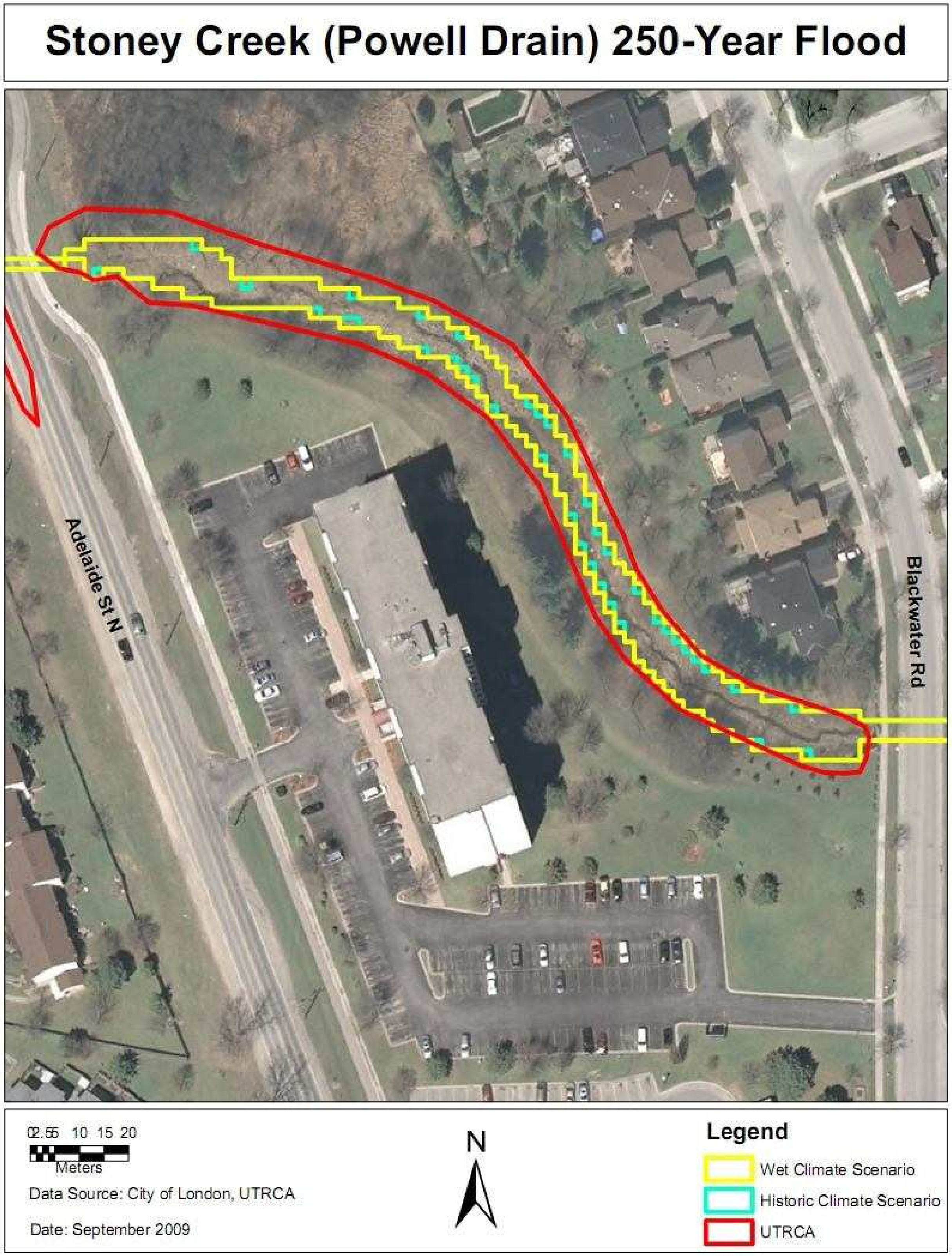


Figure 3.11 Location of special concern at the Stoney Creek (Powell Drain)

