# PROPOSED TOWNSHIP, SITUATED IN DUMFRIES B ON PORTION 1 OF THE FARM NEWINGTON 255 KU, MPUMALANGA PROVINCE

## 1:100 RETURN PERIOD FLOODLINE DETERMINATION REPORT

**April 2021, Rev 0**


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# 1. INTRODUCTION

## 1.1 Study Request

Dalimede Projects (PTY) LTD was appointed by Nkanivo Development Consultants to undertake floodline assessment relating to the township establishment in Dumfries B, on Portion 1 of the farm Newington 255 KU, Mpumalanga Province.

## 1.2 Locality

The proposed township is situated in Dumfries B (Dumphries B), 38km west of Bushbuckridge town. Bushbuckridge is in turn 100km north from Nelspruit the capital of Mpumalanga Province. The area is administered by Bushbuckridge Local Municipality, under the Ehlanzeni District Municipality. GPS coordinates of site are 24°46'47.44"S 31°19'4.18"E.

The locality map is shown on the figures below.


Figure 1 Location of development site

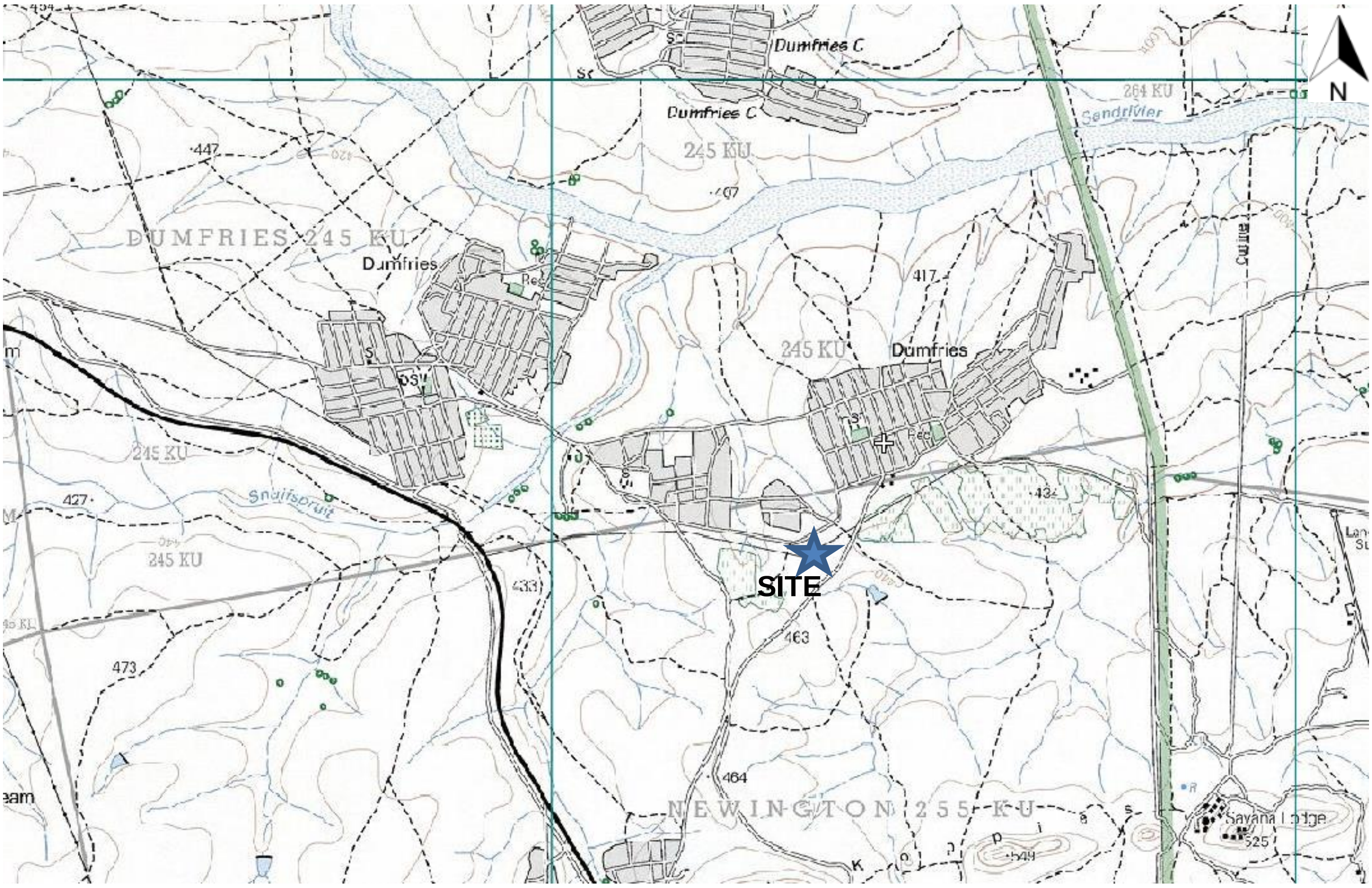


Figure 2 Project site

## 1.3 Background

A flood line analysis must be conducted along the stream / river traversing or in proximity to the site of proposed development. The streams onsite ultimately flow to the Sand river.

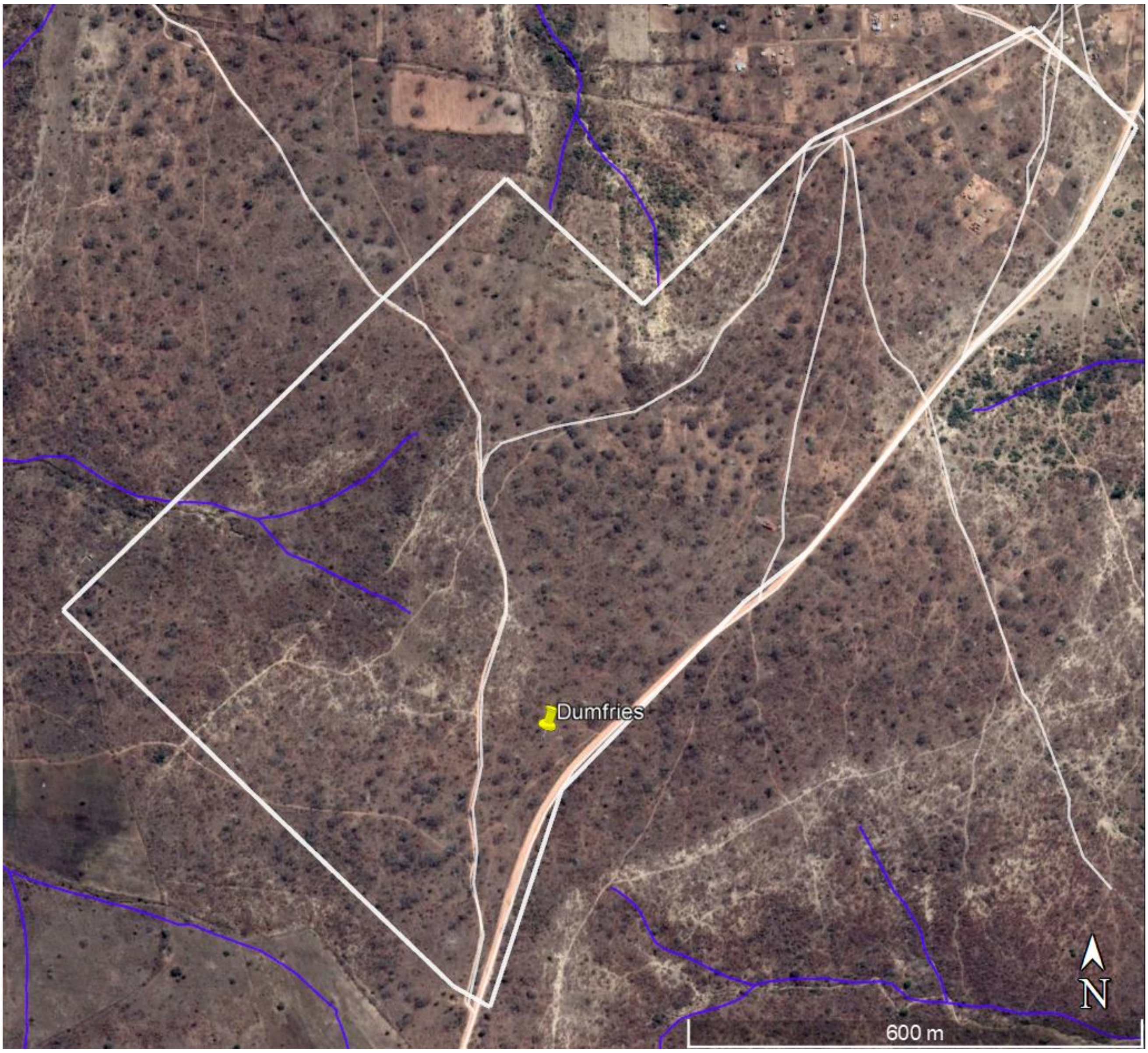

Figure 3 Streams onsite (blue line)

## 2. Methodology

### 2.1 General

The study consists of 2 major components:

- a flood analysis to determine the flood peak flow and,
- a surface water profile analysis to determine the flood line.

The magnitude of a flood is dependent on many factors, such as catchment size, slope and rainfall intensity. There are several different methods for determining floods and in general, different methods arrive at different estimates of the peak flow rate. The accepted approach is therefore to use several methods and then make a judgment call as to which method is the most applicable to the catchment under consideration. For this study, the Rational, Alternative Rational, Standard Design Flood (SDF) methods were used to determine the peak flow rate for the 1:100 return flood.

The reason for choosing these methods was because they are applicable to the catchment and to show the variance in the flood line between the method that produced the highest flood peak and the method that produced the lowest flood peak. Hence a flood line has been produced to take cognisance of the uncertainty related to estimating floods and flood lines.

The area of the catchment in which the adjacent stream is located was determined using GIS software as were additional properties applicable to the catchment, such as the length of the watercourse and the centroid of the catchment. The flood peak flows provide the flow used in the flood line analysis using the *HEC-RAS* software.

Other input required for *HEC-RAS* is channel geometry and roughness parameters. Channel cross-sections were taken at points along the river / stream course, within the area that contour lines were provided. The stream reaches that were analysed are in a natural state. See the figure below for the streams in catchment area.

### 2.2 Flood Modelling Methodology

Flood peaks for the catchments selected for flood modelling were estimated by the following methods using the Utility Programs for Drainage (UPD) software with the methods detailed in the SANRAL Drainage Manual, 2013:

- Rational Method (RM).
- Alternative Rational Method (ARM).
- Standard Design Flood (SDF).

## 2.3 Rational Method

This method is based on the conservation of mass and is applicable for catchment areas below 15 $km^2$. Aerial and time distributions of rainfall in this method are assumed to be uniform throughout the catchment. Flood peaks and empirical hydrographs can be determined by this method.

Where: The peak flow is obtained from the following relationship:

$$Q = \frac{CIA}{3.6}$$

Where: Q = peak flow ($m^3$ /s)
C = runoff coefficient (dimensionless)
I = average rainfall intensity over the catchment (mm/hour)
A = effective runoff area of the catchment ($km^2$)
3.6 = conversion factor

## 2.4 Alternative Rational Method

This method is based on the rational method with the point precipitation being adjusted using the Design Rainfall Estimation Methodology developed by Smithers and Schulze (2003) to consider local South African conditions.
Design rainfall values for the study area were extracted from the database of six closest to site South African Weather Service stations, using the Design Rainfall Utility developed by Smithers and Schulze (2000).

Table 1 Design Rainfall Values for the site

| **Duration** | | **Return Period (Years) Design Rainfall Depth (mm)** | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | **1:2** | **1:5** | **1:10** | **1:20** | **1:50** | **1:100** | **1:200** |
| **5** | m | 8.2 | 11.8 | 14.5 | 17.4 | 21.6 | 25 | 28.8 |
| **10** | m | 13.3 | 19.2 | 23.6 | 28.3 | 35 | 40.6 | 46.7 |
| **15** | m | 17.6 | 25.5 | 31.3 | 37.5 | 46.5 | 53.9 | 62 |
| **30** | m | 24.6 | 35.5 | 43.7 | 52.3 | 64.8 | 75.2 | 86.5 |
| **45** | m | 29.8 | 43.1 | 53.1 | 63.6 | 78.7 | 91.3 | 105.1 |
| **1** | h | 34.3 | 49.5 | 60.9 | 73 | 90.4 | 104.8 | 120.7 |
| **1.5** | h | 41.6 | 60.1 | 74 | 88.6 | 109.8 | 127.4 | 146.6 |
| **2** | h | 47.8 | 69 | 84.9 | 101.8 | 126 | 146.2 | 168.3 |
| **4** | h | 55.9 | 80.8 | 99.4 | 119.1 | 147.5 | 171.2 | 197 |
| **6** | h | 61.3 | 88.6 | 109.1 | 130.7 | 161.8 | 187.7 | 216.1 |
| **8** | h | 65.5 | 94.6 | 116.4 | 139.5 | 172.7 | 200.4 | 230.7 |
| **10** | h | 68.9 | 99.6 | 122.5 | 146.8 | 181.7 | 210.9 | 242.7 |
| **12** | h | 71.8 | 103.8 | 127.7 | 153 | 189.4 | 219.8 | 253 |
| **16** | h | 76.7 | 110.8 | 136.3 | 163.3 | 202.3 | 234.7 | 270.1 |
| **20** | h | 80.7 | 116.6 | 143.4 | 171.8 | 212.8 | 246.9 | 284.2 |
| **24** | h | 84.1 | 121.5 | 149.5 | 179.1 | 221.8 | 257.4 | 296.2 |
| **1** | h | 69.8 | 100.8 | 124 | 148.6 | 184 | 213.5 | 245.7 |
| **2** | h | 87.6 | 126.6 | 155.8 | 186.6 | 231.1 | 268.1 | 308.6 |
| **3** | h | 100.1 | 144.6 | 178 | 213.2 | 264 | 306.3 | 352.5 |
| **4** | h | 109.6 | 158.4 | 194.8 | 233.4 | 289.1 | 335.4 | 386 |
| **5** | h | 117.6 | 169.9 | 209 | 250.4 | 310.1 | 359.8 | 414.1 |
| **6** | h | 124.5 | 179.9 | 221.4 | 265.2 | 328.5 | 381.1 | 438.6 |
| **7** | h | 130.7 | 188.9 | 232.4 | 278.4 | 344.8 | 400.1 | 460.5 |

## 2.5 Standard Design Flood (SDF) Method

This method is an empirically calibrated version of the Rational method. A major component in the development of the SDF method was the identification of regions with homogeneous flood producing characteristics. The geographic requirement was that the boundaries had to follow catchment watersheds and related to the Department of Water and Sanitation (DWS) drainage region numbering system, formally the Department of Water Affairs and Forestry (DWAF).

The regions are called ‘basins’ to avoid confusion with DWAF’s drainage regions and the South African Weather Services’ (SAWS) rainfall districts. Each basin must contain at least one flow gauging station from the DWAF published TR102 Catalogue of hydrological catchment parameters. The only information required for its application is the area of the catchment, the length and slope of the main stream / river, and the drainage basin in which it is located.

# 3. ANALYSIS

## 3.1 Flood Analysis

To make the analysis possible, properties of the catchments that influence the runoff relating to the 1:100 return flood event need to be determined. These properties are described in the following sections.

## 3.2 Catchment Properties

The catchment topography is mainly composed of flat areas (over 95% of catchment) with a small portion of hilly areas (under 5% of catchment). The topographic elevation in the catchment ranges from 415m to 460m above sea level. The landscape soils are mostly characterised by high to moderate infiltration rates. The permeability being rapid to slightly restricted (Schulze, 2010). The soils are classified to have a moderately low runoff potential.

The Mean Annual Precipitation (MAP) of the catchment was determined from weather stations gridded from in the vicinity of the site. The MAP for the catchment is estimated to be 805mm.

Table 2 Rainfall data

| **Station Name** | **SAWS** | **Distance** | **Record** | **Latitude** | | **Longitude** | | **MAP** |
|---|---|---|---|---|---|---|---|---|
| | Number | (km) | (Years) | (°) | (') | (°) | (') | (mm) |
| Allandale | 0595463_W | 9 | 36 | 24 | 43 | 31 | 15 | 729 |
| Cunningmoore | 0595443_W | 12.1 | 32 | 24 | 53 | 31 | 15 | 727 |
| Newington | 0595711_W | 13 | 33 | 24 | 51 | 31 | 24 | 643 |
| Tsakane | 0595579_W | 14.8 | 32 | 24 | 39 | 31 | 20 | 638 |
| Cunning Moor | 0595353_W | 15.3 | 28 | 24 | 53 | 31 | 12 | 806 |
| F.C. Erasmus RSV | 0595202_W | 21.7 | 38 | 24 | 52 | 31 | 7 | 1019 |

The climate is characterised by hot and rainy summers for a long period as well as cool and dry winters over a short period.

The climate is warm and temperate. In winter, there is much less rainfall than in summer.

There are no river gauging stations on the catchment.

## 3.3 Catchment Delineation

The catchment area is within the Inkomati Water Management Area.

The catchments in the table below were delineated to cover the streams within or in proximity of the project boundary and were utilised to determine the flood peaks for 1:100 return extreme events. The catchment information is listed in the table below.

Table 3 Catchment area

| Catchment Site | Catchment area ($km^2$) | Remark | Quaternary catchment |
|---|---|---|---|
| C1 | 0.144 | Catchment | X32G |
| C2 | 0.098 | Catchment | X32G |
| C3 | 0.143 | Catchment | X32G |
| C4 | 0.077 | Catchment | X32G |

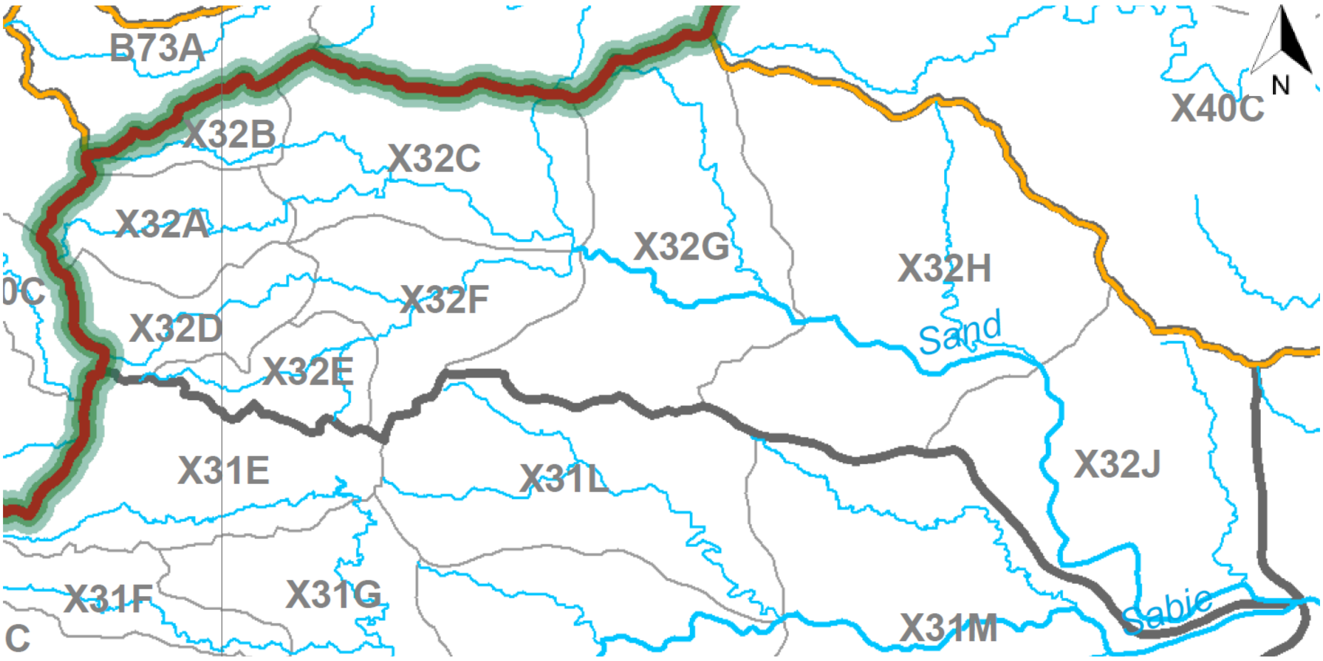

Figure 4 Quaternary catchments

The delineated catchments are shown in the figures below.

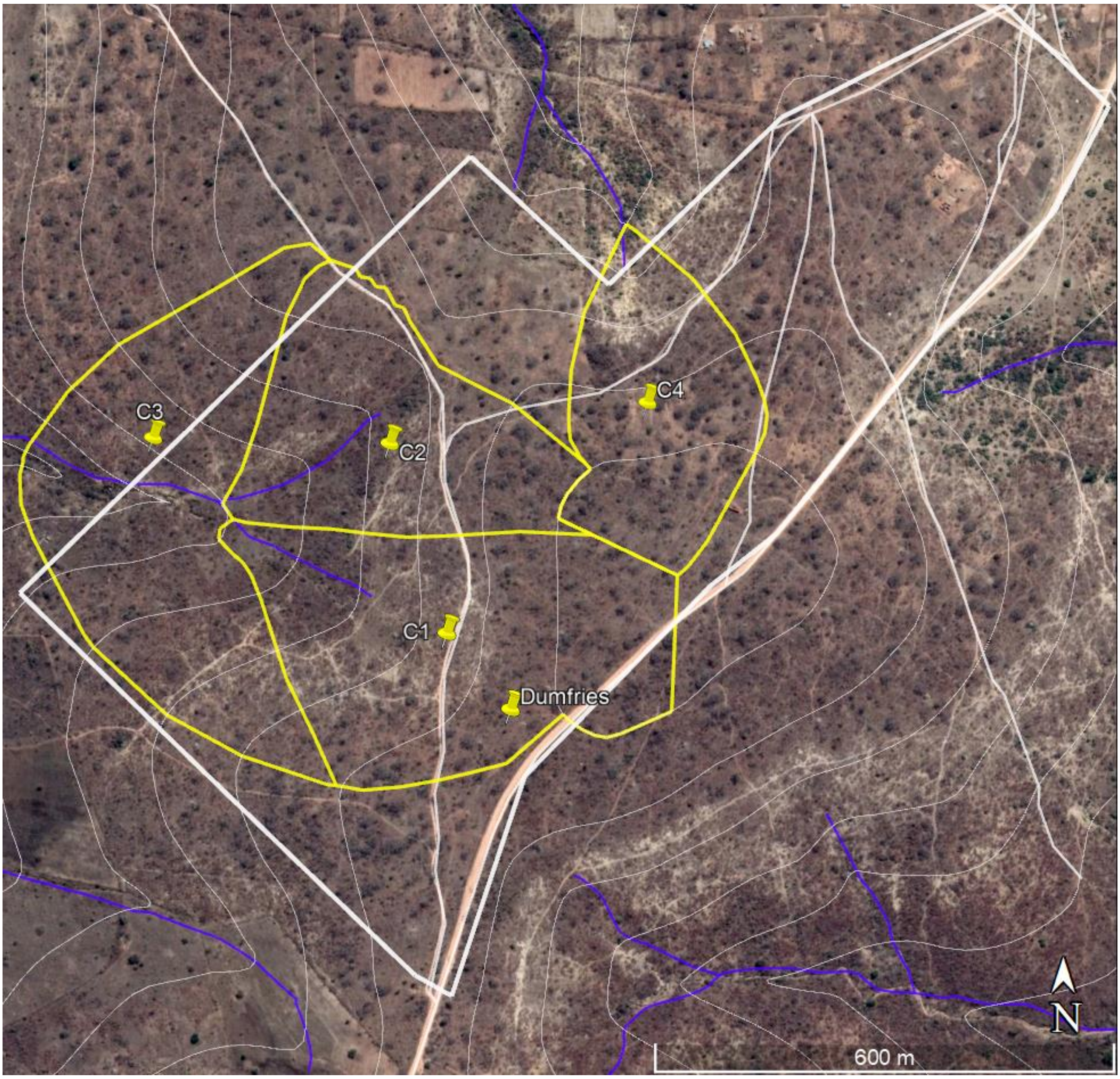

Figure 5 Catchment delineation (yellow line boundary)

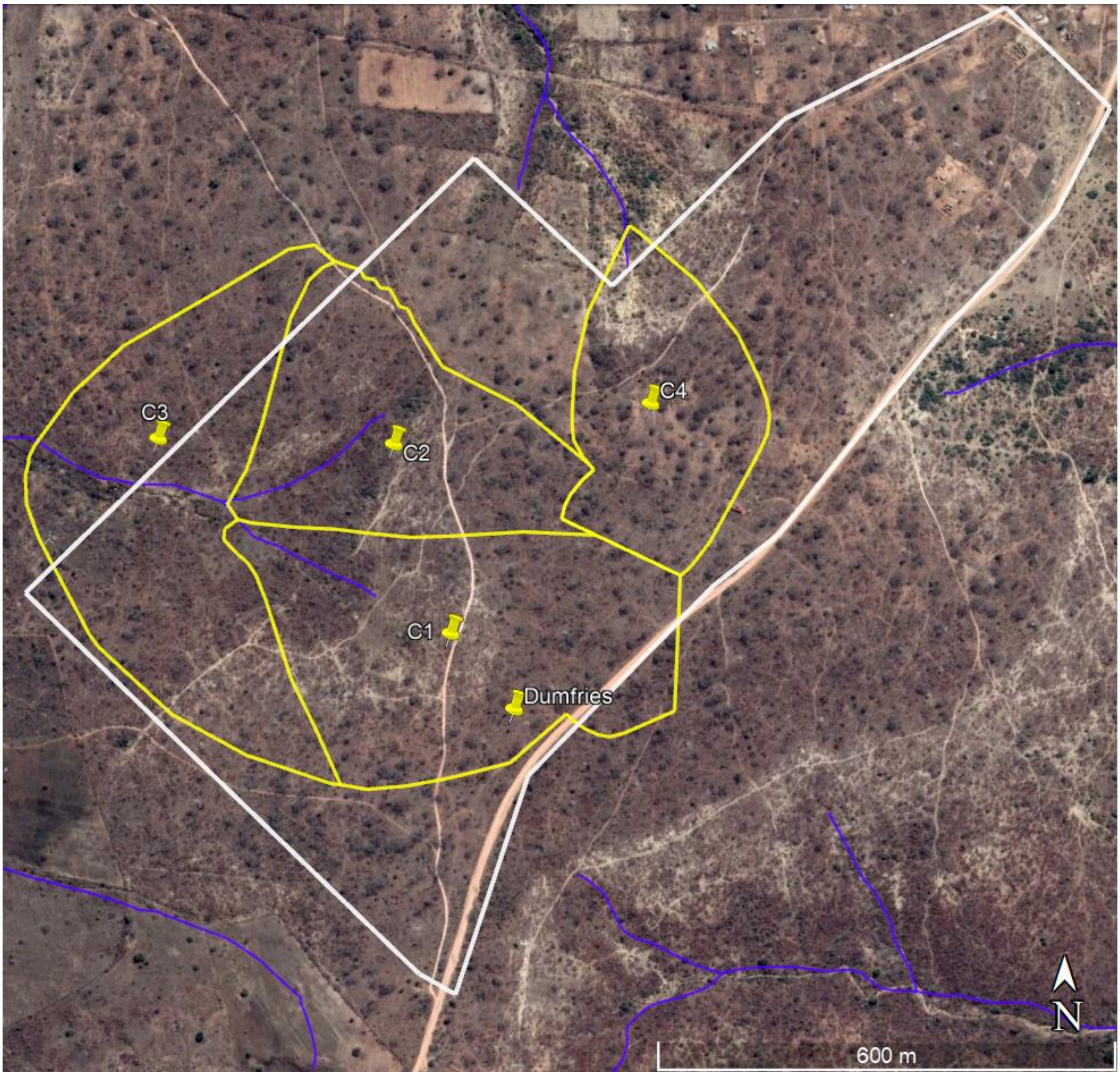

Figure 6 Catchment

## 3.4 Catchment Characteristics

The catchment characteristics are shown the following tables below.

Table 4 Catchment Characteristic

| Characteristic | Rural | Urban | Lakes | Total |
|---|---|---|---|---|
| | Distribution | Distribution | Distribution | |
| **Catchment** | **%** | **%** | **%** | **(%)** |
| C1 | 100% | 0% | 0% | 100% |
| C2 | 100% | 0% | 0% | 100% |
| C3 | 100% | 0% | 0% | 100% |
| C4 | 100% | 0% | 0% | 100% |

Table 5 Rural area - Surface slope

| Rural area - Surface slope | Lakes and pans (<3%) | Flat area (3 to 10%) | Hilly (10 to 30%) | Steep areas (>30%) | Total |
|---|---|---|---|---|---|
| | Distribution | Distribution | Distribution | Distribution | |
| **Catchment** | **(%)** | **(%)** | **(%)** | **(%)** | **(%)** |
| C1 | 30% | 70% | 0% | 0% | 100% |
| C2 | 10% | 89% | 1% | 0% | 100% |
| C3 | 4% | 91% | 5% | 0% | 100% |
| C4 | 32% | 68% | 0% | 0% | 100% |

Table 6 Rural area – Permeability

| Rural area - Permeability | Very permeable | Permeable | Semi-permeable | Impermeable | Total |
|---|---|---|---|---|---|
| | Distribution | Distribution | Distribution | Distribution | |
| **Catchment** | **(%)** | **(%)** | **(%)** | **(%)** | **(%)** |
| C1 | 30% | 63% | 5% | 2% | 100% |
| C2 | 30% | 63% | 5% | 2% | 100% |
| C3 | 30% | 63% | 5% | 2% | 100% |
| C4 | 30% | 63% | 5% | 2% | 100% |

Table 7 Rural area - Vegetation

| Rural area - Vegetation | Thick bush & forests | Light bush & cultivated land | Grasslands | Bare | Total |
|---|---|---|---|---|---|
| | Distribution | Distribution | Distribution | Distribution | |
| **Catchment** | | | | | **(%)** |
| C1 | 70% | 20% | 5% | 5% | 100% |
| C2 | 65% | 27% | 4% | 4% | 100% |
| C3 | 75% | 19% | 3% | 3% | 100% |
| C4 | 63% | 22% | 7% | 8% | 100% |

Table 8 Run-off factors

| Catchment | Run-off factor | | | |
|---|---|---|---|---|
| | **Rural ($C_R$)** | **Urban ($C_U$)** | **Lakes ($C_L$)** | **Combined (C )** |
| C1 | 0.215 | 0 | 0 | **0.215** |
| C2 | 0.227 | 0 | 0 | **0.227** |
| C3 | 0.223 | 0 | 0 | **0.223** |
| C4 | 0.226 | 0 | 0 | **0.226** |

Table 9 Hydrological input data

| Catchment | Catchment Area ($km^2$) | Longest water course (km) | Height difference 1085 method (m) | Days thunder was heard (No.) | Area Dolomite (%) | Mean Annual Precipitation (mm) | SDF Basin no. (No.) |
|---|---|---|---|---|---|---|---|
| C1 | 0.144 | 0.601 | 23.7 | 40 | 0 | 805 | 29 |
| C2 | 0.098 | 0.490 | 19.8 | 40 | 0 | 805 | 29 |
| C3 | 0.143 | 0.611 | 24.4 | 40 | 0 | 805 | 29 |
| C4 | 0.077 | 0.539 | 16.7 | 40 | 0 | 805 | 29 |

Table 10 Catchment characteristics

| Catchment Site | Catchment area ($km^2$) | Longest water course, L (km) | Height difference along 10-85 slope (m) | Average slope $S_{av}$ (m/m) | Time of concentration, Tc (hours) | % Slope | MAP (mm) | Run-off factor C |
|---|---|---|---|---|---|---|---|---|
| C1 | 0.144 | 0.601 | 23.7 | 0.05260161 | 0.139198778 | 5.26% | 805 | 0.215 |
| C2 | 0.098 | 0.490 | 19.8 | 0.05390257 | 0.117949325 | 5.39% | 805 | 0.227 |
| C3 | 0.143 | 0.611 | 24.4 | 0.05319516 | 0.140512835 | 5.32% | 805 | 0.223 |
| C4 | 0.077 | 0.539 | 16.7 | 0.04130369 | 0.140534196 | 4.13% | 805 | 0.226 |

## 3.5 Flood magnitudes

The flood magnitudes from the 1:2 return up to 1:100 return floods are presented in the Tables below.