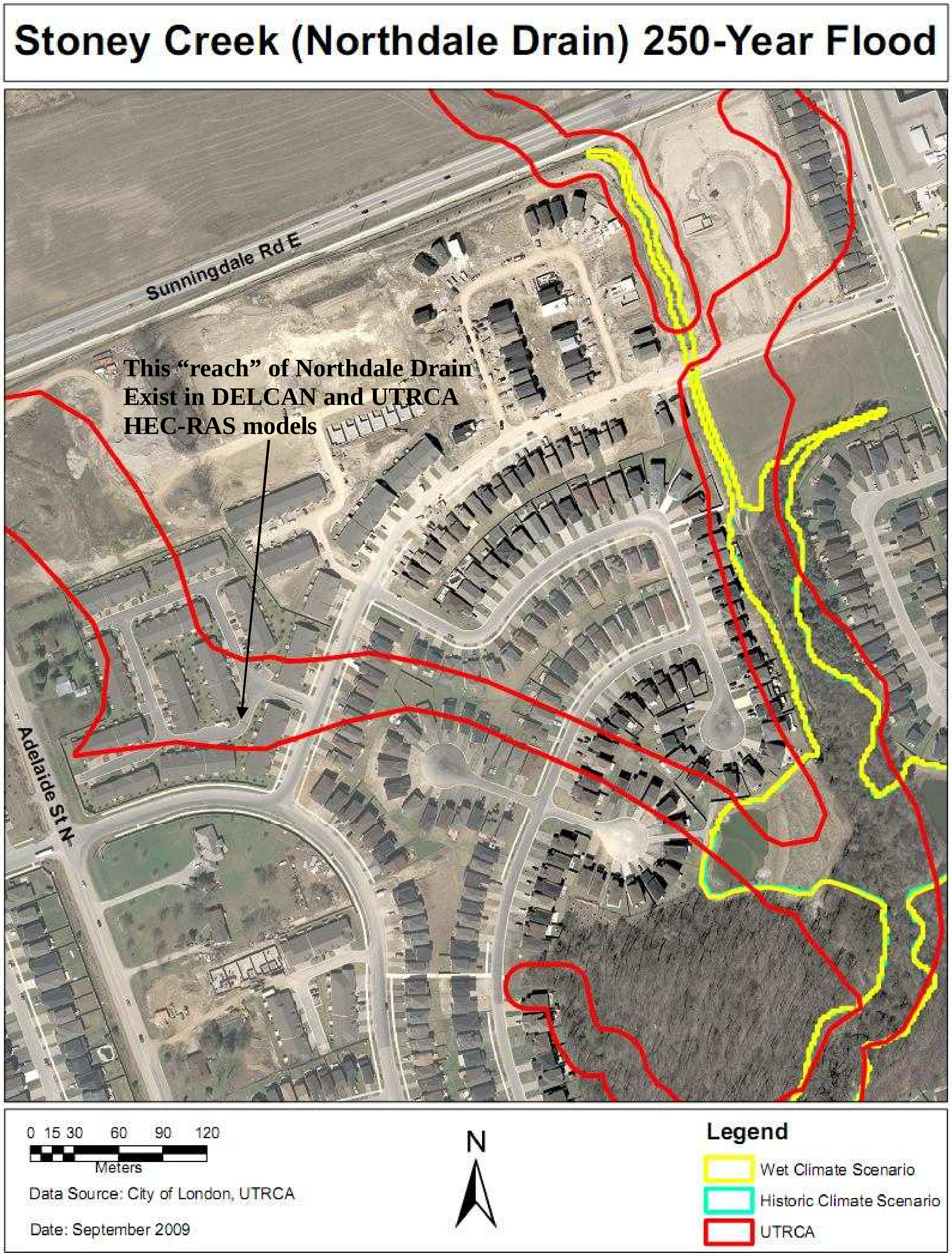


Figure 3.12 Location of special concern at the Stoney Creek (Northdale Drain)