Table 11 Estimated stormwater flow ($m^3/s$)

| | Rational method | | | | | | Alternative rational method | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Return** | **1:2** | **1:5** | **1:10** | **1:20** | **1:50** | **1:100** | **1:2** | **1:5** | **1:10** | **1:20** | **1:50** | **1:100** |
| **Catchment** | | | | | | | | | | | | |
| C1 | 0.69 | 1.00 | 1.34 | 1.75 | 2.40 | 3.11 | 0.74 | 1.33 | 1.85 | 2.42 | 3.20 | 3.88 |
| C2 | 0.52 | 0.75 | 1.01 | 1.32 | 1.81 | 2.35 | 0.57 | 1.02 | 1.41 | 1.85 | 2.45 | 2.97 |
| C3 | 0.71 | 1.02 | 1.38 | 1.80 | 2.47 | 3.20 | 0.76 | 1.37 | 1.90 | 2.48 | 3.28 | 3.98 |
| C4 | 0.39 | 0.56 | 0.75 | 0.98 | 1.35 | 1.75 | 0.41 | 0.75 | 1.04 | 1.35 | 1.79 | 2.17 |

Table 12 Estimated stormwater flow ($m^3/s$)

| | Standard design flood method | | | | | |
|---|---|---|---|---|---|---|
| **Return** | **1:2** | **1:5** | **1:10** | **1:20** | **1:50** | **1:100** |
| **Catchment** | | | | | | |
| C1 | 0.44 | 1.38 | 2.23 | 3.19 | 4.61 | 5.80 |
| C2 | 0.32 | 1.00 | 1.62 | 2.32 | 3.35 | 4.21 |
| C3 | 0.44 | 1.36 | 2.21 | 3.16 | 4.57 | 5.75 |
| C4 | 0.24 | 0.73 | 1.19 | 1.70 | 2.46 | 3.09 |

The applications and limitation of flood calculation methods are shown in the table below.

Table 13 Applications and limitation of flood calculation methods

| Method | Recommended maximum area ($km^2$) | Return period of floods that could be determined |
|---|---|---|
| Statistical method | No limitation (larger areas) | 1:2 to 1:200 |
| Rational method | Usually less than 15$km^2$ | 1:2 to 1:200 |
| Unit Hydrograph method | 15$km^2$ to 5,000$km^2$ | 1:2 to 1:100 |
| Standard Design Flood method | No limitation | 1:2 to 1:200 |
| SCS-SA method | Less than 30$km^2$ | 1:2 to 1:100 |
| Empirical methods | No limitation (larger areas) | 1:10 to 1:100 |

### 3.6 Flood magnitudes for the 1:100-year floods

The Rational, Alternative Rational (AR), and Standard Design Flood (SDF) methods were used to select the flood peak.

The results from the various methods were similar, hence the method with the highest magnitude of the peak flow was used for the 1:100 return flood for a sub-catchment.

The selected maximum peak flows are shown in the table below.

Table 14 Catchment generated estimated 1:100 peak flow

| | | | |
|---|---|---|---|
| **C1** | Catchment, estimated 100year peak flow = | 5.80 | $m^3/s$ |
| **C2** | Catchment, estimated 100year peak flow = | 4.21 | $m^3/s$ |
| **C3** | Catchment, estimated 100year peak flow = | 5.75 | $m^3/s$ |
| **C4** | Catchment, estimated 100year peak flow = | 3.09 | $m^3/s$ |

The estimated 1:100 stream flow is listed in the table below.

Table 15 Stream Peak flows estimates

| Stream - Reach | Flow ($m^3/s$) |
|---|---|
| Stream C1 | 5.80 |
| Stream C2 | 4.21 |
| Stream C3 | 15.76 |
| Stream C4 | 3.09 |

## 3.7 Flood line Modelling

The HEC-RAS model was used to determine the flood line during the event of a flood for any return period, and in this case the 1:100-year floods were modelled.

## 3.8 Cross section profile

Cross sectional data was generated using GIS and CAD software, as well as the 5m contour lines that were obtained from the National Geo-Spatial Information (NGI). Sections shown in Annexure 5 were used to approximate the geometry for the river / stream.

## 3.9 Flood profiles

Annexure 4 shows the longitudinal profile for the 1:100 return peak flow.

## 4. CONCLUSION

The determination of the 1:100 return period floodlines was undertaken for the site of the proposed development. The results of this determination provide an indication as to the extent of the areas that will be inundated by the 1:100 return design flood.

It is recommended that a buffer zone of 20m should be provided between the 1:100 flood line and any proposed development.

The lateral extent of the 1:100 return flood line is shown in Annexure 2. These flood lines have also been provided as Gauss Conform WGS84 LO31 coordinated CAD dwg softcopy files.

## 5. REFERENCES


- Smithers J.C. and Schulze R.E. (2002): Drainage rainfall and flood estimation in South Africa, WRC project KS/1060.

- The South African National Roads Agency Limited (2013): Drainage manual, 6th Edition.

## ANNEXURE 1: FLOODLINE CERTIFICATE

Reg. No: 2014 / 233383 / 07

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# FLOOD LINE CERTIFICATE

Dalimede Projects (PTY) LTD was appointed by Nkanivo Development Consultants to undertake floodline assessment relating to the township establishment in Dumfries B, on Portion 1 of the farm Newington 255 KU, Mpumalanga Province.

This will entail to delineate the 1:100 return flood line.

**Site:** *Portion 1 of the farm Newington 255 KU, Mpumalanga Province*

**Township Name:** *Dumfries B*

**Co-ordinates:** *24°46'47.44"S 31°19'4.18"E*

**Municipality:** *Bushbuckridge Local Municipality, in Ehlanzeni District*

In terms of section 114 of the National Water Act, Act 36 of 1998 the above-mentioned property is partially affected by flood water within the 1:100 period from the stream / river as indicated in the floodline report. Development must be done outside of the floodline.

It is recommended that a buffer zone of 20m should be provided between the 1:100 flood line and any proposed development.

Thus, done and signed in ……………………….………… on this day………………..………………………..

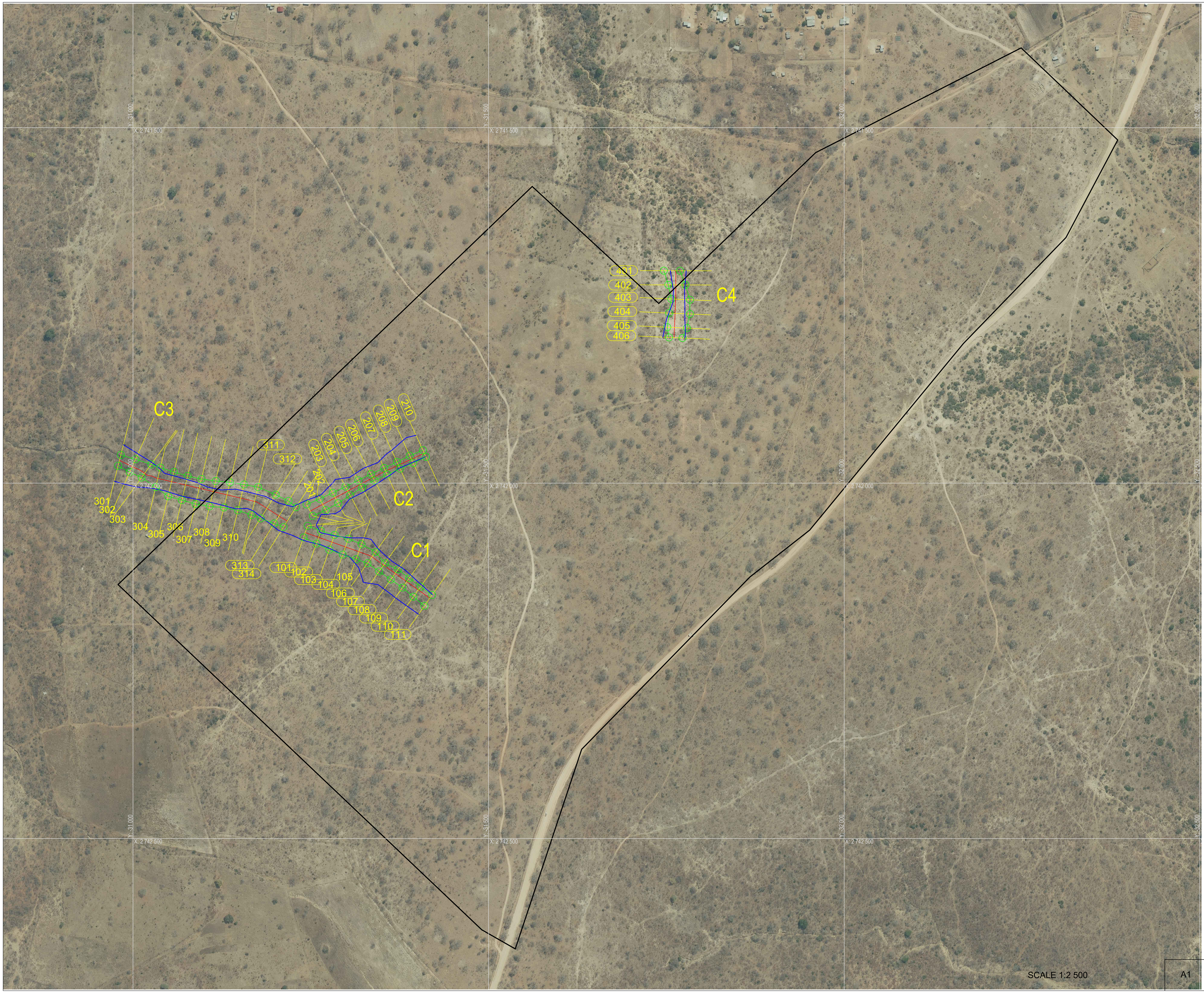
Signature: …………………….................

Engineer: Litmos Mthunzi

Pr Tech Eng

Pr no.: …………………………

## ANNEXURE 2: FLOODLINE DELINEATION




A1

## NOTES

## KEY

FLOODLINE

CROSS SECTION

STREAM / RIVER

## REVISIONS

| REV | DATE | SIGN | DESCRIPTION |
|---|---|---|---|
| 0 | .../.../... | .... | ............. |

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## DRAWING STATUS

FOR INFORMATION

## PROJECT TITLE

Township development in Dumfries B, on Portion 1 of the farm Newington 255 KU, Mpumalanga Province

## PROJECT LOCATION

The proposed township is situated in Dumfries B (Dumphries B), 38km west of Bushbuckridge town. Bushbuckridge is 100km north from Nelspruit the capital of Mpumalanga Province. GPS coordinates of site are 24°46'47.44"S 31°19'4.18"E.

## DRAWING DESCRIPTION

FLOODLINE DELINEATION 1:100 RETURN PERIOD

| SCALE | DATE | DESIGNED | DRAWN | CHECKED |
|---|---|---|---|---|
| As Shown | April 2021 | LM | HM | CM |

| DRAWING No. | REVISION |
|---|---|
| DUMPHRIES/FL/01 | A |

## ANNEXURE 3: HEC-RAS PROGRAMME MODELLING RESULTS

HEC-RAS Plan: Current mode River: C Reach: 1 Profile: 1:100yr

| Reach | River Sta | Profile | Q Total | Min Ch El | W.S. Elev | Crit W.S. | E.G. Elev | E.G. Slope | Vel Chnl | Flow Area | Top Width | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (m3/s) | (m) | (m) | (m) | (m) | (m/m) | (m/s) | (m2) | (m) | |
| 1 | 111 | 1:100yr | 5.80 | 440.20 | 440.40 | 440.40 | 440.48 | 0.023786 | 1.38 | 5.20 | 35.27 | 1.05 |
| 1 | 110 | 1:100yr | 5.80 | 439.14 | 439.33 | 439.33 | 439.41 | 0.025921 | 1.41 | 5.32 | 37.26 | 1.09 |
| 1 | 109 | 1:100yr | 5.80 | 438.10 | 438.29 | 438.29 | 438.37 | 0.027547 | 1.44 | 5.33 | 37.24 | 1.12 |
| 1 | 108 | 1:100yr | 5.80 | 437.06 | 437.25 | 437.25 | 437.33 | 0.026540 | 1.40 | 5.32 | 37.60 | 1.10 |
| 1 | 107 | 1:100yr | 5.80 | 436.02 | 436.22 | 436.22 | 436.29 | 0.022684 | 1.43 | 5.73 | 40.53 | 1.04 |
| 1 | 106 | 1:100yr | 5.80 | 434.98 | 435.15 | 435.15 | 435.22 | 0.024829 | 1.31 | 6.09 | 50.22 | 1.06 |
| 1 | 105 | 1:100yr | 5.80 | 433.96 | 434.15 | 434.15 | 434.22 | 0.032817 | 1.32 | 5.56 | 44.86 | 1.17 |
| 1 | 104 | 1:100yr | 5.80 | 432.98 | 433.17 | 433.17 | 433.24 | 0.031783 | 1.32 | 5.22 | 38.84 | 1.16 |
| 1 | 103 | 1:100yr | 5.80 | 432.01 | 432.19 | 432.19 | 432.27 | 0.030118 | 1.34 | 5.16 | 35.62 | 1.14 |
| 1 | 102 | 1:100yr | 5.80 | 431.02 | 431.22 | 431.22 | 431.30 | 0.029833 | 1.41 | 4.91 | 31.73 | 1.15 |
| 1 | 101 | 1:100yr | 5.80 | 430.03 | 430.28 | 430.28 | 430.37 | 0.018187 | 1.40 | 4.84 | 29.06 | 0.96 |

HEC-RAS  Plan: Current mode   River: C   Reach: 2    Profile: 1:100yr

| Reach | River Sta | Profile | Q Total | Min Ch El | W.S. Elev | Crit W.S. | E.G. Elev | E.G. Slope | Vel Chnl | Flow Area | Top Width | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (m3/s) | (m) | (m) | (m) | (m) | (m/m) | (m/s) | (m2) | (m) | |
| 2 | 210 | 1:100yr | 4.21 | 438.57 | 438.38 | 438.36 | 438.44 | 0.048480 | | 3.81 | 23.06 | 0.00 |
| 2 | 209 | 1:100yr | 4.21 | 437.43 | 437.41 | 437.39 | 437.47 | 0.048152 | | 3.69 | 21.16 | 0.00 |
| 2 | 208 | 1:100yr | 4.21 | 436.26 | 436.39 | 436.39 | 436.46 | 0.053482 | 1.32 | 3.64 | 27.54 | 1.41 |
| 2 | 207 | 1:100yr | 4.21 | 435.08 | 435.32 | 435.32 | 435.41 | 0.023831 | 1.47 | 3.90 | 25.52 | 1.07 |
| 2 | 206 | 1:100yr | 4.21 | 434.22 | 434.45 | 434.45 | 434.53 | 0.021302 | 1.44 | 4.12 | 28.22 | 1.02 |
| 2 | 205 | 1:100yr | 4.21 | 433.38 | 433.63 | 433.63 | 433.70 | 0.016367 | 1.32 | 4.43 | 31.92 | 0.91 |
| 2 | 204 | 1:100yr | 4.21 | 432.55 | 432.79 | 432.79 | 432.86 | 0.017605 | 1.29 | 4.24 | 31.30 | 0.92 |
| 2 | 203 | 1:100yr | 4.21 | 431.71 | 431.93 | 431.93 | 432.00 | 0.023737 | 1.29 | 4.05 | 29.63 | 1.03 |
| 2 | 202 | 1:100yr | 4.21 | 430.87 | 431.07 | 431.07 | 431.15 | 0.028667 | 1.31 | 3.84 | 27.06 | 1.11 |
| 2 | 201 | 1:100yr | 4.21 | 430.01 | 430.23 | 430.23 | 430.31 | 0.022375 | 1.30 | 3.68 | 24.42 | 1.01 |

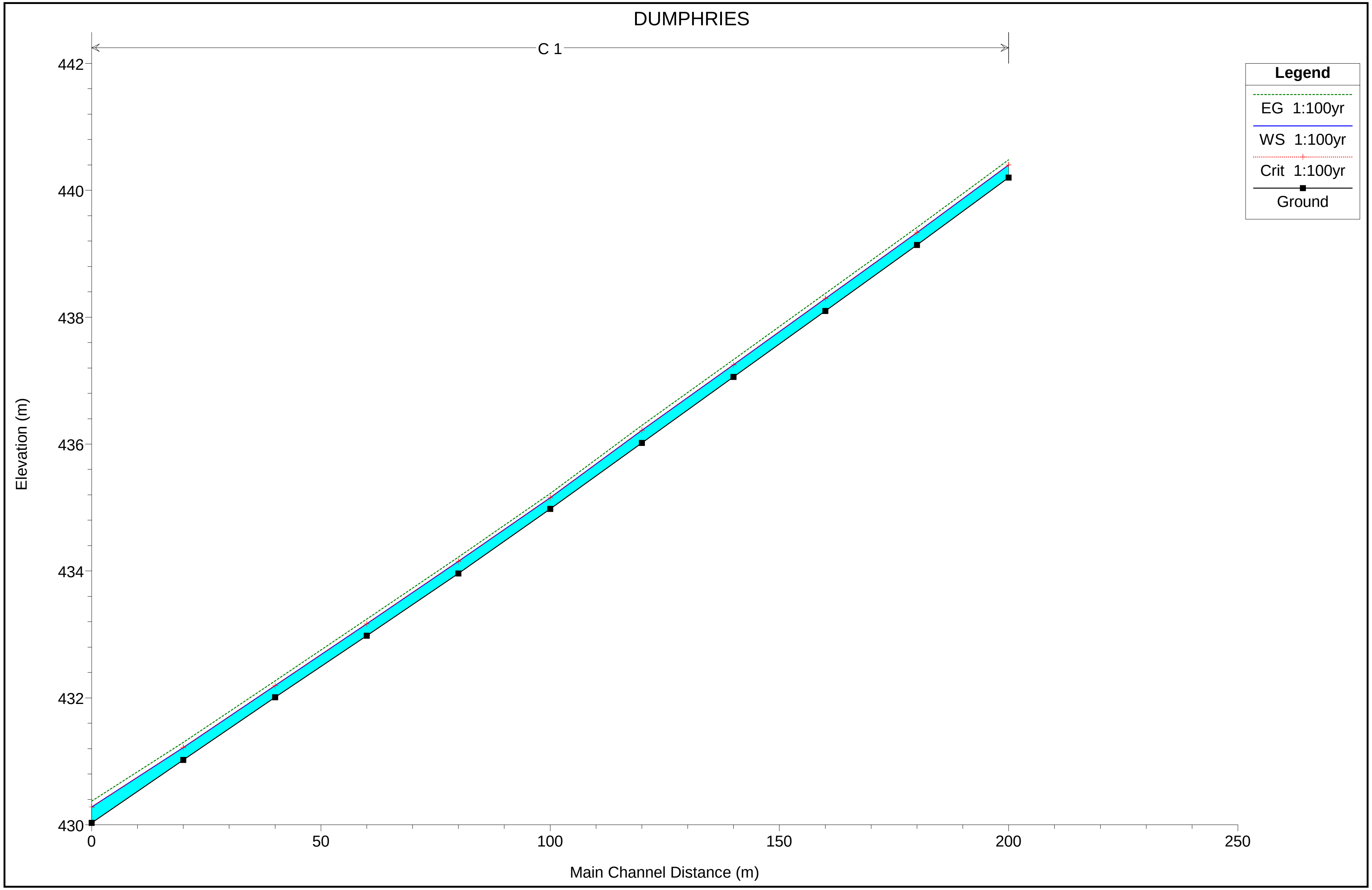
HEC-RAS  Plan: Current mode   River: C   Reach: 3    Profile: 1:100yr

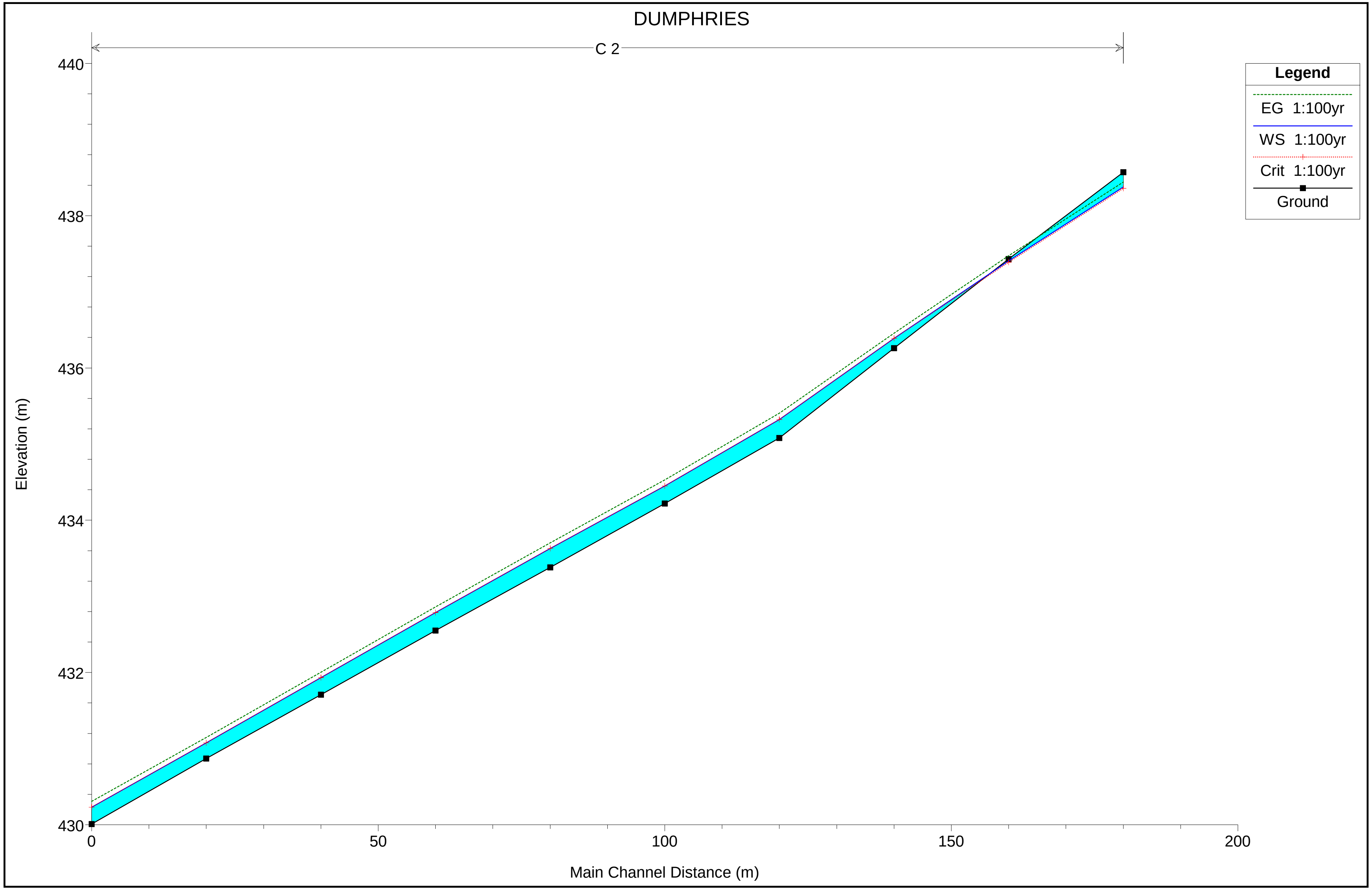
| Reach | River Sta | Profile | Q Total | Min Ch El | W.S. Elev | Crit W.S. | E.G. Elev | E.G. Slope | Vel Chnl | Flow Area | Top Width | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (m3/s) | (m) | (m) | (m) | (m) | (m/m) | (m/s) | (m2) | (m) | |
| 3 | 314 | 1:100yr | 15.76 | 428.17 | 428.61 | 428.61 | 428.75 | 0.017617 | 1.70 | 9.70 | 34.94 | 0.99 |
| 3 | 313 | 1:100yr | 15.76 | 427.30 | 427.77 | 427.77 | 427.92 | 0.018137 | 1.75 | 9.01 | 29.40 | 1.01 |
| 3 | 312 | 1:100yr | 15.76 | 426.06 | 426.62 | 426.62 | 426.80 | 0.017158 | 1.90 | 8.29 | 22.84 | 1.01 |
| 3 | 311 | 1:100yr | 15.76 | 424.89 | 425.81 | 425.81 | 426.02 | 0.016234 | 2.04 | 7.74 | 18.38 | 1.00 |
| 3 | 310 | 1:100yr | 15.76 | 424.20 | 425.45 | 425.45 | 425.67 | 0.016725 | 2.06 | 7.66 | 18.06 | 1.01 |
| 3 | 309 | 1:100yr | 15.76 | 423.52 | 424.77 | 424.77 | 425.01 | 0.015768 | 2.20 | 7.17 | 14.61 | 1.00 |
| 3 | 308 | 1:100yr | 15.76 | 422.83 | 424.04 | 424.04 | 424.27 | 0.015891 | 2.15 | 7.34 | 15.65 | 1.00 |
| 3 | 307 | 1:100yr | 15.76 | 422.14 | 423.28 | 423.28 | 423.51 | 0.016260 | 2.10 | 7.50 | 16.89 | 1.01 |
| 3 | 306 | 1:100yr | 15.76 | 421.45 | 422.51 | 422.51 | 422.73 | 0.016636 | 2.08 | 7.59 | 17.77 | 1.01 |
| 3 | 305 | 1:100yr | 15.76 | 420.76 | 421.72 | 421.72 | 421.94 | 0.016423 | 2.07 | 7.63 | 17.86 | 1.01 |
| 3 | 304 | 1:100yr | 15.76 | 420.07 | 421.03 | | 421.17 | 0.009161 | 1.64 | 9.59 | 20.50 | 0.77 |
| 3 | 303 | 1:100yr | 15.76 | 420.00 | 421.08 | | 421.10 | 0.000664 | 0.68 | 27.30 | 36.56 | 0.23 |
| 3 | 302 | 1:100yr | 15.76 | 419.99 | 421.07 | | 421.09 | 0.000499 | 0.66 | 29.72 | 38.64 | 0.21 |
| 3 | 301 | 1:100yr | 15.76 | 419.98 | 421.06 | 420.39 | 421.08 | 0.000500 | 0.67 | 33.66 | 44.09 | 0.21 |

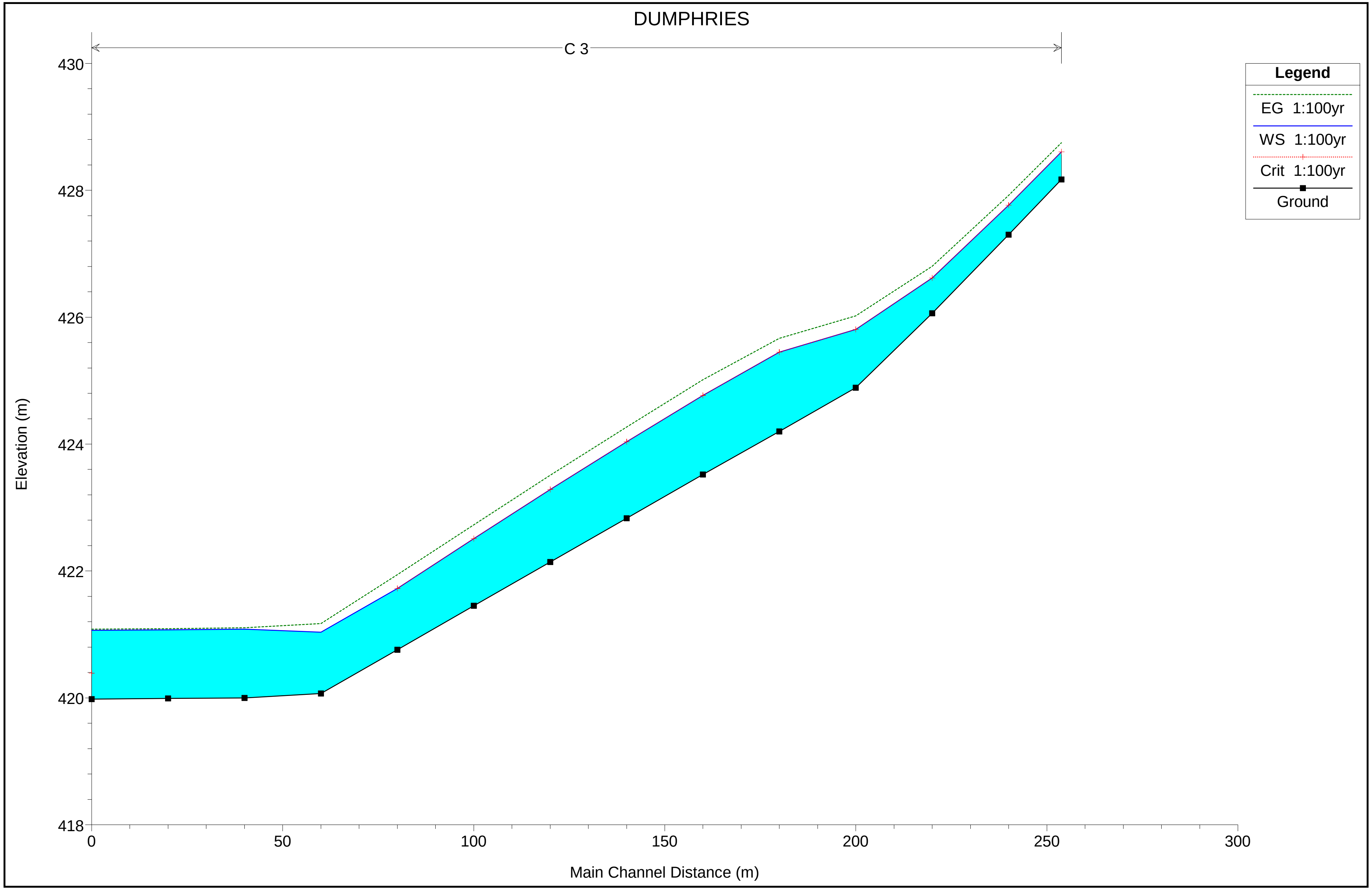
HEC-RAS Plan: Current mode River: C Reach: 4 Profile: 1:100yr

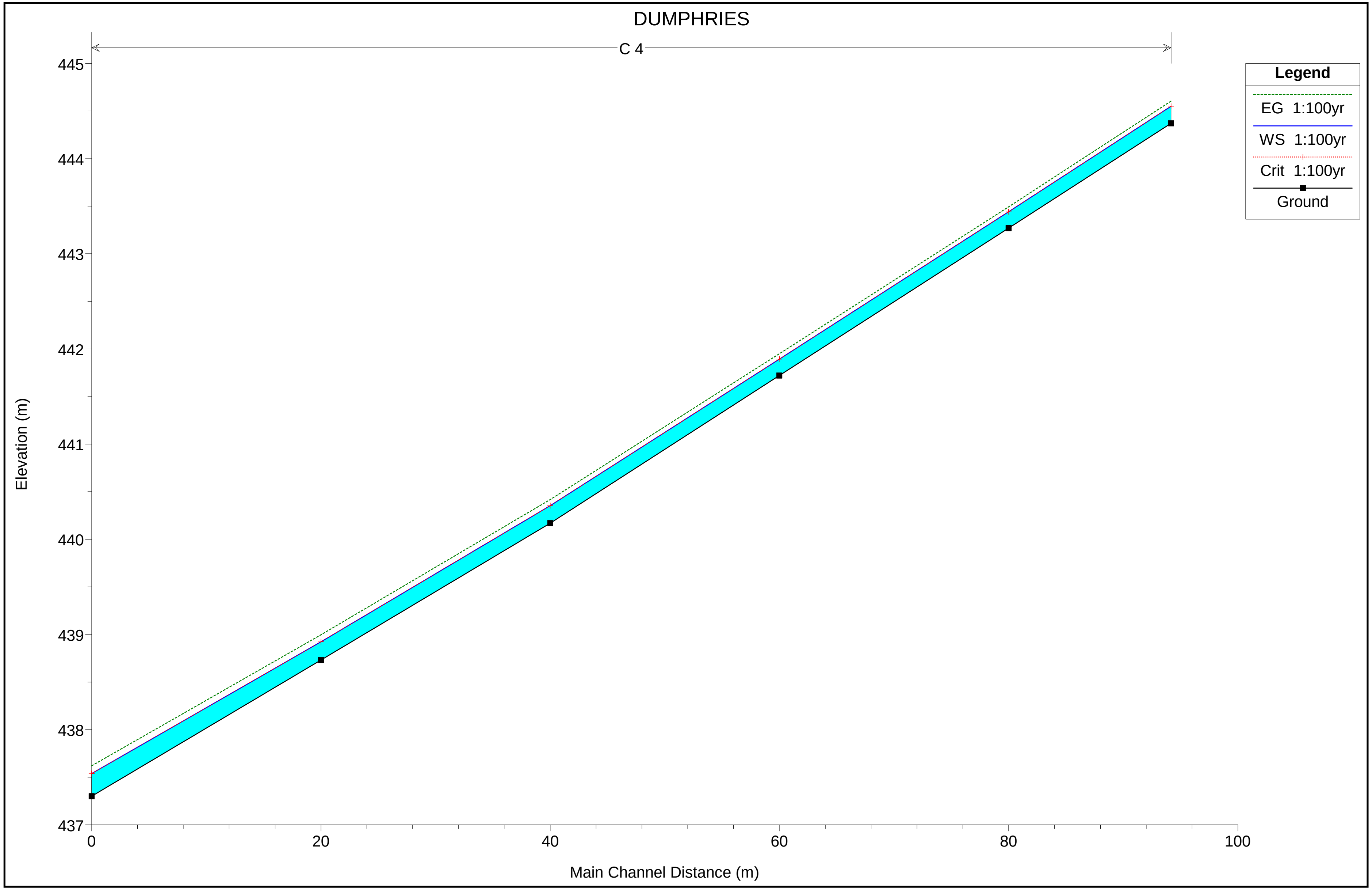
| Reach | River Sta | Profile | Q Total | Min Ch El | W.S. Elev | Crit W.S. | E.G. Elev | E.G. Slope | Vel Chnl | Flow Area | Top Width | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (m3/s) | (m) | (m) | (m) | (m) | (m/m) | (m/s) | (m2) | (m) | |
| 4 | 406 | 1:100yr | 3.09 | 444.37 | 444.55 | 444.55 | 444.60 | 0.020487 | 1.08 | 3.46 | 34.51 | 0.94 |
| 4 | 405 | 1:100yr | 3.09 | 443.27 | 443.44 | 443.44 | 443.49 | 0.024802 | 1.02 | 3.13 | 30.88 | 0.99 |
| 4 | 404 | 1:100yr | 3.09 | 441.72 | 441.89 | 441.89 | 441.95 | 0.025414 | 1.06 | 2.92 | 26.68 | 1.01 |
| 4 | 403 | 1:100yr | 3.09 | 440.17 | 440.35 | 440.35 | 440.42 | 0.024281 | 1.13 | 2.72 | 21.16 | 1.01 |
| 4 | 402 | 1:100yr | 3.09 | 438.73 | 438.92 | 438.92 | 439.00 | 0.023222 | 1.20 | 2.57 | 17.76 | 1.01 |
| 4 | 401 | 1:100yr | 3.09 | 437.30 | 437.54 | 437.54 | 437.62 | 0.020981 | 1.31 | 2.59 | 16.32 | 0.99 |