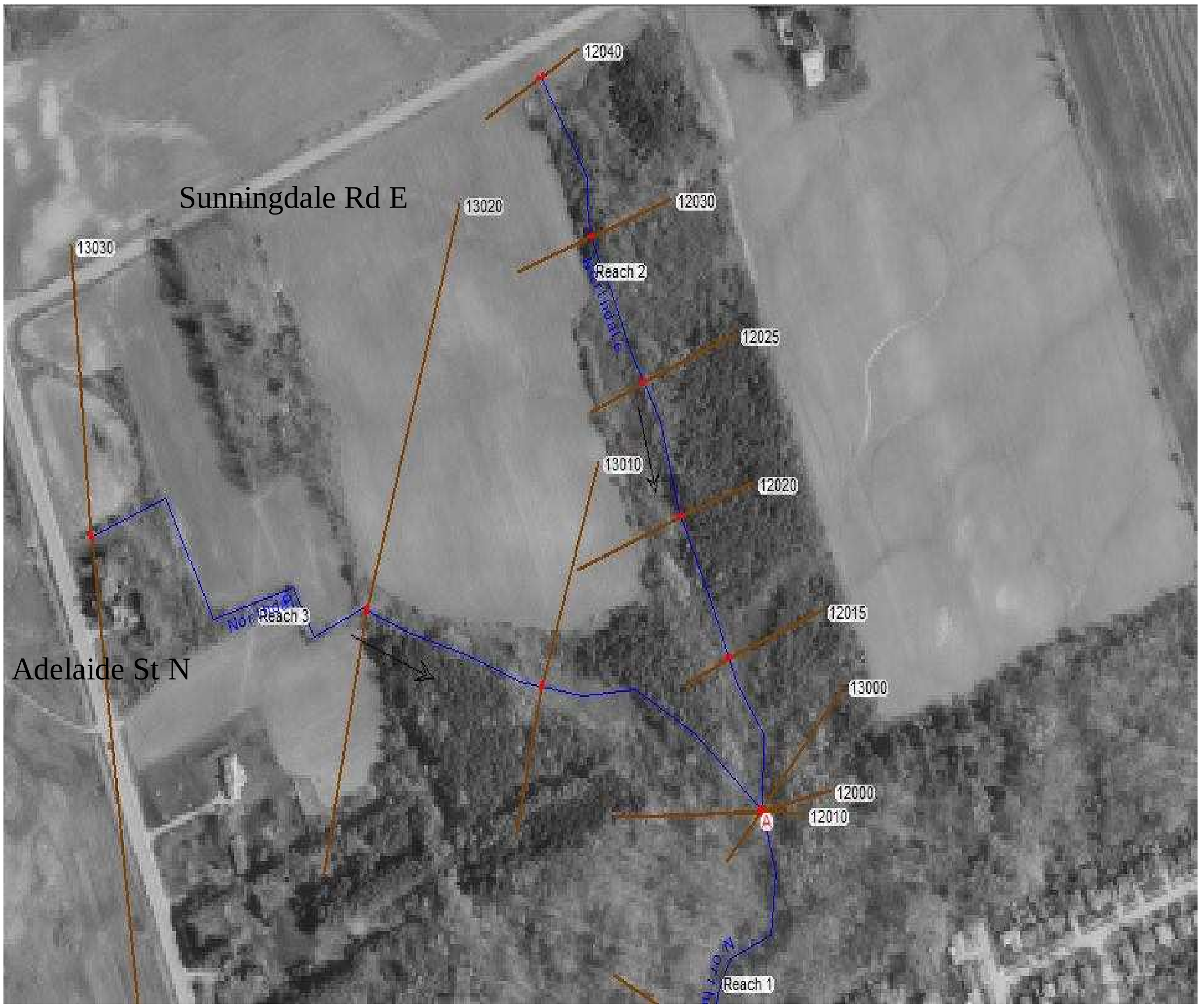


Figure 3.13 Location of special concern at the Stoney Creek (Northdale Drain)
Source: UTRCA HEC-RAS model (Stoney Creek and Tributaries)

HEC-RAS results and Floodplain Mapping results for all rivers and creeks are included on 4 DVDs in Appendix A. The content of each DVD with its accompanying software requirements, data and results locations, and detailed instructions on how to open and rerun each model are presented in Read_Me doc.file.

## 4. CONCLUSIONS AND RECOMMENDATIONS

Completed hydraulic and floodplain mapping analyses under climate change for the territory of the City of London have been done using existing data (as presented in earlier Chapters) and new computer-based approach that combines GIS tools and classical hydraulic modelling. Data quality and modelling approach used have certain limitations that are affecting the accuracy of the modelling results. Following sections present the limitations of the work presented in this report and set of recommendations that are based on the identified limitations.

### 4.1. Limitations

*Cross section data.* One of the biggest limitations of the Hydraulic and Floodplain Mapping activities conducted in the project is the quality of cross sections provided by the UTRCA. The cross sections data is one of the key inputs for the HEC-RAS hydraulic analyses and therefore the quality of cross sections has direct impact on the water surface elevation results and therefore on floodplain mapping results.

Firstly, the available cross sections are not georeferenced due to unavailability of necessary data. This prevents the use of cross section data with any software (like HEC-GeoRAS) for automatic floodplain delineation and risk analyses. Second, the available cross sections were surveyed during 1970's and 1980's. The geomorphology of the channel and surrounding area is significantly changed at many locations due to sedimentation and erosion as well as land use change. Third, the available cross sections were initially surveyed for the use with HEC-2 hydraulic model (previous version of the HEC-RAS). At that time, there was no rule for surveying cross sections from left to right (looking downstream). Therefore, the current cross sections include the mix of data surveyed in different directions. As a result of mixed data at bridge cross sections, entering bridge data in this project was made significantly more complicated. Fourth, many cross sections were not wide enough to cover the entire floodplain.

*TIN data.* Since the TIN is used for creating geometric data during pre-processing and floodplain mapping during post-processing, limitations related to TIN are seriously considered. The inaccuracy of contour lines threatened the overall quality of TIN. The TIN accuracy within the river channel has been improved by recreation TIN within the channel. This is done by using information from the available UTRCA cross sections.

There have been some noticeable limitations in TIN quality at some locations in the floodplain. At those locations, the contour lines were broken, or insufficient for the representation terrain. In most cases this limitation is reflected in the final result through straight line representation of flood lines.

### 4.2 Recommendations

All the limitations identified during the project have direct impact on the quality of final results and therefore the following section provides a set of recommendations that can improve the accuracy of future floodplain analyses.

- New georeferenced cross sections should be surveyed for London's rivers and Creeks. Cross sections should be surveyed from left to right (looking at downstream direction) and they should be wide enough to capture the whole floodplain.
- The new cross sections should be incorporated into existing TINs to ensure higher level of accuracy.
- If possible a LIDAR surveying and TIN creation from LIDAR data is recommended. It has been reported in the literature that LIDAR collected data produce more accurate

results. A very accurate Medway TIN has been generated from LIDAR data. Even with LIDAR data it is still necessary to do surveying within the river in conventional ways in order to incorporate the river channel cross sections results into the LIDAR TIN.

- A new land use shape file with appropriate Manning's *n* values should be created in high resolution for whole area within the City of London. Manning's values could then be automatically assigned to each cross section, particularly in the pre-processing phase of HEC-GeoRAS use.
- If new data is available, repeat the pre-processing to generate more accurate geometric data. Run the HEC-RAS models with more accurate geometric data to get more accurate water surface elevation results. Repeat the floodplain mapping analyses.

**ACKNOWLEDGMENTS**

We thank the City of London team (Ms. Shawna Milanovic, Mr. Billy Haklander, and Mr. Andrew Galloway) for providing data used in this project. We also thank the Upper Thames River Conservation Authority (UTRCA) staff for providing necessary data and useful advice for this project. A special thanks goes to Mr. Mark Helsten, Mr. Mark Shifflett, Mr. Philip Simm and Mr. Imtiaz Shah

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Appendix A: Data on the attached DVD's

**Vulnerability of Infrastructure to Climate Change: The City of London**
**Principal Investigator: Prof. Slobodan P. Simonovic**
**Research Associate: Dragan Sredojevic, M.Sc Student**
**Date: September 2009**
**Hydraulic Modeling and Floodplain Mapping**

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► **Required Software**
- HEC-RAS (version 3.1.3 or higher)
- Arc View ( version 9.3)
- Copy content from DVD discs to the C drive

► **Input Data**
- Geometry input data are generated in Arc Map by using HEC-GeoRAS Extension (From TIN terrain model)
- RAS Gis Import File (.RASImport.sdf) was created and located in Maps folder
- Input data for HEC-RAS models: Newly generated 100 and 250 years flows under 2 climate change scenarios (Historic and Wet Scenarios); Newly generated boundary conditions (Known WS); Bridge data and Manning values (UTRCA HEC-RAS Models); Bridge drawings (City of London) ;

► **HEC-RAS Modeling**
- Create HEC-RAS project and Import RAS GIS Import file
- Complete geometric, hydraulic structures (bridges) and flow data
- Compute HEC-RAS results and review results for hydraulic correctness
- Create the RAS GIS Export File (.RASexport.sdf) with HEC-RAS simulations results-water surface data at same location as HEC-RAS model

► **Output Data**
- Convert .RASexport.sdf to XML and Import it in Arc Map
- Layer Setup for Inundation Mapping Results
- Generate Water surface Tin
- Generate floodplain and depth grid

  Location of Data Base with Floodplain Mapping Results:
- Geo HECRAS Project>Results>Models>Geo HECRAS >Final results

► **DVDs Content**

► **DVD 1**

1. **GeoHECRAS Project-Main Thames**

   **Opening of Arc Map with Geometry**:
- Open Arc Map>Check an existing map>Brows for map >Results >Maps>Main_New.mxd>Activate Main Geometry Layer

  **Opening of Arc Map with Floodplain Mapping Results**:
- Open Arc Map>Check an existing map>Brows for map >Results >Maps>Main_New.mxd>Activate Main Thames in London_ New Flows1 Layer
- **Opening of HEC-RAS Model**:

- Start HEC-RAS>Open Project>Results>Models>HECRAS >Final Results > Open Project: Main Thames_ London_NewFlows1

**2. GeoHECRAS Project-South Thames**

**Opening of Arc Map with Geometry:**

- Open Arc Map>Check an existing map>Brows for map>Results> Maps>South.mxd>Activate South Geometry Layer

**Opening of Arc Map with Floodplain Mapping Results:**

- Open Arc Map>Check an existing map>Brows for map >Results >Maps>South_New.mxd>Activate South Thames_City Boundary_New Flows Layer

**Opening of HEC-RAS Model:**

- Start HEC-RAS>Open Project>Results>Models>HECRAS >Final Results > Open Project: South Thames in London_New Flows

**3. GeoHECRAS Project-Mud Creek**

**Opening of Arc Map with Geometry:**

- Open Arc Map>Check an existing map>Brows for map>Results> Maps>Mud.mxd> Activate Mud_Cr_ Geometry Layer

**Opening of Arc Map with Floodplain Mapping Results:**

- Open Arc Map>Check an existing map>Brows for map >Results >Maps>Mud.mxd> Activate Mud Creek_New Flows Layer

**Opening of HEC-RAS Model:**

- Start HEC-RAS>Open Project>Results>Models>HECRAS >Final Results > Open Project: Mud Creek in London_New Flows

**► DVD 2**

**1. GeoHECRAS Project-North Thames**

**Opening of Arc Map with Geometry**:

- Open Arc Map>Check an existing map>Brows for map >Results >Maps>North_New.mxd>Activate North Geometry Layer

**Opening of Arc Map with Floodplain Mapping Results**:

- Open Arc Map>Check an existing map>Brows for map >Results >Maps>North_New.mxd>Activate North Thames_New Flows Layer
- **Opening of HEC-RAS Model**:
- Start HEC-RAS>Open Project>Results>Models>HECRAS >Final Results > Open Project: North Branch of Thames River_NewFlows

**2. GeoHECRAS Project-Medway Creek New**

**Opening of Arc Map with Geometry:**

- Open Arc Map>Check an existing map>Brows for map>Results > Maps>Medway new.mxd>Activate Medway Geometry Layer

**Opening of Arc Map with Floodplain Mapping Results:**

- Open Arc Map>Check an existing map>Brows for map >Results >Maps>South_New.mxd>Activate Medway_New Flows Layer

**Opening of HEC-RAS Model:**

- Start HEC-RAS>Open Project>Results>Models>HECRAS >Final Results > Open Project: Medway in London_New Flows

► **DVD 3**

**1. GeoHECRAS Project-Pottersburg Creek**

**Opening of Arc Map with Geometry**:

- Open Arc Map>Check an existing map>Brows for map >Results >Maps>Pottersburg.mxd

**Opening of Arc Map with Floodplain Mapping Results**:

- Open Arc Map>Check an existing map>Brows for map >Results >Maps>Pottersburg Creek_NewFlows.mxd
- **Opening of HEC-RAS Model**:
- Start HEC-RAS>Open Project>Results>Models>HECRAS >Final Results > Open Project: Pottersburg Creek_London_New Flows

**2. GeoHECRAS Project-Stoney Creek and Tributaries**

**Opening of Arc Map with Geometry:**

- Open Arc Map>Check an existing map>Brows for map>Results > Maps>Stoney.mxd>Activate Stoney _Geometry Layer

**Opening of Arc Map with Floodplain Mapping Results:**

- Open Arc Map>Check an existing map>Brows for map >Results >Maps>South_New.mxd>Activate Stoney_New Flows Layer

**Opening of HEC-RAS Model:**

- Start HEC-RAS>Open Project>Results>Models>HECRAS >Newest Results > Open Project: Stoney Creek in London_New Flows

► **DVD 4**

**1. GeoHECRAS Project-Dingman Results**

**Opening of Arc Map with Geometry**:

- Open Arc Map>Check an existing map>Brows for map >Results >Maps>Dingman.mxd

**Opening of Arc Map with Floodplain Mapping Results**:

- Open Arc Map>Check an existing map>Brows for map >Results >Maps>WholeDingman_NewFlows.mxd
- **Opening of HEC-RAS Model**:
- Start HEC-RAS>Open Project>Results>Models>HECRAS > Open Project: Dingman Creek New Flows

► **Remarks**

- Since Arc GIS required identical folder structure, some of layer links in the Arc Map may be broken
- To fix it, click on red sign (!) beside the layer and set up data source

Appendix B: Previous Reports in the Series

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