## ANNEXURE 4: LONGITUDINAL FLOW PROFILE FOR THE FLOOD PEAK

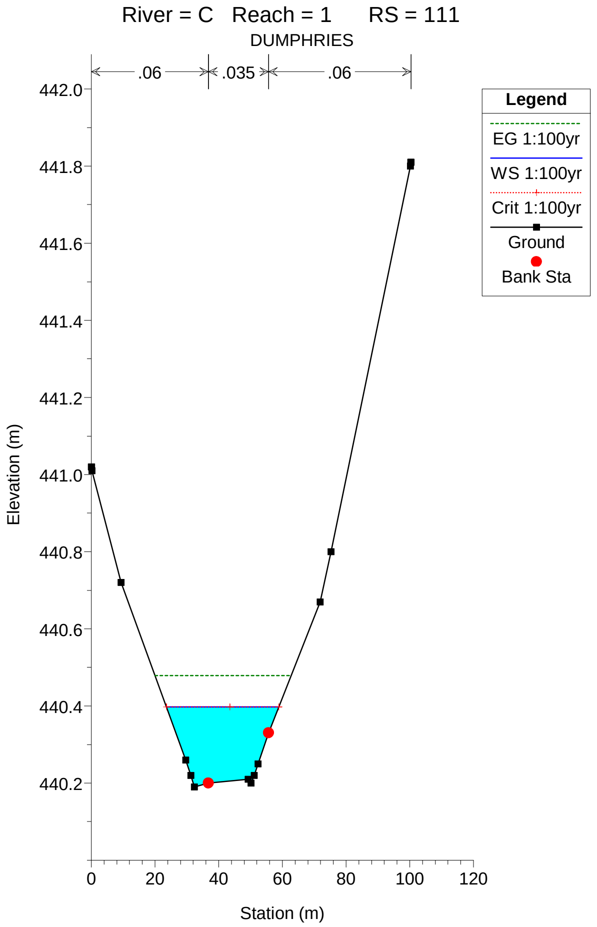

DUMPHRIES
C 1
Legend
EG 1:100yr
WS 1:100yr
Crit 1:100yr
Ground
Elevation (m)
442
440
438
436
434
432
430
0
50
100
150
200
250
Main Channel Distance (m)

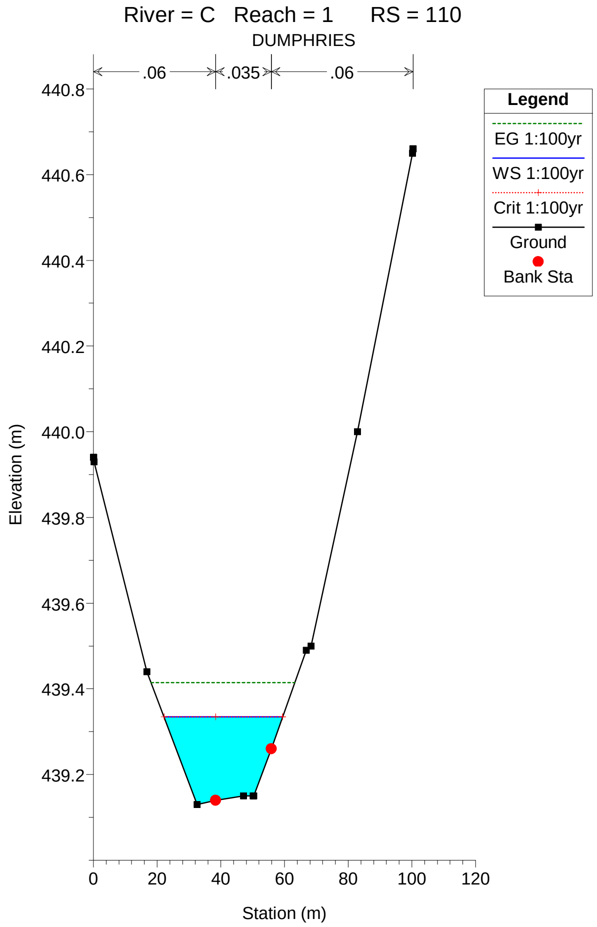

DUMPHRIES
C 2
Legend
EG 1:100yr
WS 1:100yr
Crit 1:100yr
Ground
Elevation (m)
430
432
434
436
438
440
0
50
100
150
200
Main Channel Distance (m)

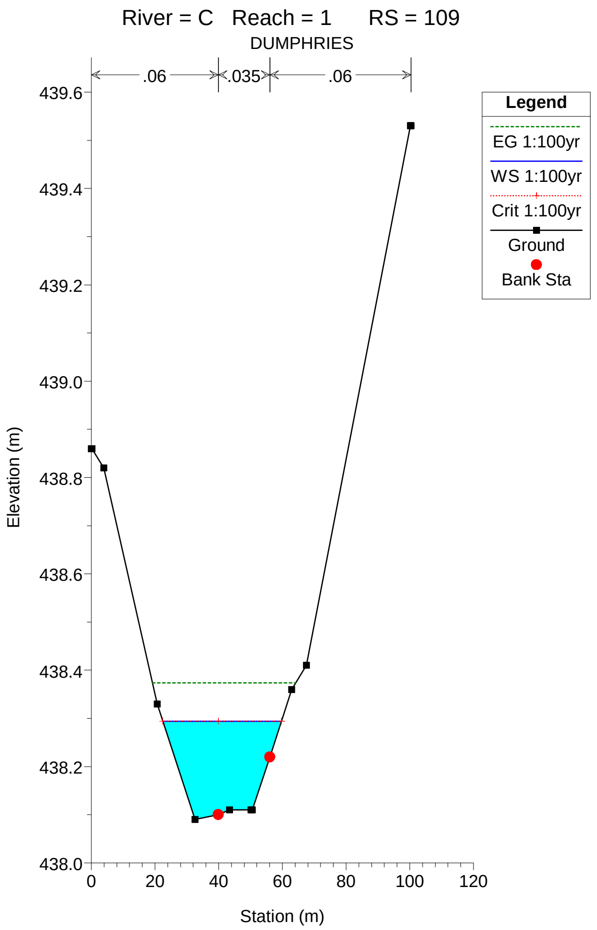

DUMPHRIES
C 3
Legend
EG 1:100yr
WS 1:100yr
Crit 1:100yr
Ground
Elevation (m)
430
428
426
424
422
420
418
0
50
100
150
200
250
300
Main Channel Distance (m)

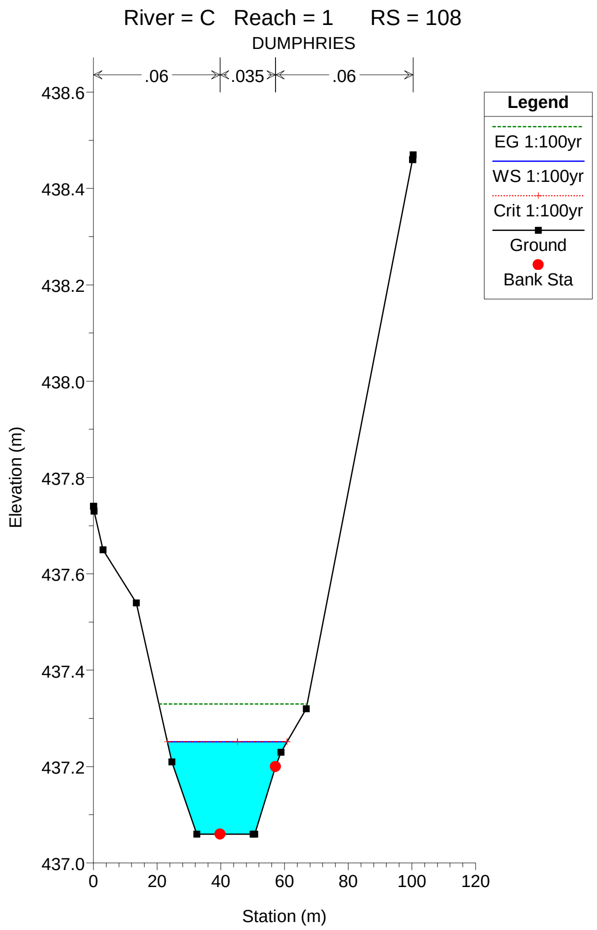

DUMPHRIES
C 4
445
444
443
442
441
440
439
438
437
Elevation (m)
0
20
40
60
80
100
Main Channel Distance (m)
Legend
EG 1:100yr
WS 1:100yr
Crit 1:100yr
Ground

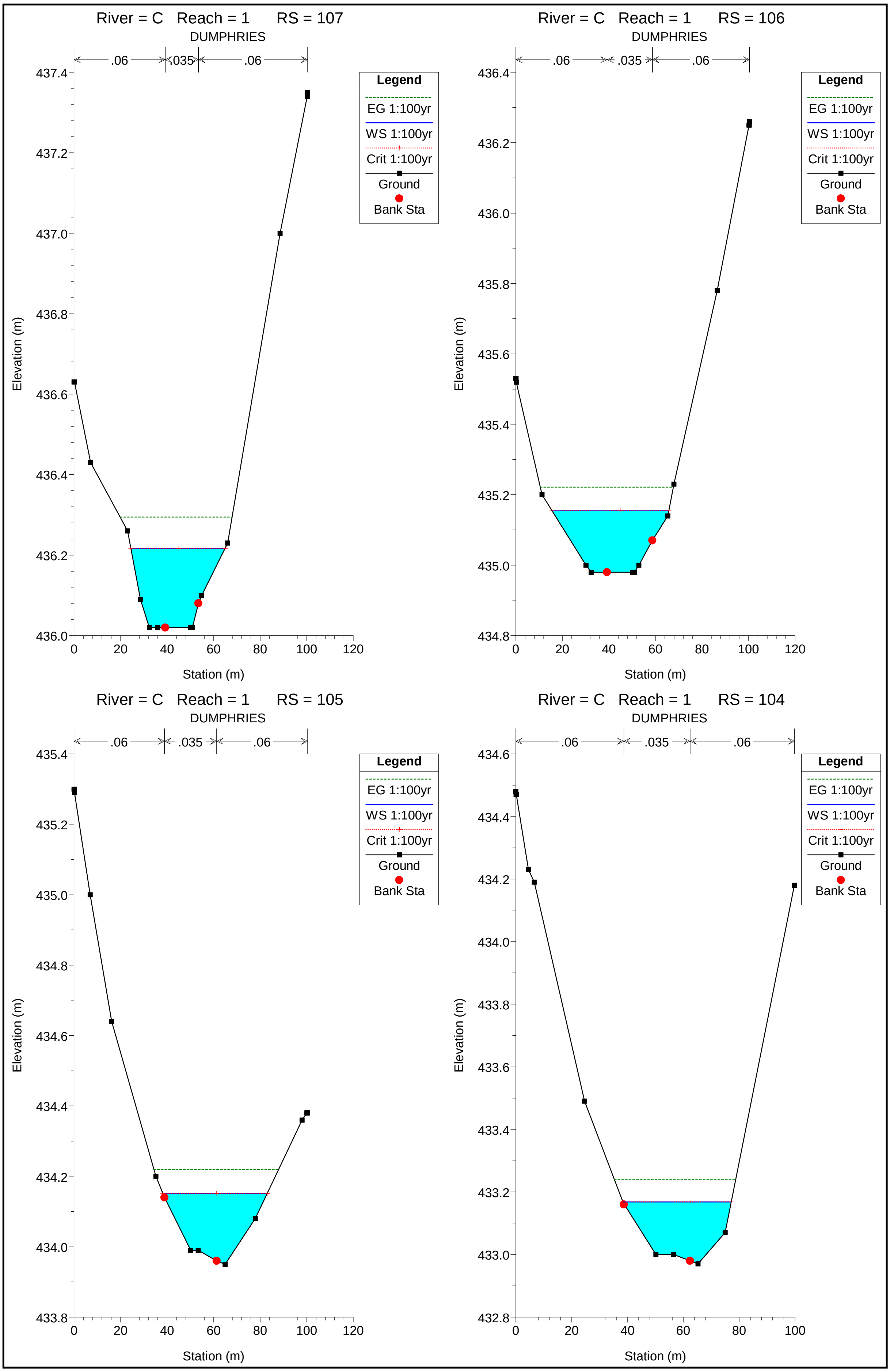
## ANNEXURE 5: FLOW CROSS SECTIONS FOR THE FLOOD PEAK

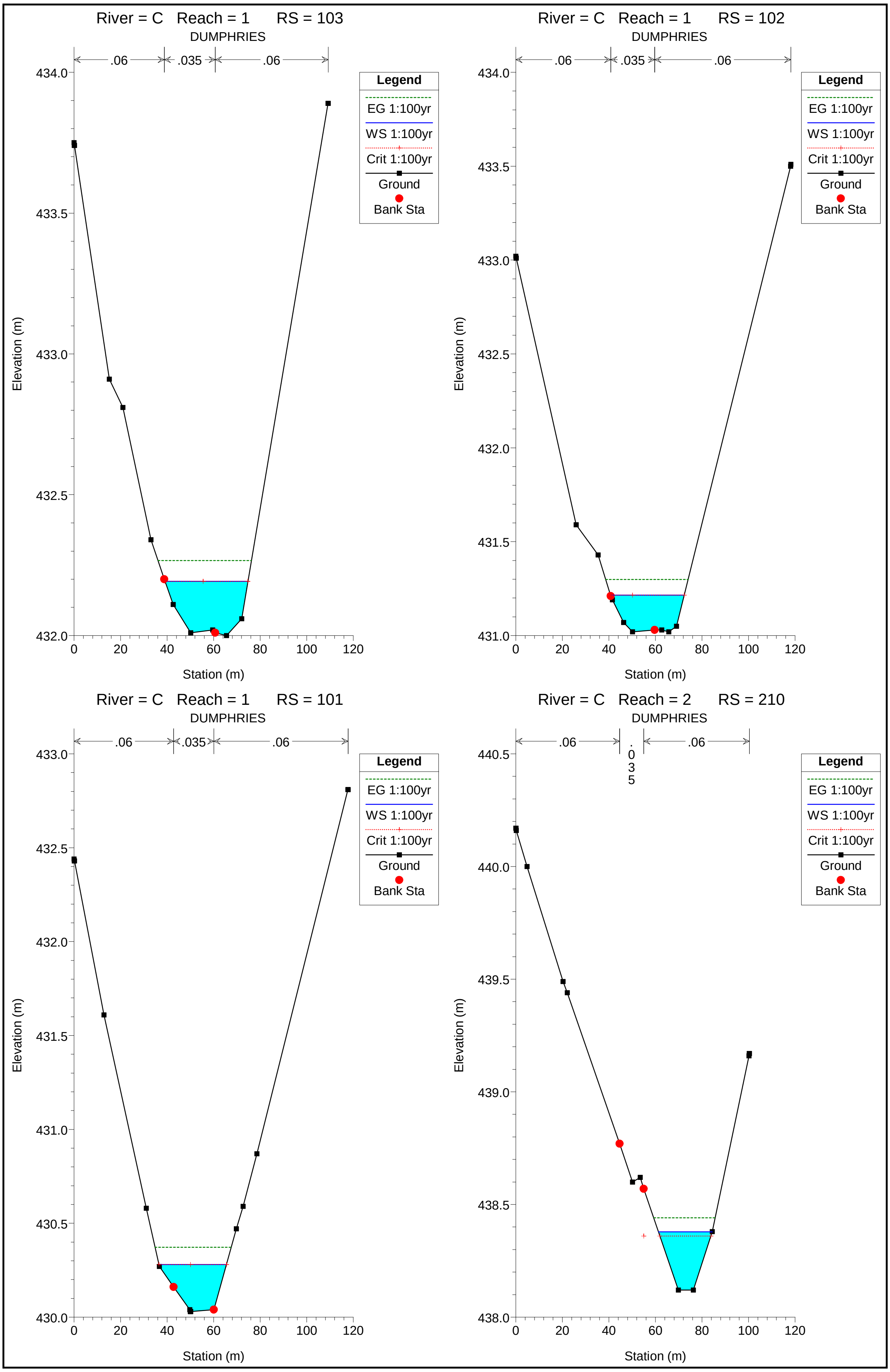

River = C Reach = 1 RS = 111
DUMPHRIES
.06
.035
.06
Legend
EG 1:100yr
WS 1:100yr
Crit 1:100yr
Ground
Bank Sta
Elevation (m)
442.0
441.8
441.6
441.4
441.2
441.0
440.8
440.6
440.4
440.2
0
20
40
60
80
100
120
Station (m)


River = C Reach = 1 RS = 110
DUMPHRIES
.06
.035
.06
Legend
EG 1:100yr
WS 1:100yr
Crit 1:100yr
Ground
Bank Sta
Elevation (m)
440.8
440.6
440.4
440.2
440.0
439.8
439.6
439.4
439.2
0
20
40
60
80
100
120
Station (m)

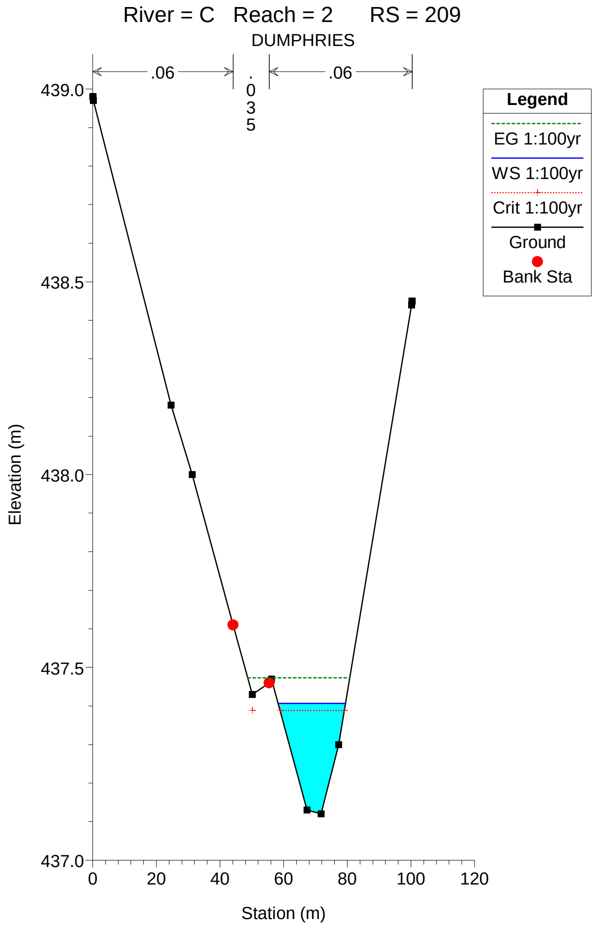

River = C Reach = 1 RS = 109
DUMPHRIES
.06
.035
.06
Legend
EG 1:100yr
WS 1:100yr
Crit 1:100yr
Ground
Bank Sta
Elevation (m)
439.6
439.4
439.2
439.0
438.8
438.6
438.4
438.2
438.0
0
20
40
60
80
100
120
Station (m)

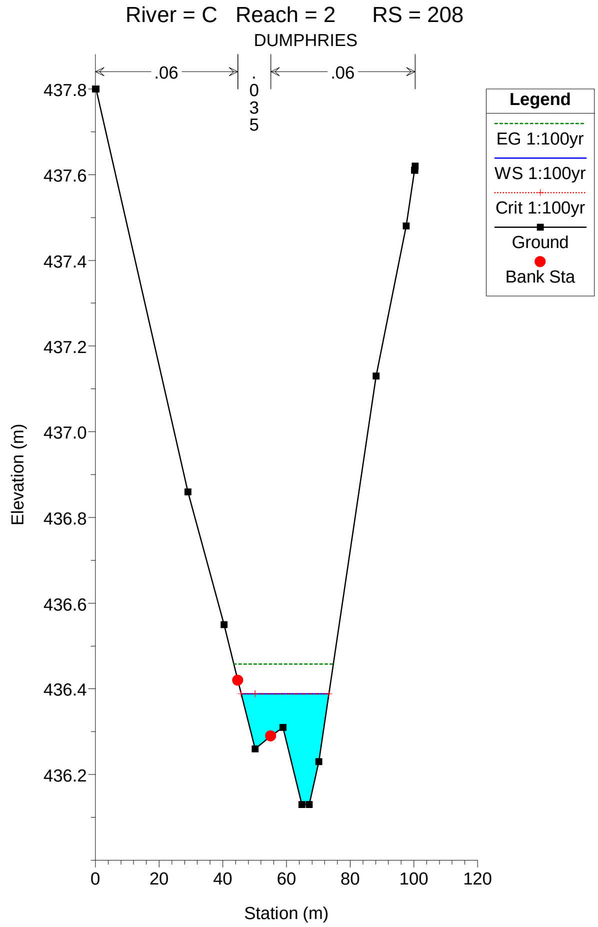

River = C Reach = 1 RS = 108
DUMPHRIES
.06
.035
.06
Legend
EG 1:100yr
WS 1:100yr
Crit 1:100yr
Ground
Bank Sta
Elevation (m)
438.6
438.4
438.2
438.0
437.8
437.6
437.4
437.2
437.0
0
20
40
60
80
100
120
Station (m)

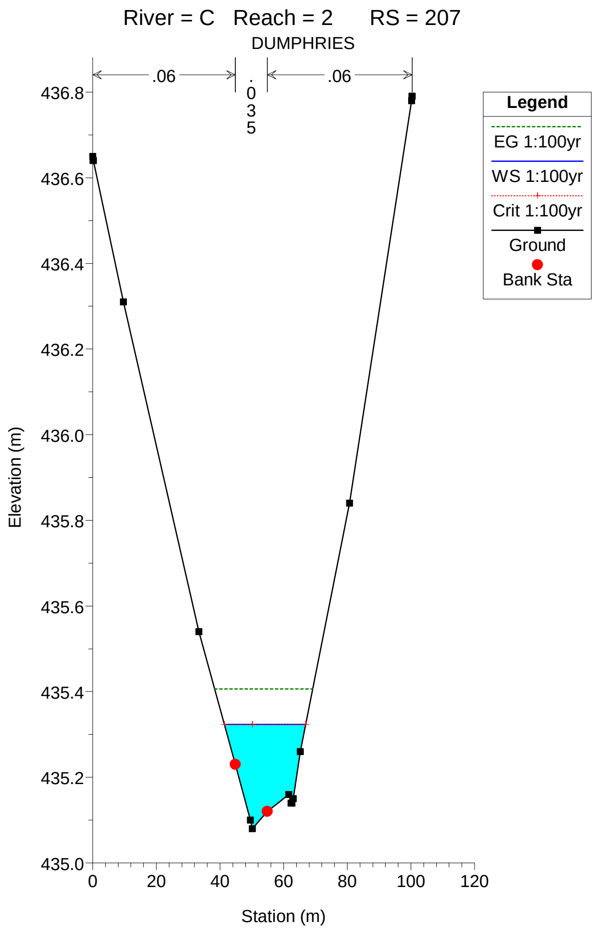

River = C Reach = 1 RS = 107
DUMPHRIES
.06
.035
.06
Legend
EG 1:100yr
WS 1:100yr
Crit 1:100yr
Ground
Bank Sta
Elevation (m)
Station (m)
River = C Reach = 1 RS = 106
DUMPHRIES
.06
.035
.06
Legend
EG 1:100yr
WS 1:100yr
Crit 1:100yr
Ground
Bank Sta
Elevation (m)
Station (m)
River = C Reach = 1 RS = 105
DUMPHRIES
.06
.035
.06
Legend
EG 1:100yr
WS 1:100yr
Crit 1:100yr
Ground
Bank Sta
Elevation (m)
Station (m)
River = C Reach = 1 RS = 104
DUMPHRIES
.06
.035
.06
Legend
EG 1:100yr
WS 1:100yr
Crit 1:100yr
Ground
Bank Sta
Elevation (m)
Station (m)

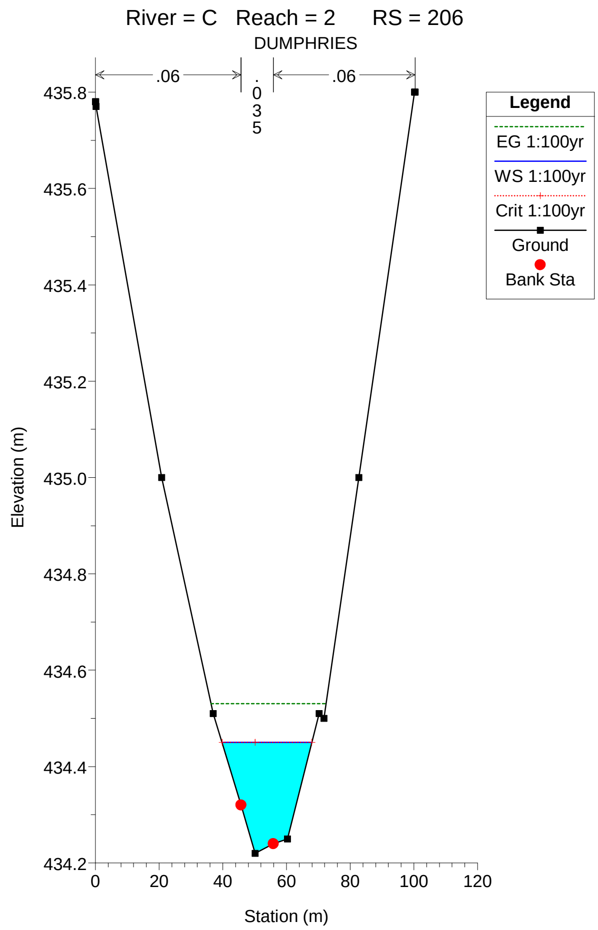


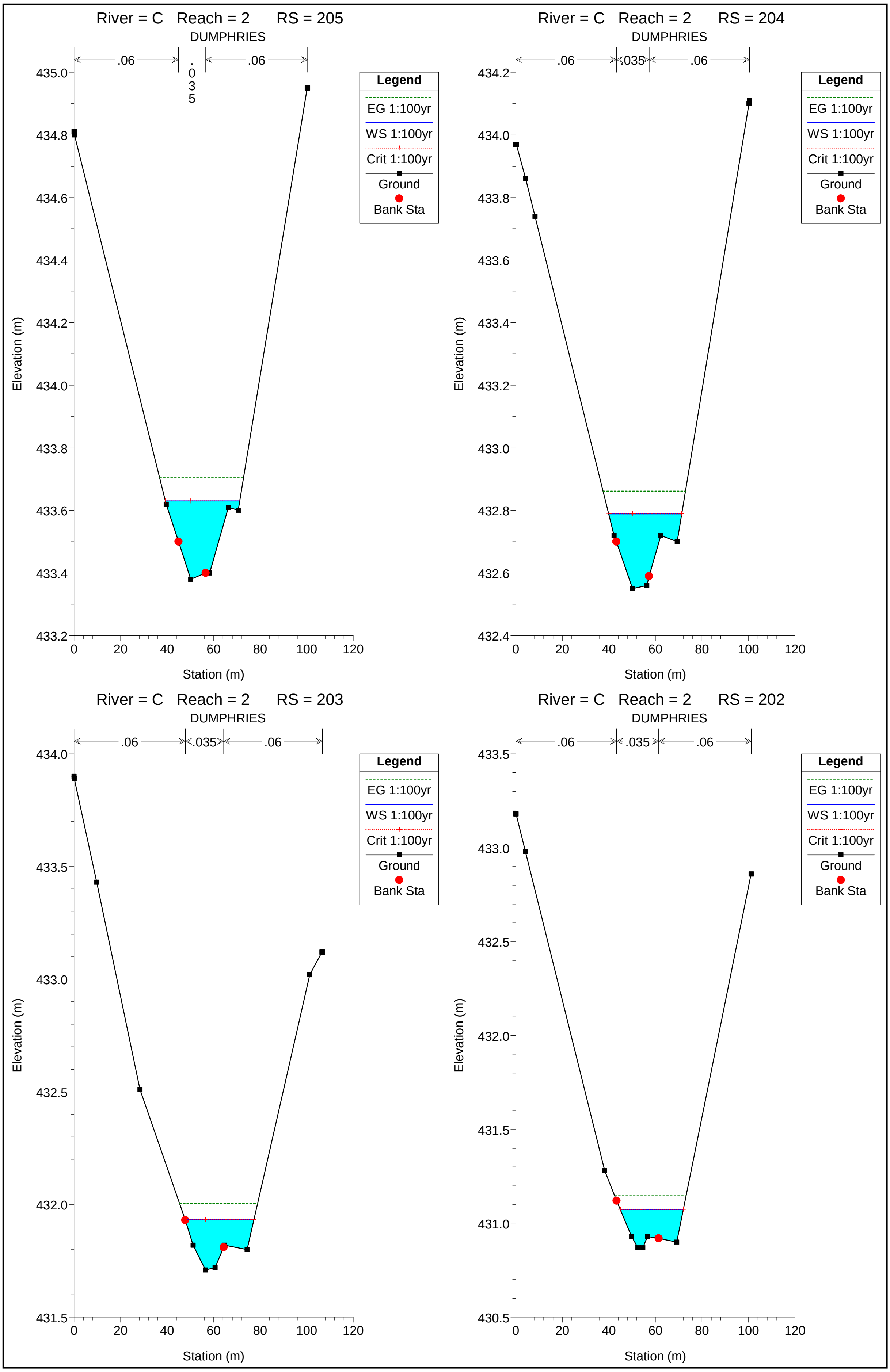
River = C Reach = 1 RS = 103
DUMPHRIES
.06 .035 .06
Legend
EG 1:100yr
WS 1:100yr
Crit 1:100yr
Ground
Bank Sta
Elevation (m)
434.0
433.5
433.0
432.5
432.0
Station (m)
0 20 40 60 80 100 120
River = C Reach = 1 RS = 102
DUMPHRIES
.06 .035 .06
Legend
EG 1:100yr
WS 1:100yr
Crit 1:100yr
Ground
Bank Sta
Elevation (m)
434.0
433.5
433.0
432.5
432.0
431.5
431.0
Station (m)
0 20 40 60 80 100 120
River = C Reach = 1 RS = 101
DUMPHRIES
.06 .035 .06
Legend
EG 1:100yr
WS 1:100yr
Crit 1:100yr
Ground
Bank Sta
Elevation (m)
433.0
432.5
432.0
431.5
431.0
430.5
430.0
Station (m)
0 20 40 60 80 100 120
River = C Reach = 2 RS = 210
DUMPHRIES
.06 .035 .06
Legend
EG 1:100yr
WS 1:100yr
Crit 1:100yr
Ground
Bank Sta
Elevation (m)
440.5
440.0
439.5
439.0
438.5
438.0
Station (m)
0 20 40 60 80 100 120

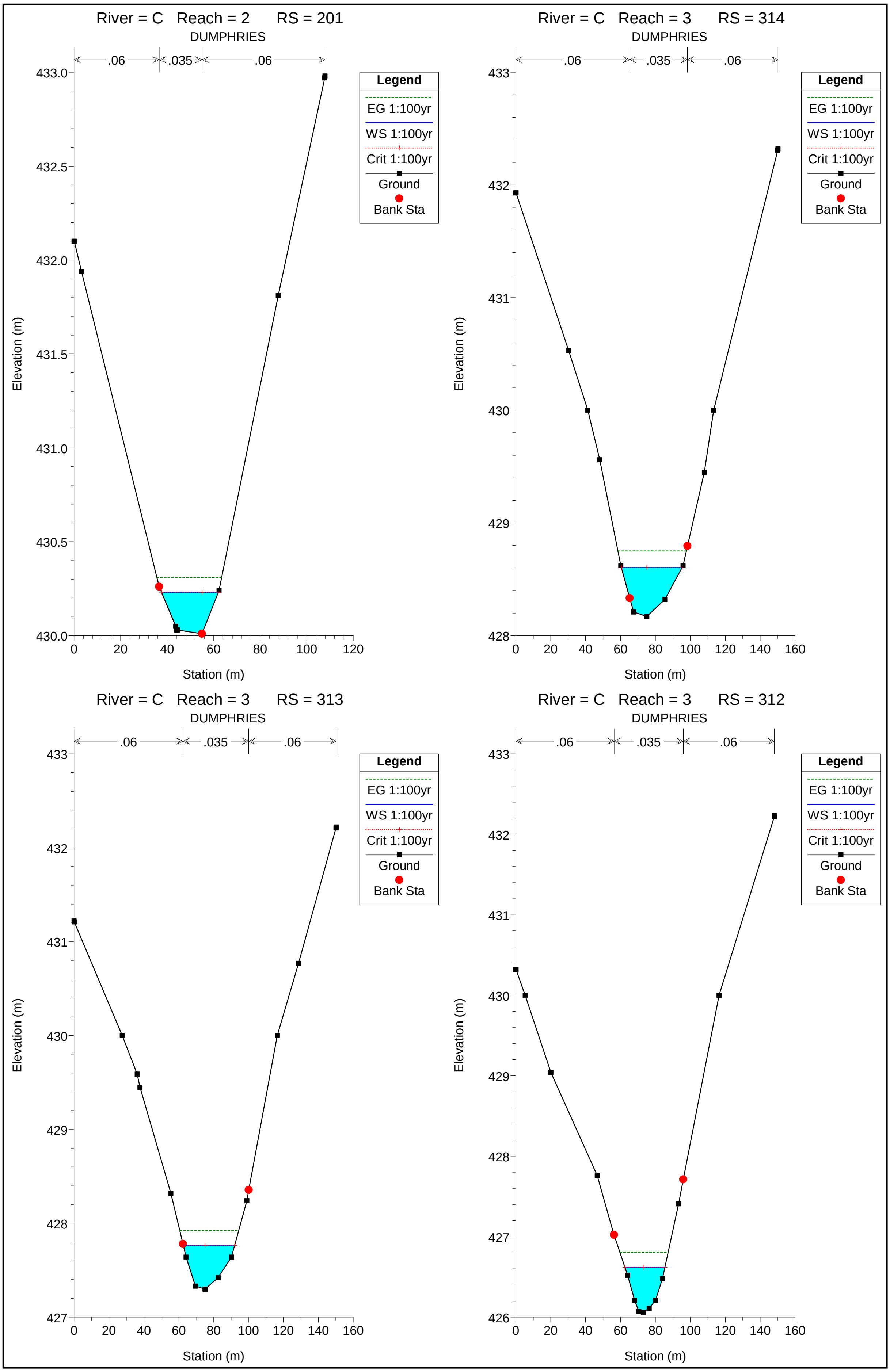

River = C Reach = 2 RS = 209
DUMPHRIES
.06
.035
.06
Legend
EG 1:100yr
WS 1:100yr
Crit 1:100yr
Ground
Bank Sta
Elevation (m)
439.0
438.5
438.0
437.5
437.0
0
20
40
60
80
100
120
Station (m)

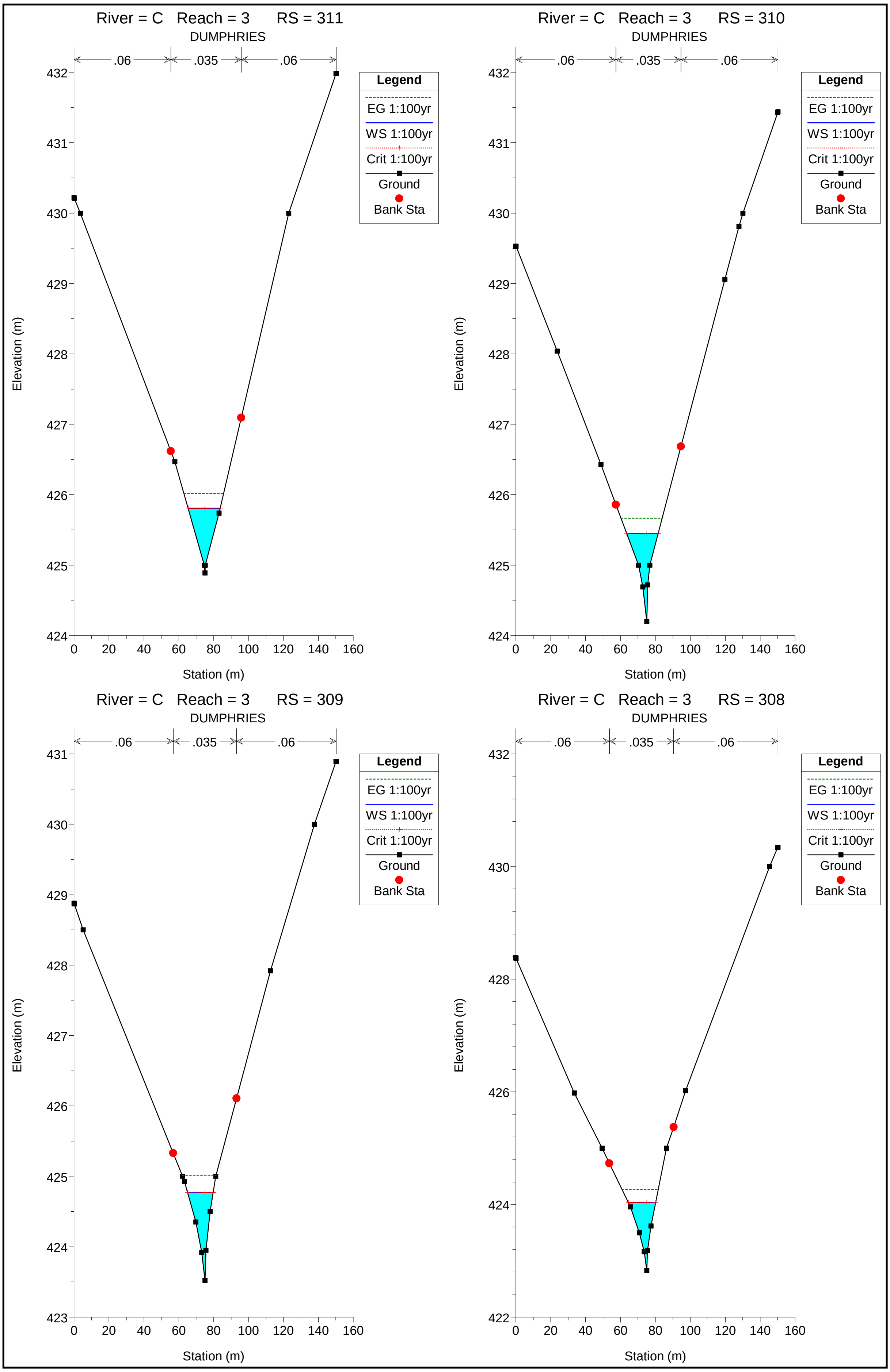

River = C Reach = 2 RS = 208
DUMPHRIES
.06
.035
.06
Legend
EG 1:100yr
WS 1:100yr
Crit 1:100yr
Ground
Bank Sta
Elevation (m)
437.8
437.6
437.4
437.2
437.0
436.8
436.6
436.4
436.2
0
20
40
60
80
100
120
Station (m)

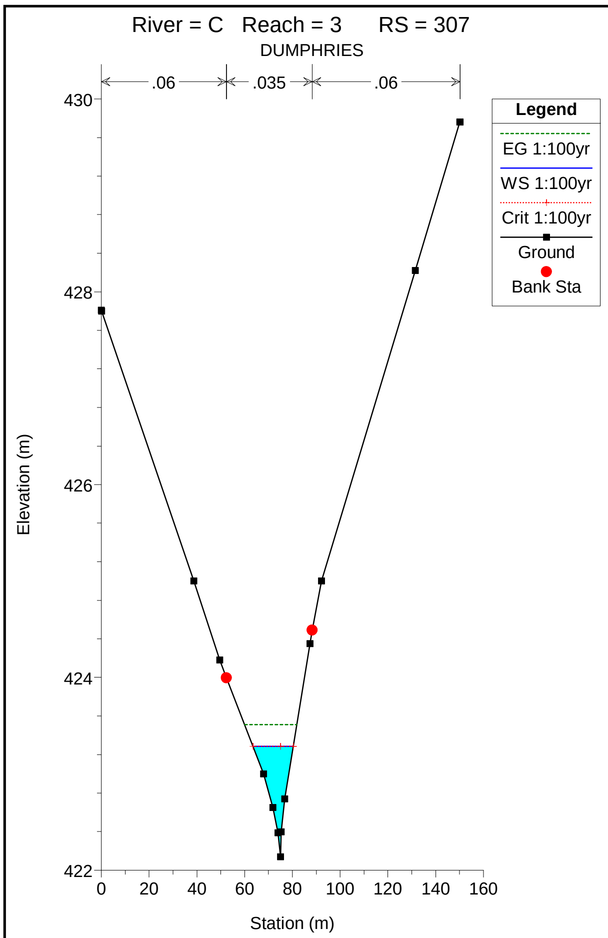

River = C Reach = 2 RS = 207
DUMPHRIES
.06
.035
.06
Legend
EG 1:100yr
WS 1:100yr
Crit 1:100yr
Ground
Bank Sta
Elevation (m)
436.8
436.6
436.4
436.2
436.0
435.8
435.6
435.4
435.2
435.0
0
20
40
60
80
100
120
Station (m)

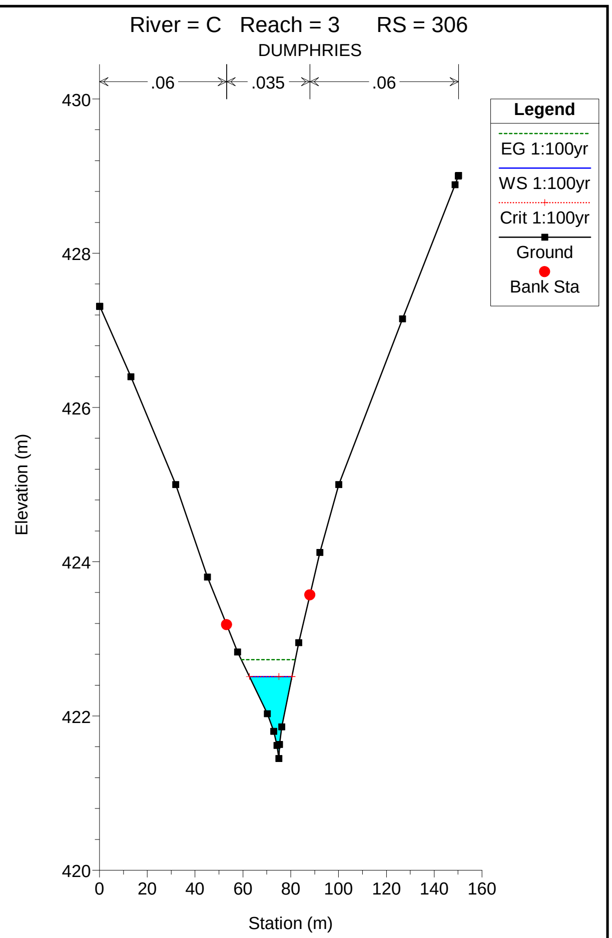

River = C Reach = 2 RS = 206
DUMPHRIES
.06
.035
.06
Legend
EG 1:100yr
WS 1:100yr
Crit 1:100yr
Ground
Bank Sta
Elevation (m)
435.8
435.6
435.4
435.2
435.0
434.8
434.6
434.4
434.2
0
20
40
60
80
100
120
Station (m)

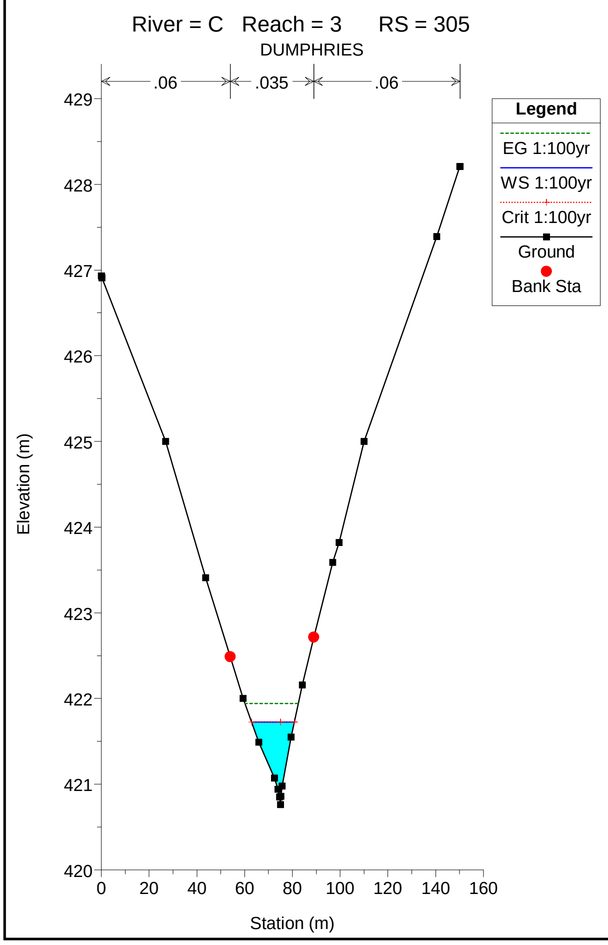

River = C Reach = 2 RS = 205
DUMPHRIES
.06
.035
.06
Legend
EG 1:100yr
WS 1:100yr
Crit 1:100yr
Ground
Bank Sta
Elevation (m)
435.0
434.8
434.6
434.4
434.2
434.0
433.8
433.6
433.4
433.2
Station (m)
0
20
40
60
80
100
120
River = C Reach = 2 RS = 204
DUMPHRIES
.06
.035
.06
Legend
EG 1:100yr
WS 1:100yr
Crit 1:100yr
Ground
Bank Sta
Elevation (m)
434.2
434.0
433.8
433.6
433.4
433.2
433.0
432.8
432.6
432.4
Station (m)
0
20
40
60
80
100
120
River = C Reach = 2 RS = 203
DUMPHRIES
.06
.035
.06
Legend
EG 1:100yr
WS 1:100yr
Crit 1:100yr
Ground
Bank Sta
Elevation (m)
434.0
433.5
433.0
432.5
432.0
431.5
Station (m)
0
20
40
60
80
100
120
River = C Reach = 2 RS = 202
DUMPHRIES
.06
.035
.06
Legend
EG 1:100yr
WS 1:100yr
Crit 1:100yr
Ground
Bank Sta
Elevation (m)
433.5
433.0
432.5
432.0
431.5
431.0
430.5
Station (m)
0
20
40
60
80
100
120

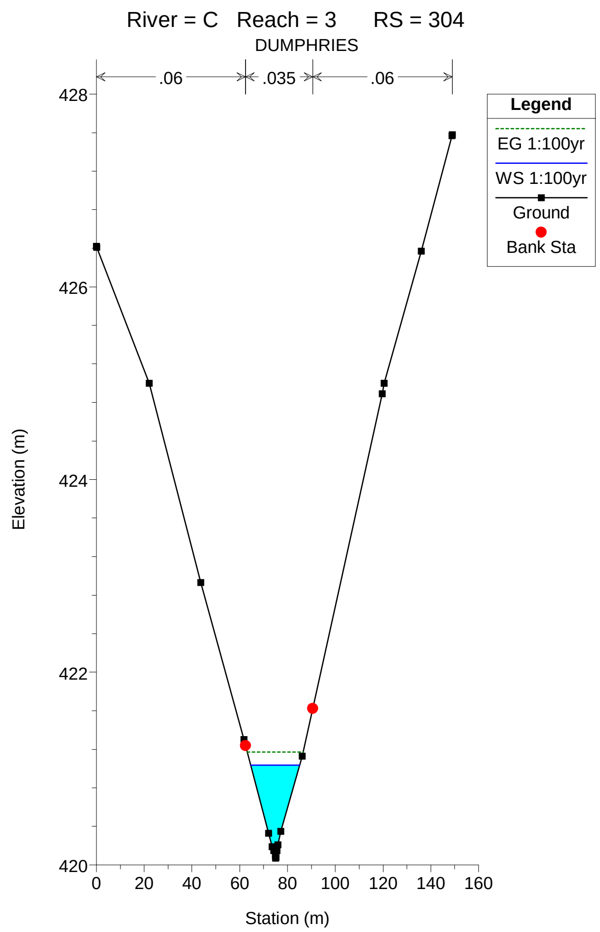

River = C Reach = 2 RS = 201
DUMPHRIES
.06 .035 .06
Legend
EG 1:100yr
WS 1:100yr
Crit 1:100yr
Ground
Bank Sta
Elevation (m)
433.0
432.5
432.0
431.5
431.0
430.5
430.0
0 20 40 60 80 100 120
Station (m)
River = C Reach = 3 RS = 314
DUMPHRIES
.06 .035 .06
Legend
EG 1:100yr
WS 1:100yr
Crit 1:100yr
Ground
Bank Sta
Elevation (m)
433
432
431
430
429
428
0 20 40 60 80 100 120 140 160
Station (m)
River = C Reach = 3 RS = 313
DUMPHRIES
.06 .035 .06
Legend
EG 1:100yr
WS 1:100yr
Crit 1:100yr
Ground
Bank Sta
Elevation (m)
433
432
431
430
429
428
427
0 20 40 60 80 100 120 140 160
Station (m)
River = C Reach = 3 RS = 312
DUMPHRIES
.06 .035 .06
Legend
EG 1:100yr
WS 1:100yr
Crit 1:100yr
Ground
Bank Sta
Elevation (m)
433
432
431
430
429
428
427
426
0 20 40 60 80 100 120 140 160
Station (m)

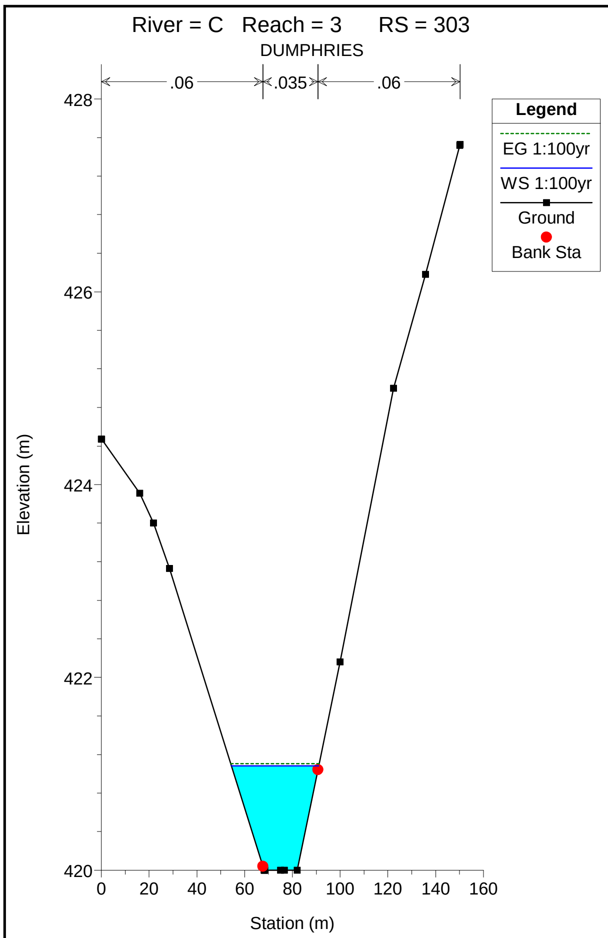

River = C Reach = 3 RS = 311
DUMPHRIES
.06
.035
.06
Legend
EG 1:100yr
WS 1:100yr
Crit 1:100yr
Ground
Bank Sta
Elevation (m)
424
425
426
427
428
429
430
431
432
Station (m)
0
20
40
60
80
100
120
140
160
River = C Reach = 3 RS = 310
DUMPHRIES
.06
.035
.06
Legend
EG 1:100yr
WS 1:100yr
Crit 1:100yr
Ground
Bank Sta
Elevation (m)
424
425
426
427
428
429
430
431
432
Station (m)
0
20
40
60
80
100
120
140
160
River = C Reach = 3 RS = 309
DUMPHRIES
.06
.035
.06
Legend
EG 1:100yr
WS 1:100yr
Crit 1:100yr
Ground
Bank Sta
Elevation (m)
423
424
425
426
427
428
429
430
431
Station (m)
0
20
40
60
80
100
120
140
160
River = C Reach = 3 RS = 308
DUMPHRIES
.06
.035
.06
Legend
EG 1:100yr
WS 1:100yr
Crit 1:100yr
Ground
Bank Sta
Elevation (m)
422
424
426
428
430
432
Station (m)
0
20
40
60
80
100
120
140
160

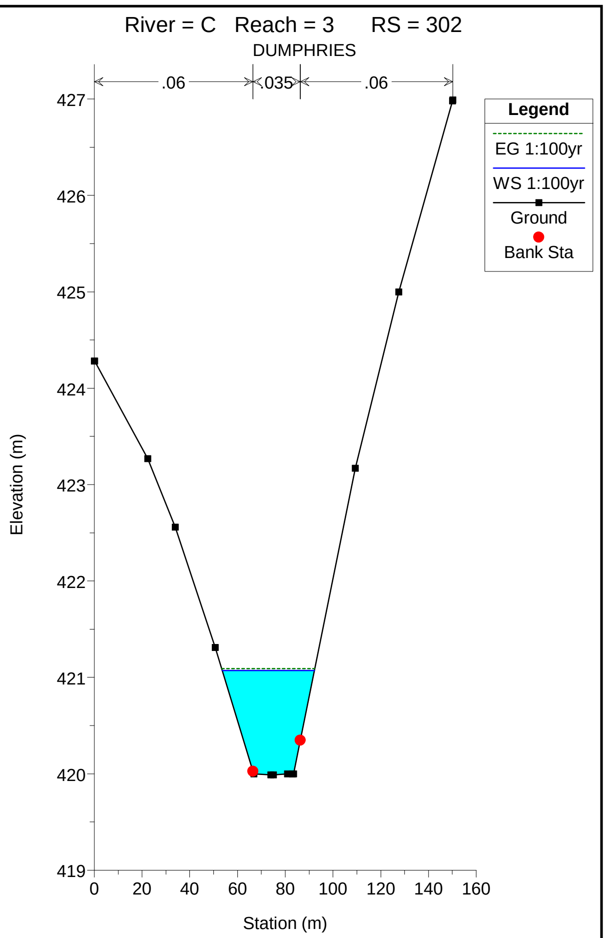

River = C Reach = 3 RS = 307
DUMPHRIES
.06
.035
.06
Legend
EG 1:100yr
WS 1:100yr
Crit 1:100yr
Ground
Bank Sta
Elevation (m)
430
428
426
424
422
0
20
40
60
80
100
120
140
160
Station (m)

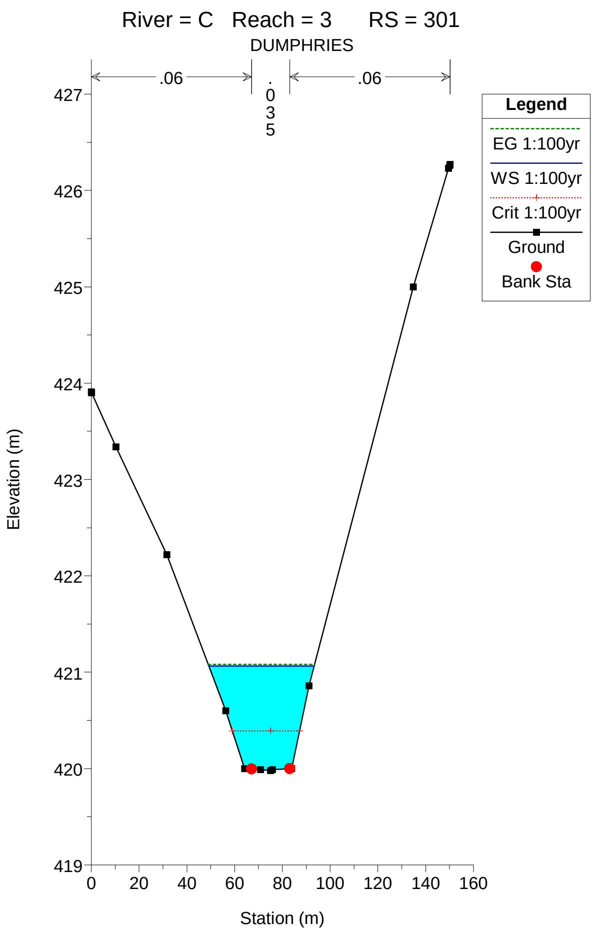

River = C Reach = 3 RS = 306
DUMPHRIES
.06
.035
.06
Legend
EG 1:100yr
WS 1:100yr
Crit 1:100yr
Ground
Bank Sta
Elevation (m)
430
428
426
424
422
420
0
20
40
60
80
100
120
140
160
Station (m)

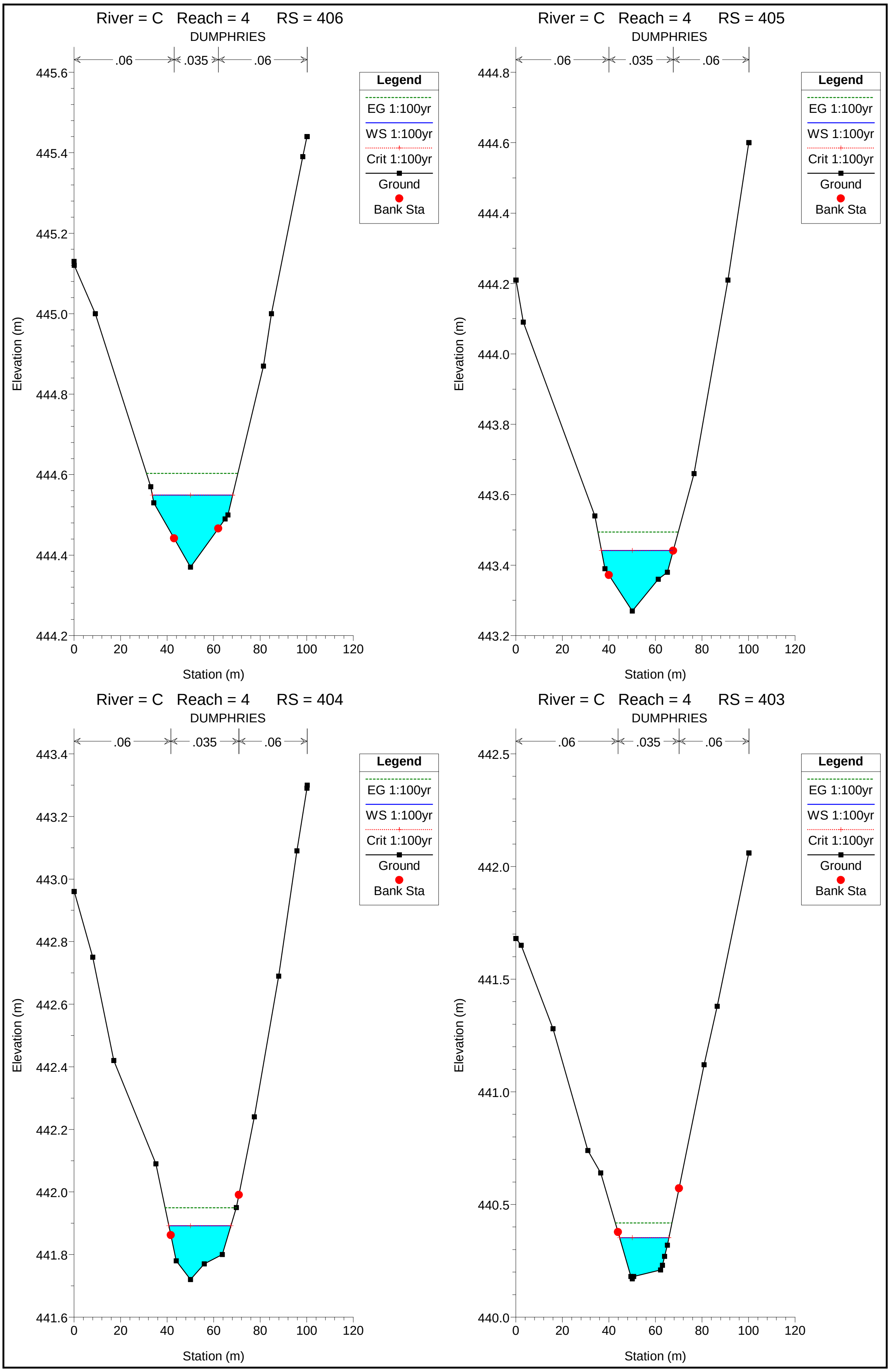

River = C Reach = 3 RS = 305
DUMPHRIES
.06
.035
.06
Legend
EG 1:100yr
WS 1:100yr
Crit 1:100yr
Ground
Bank Sta
Elevation (m)
429
428
427
426
425
424
423
422
421
420
0
20
40
60
80
100
120
140
160
Station (m)

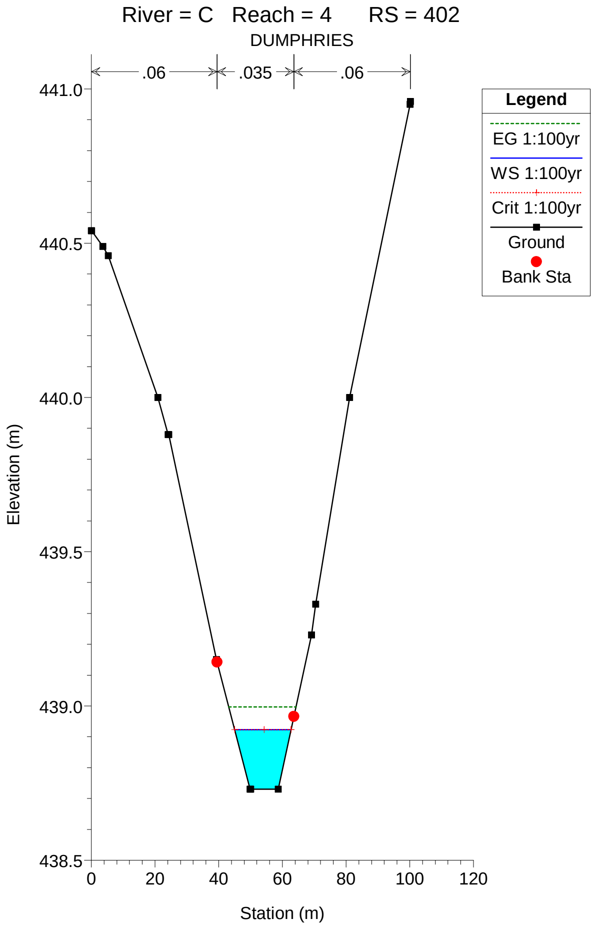

River = C Reach = 3 RS = 304
DUMPHRIES
.06
.035
.06
Legend
EG 1:100yr
WS 1:100yr
Ground
Bank Sta
Elevation (m)
428
426
424
422
420
0
20
40
60
80
100
120
140
160
Station (m)

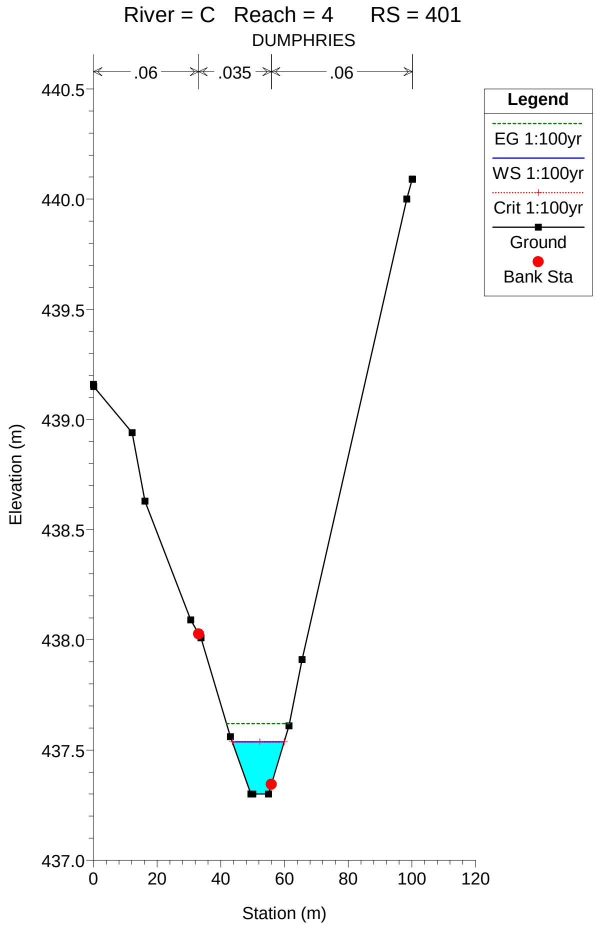

River = C Reach = 3 RS = 303
DUMPHRIES
.06
.035
.06
Legend
EG 1:100yr
WS 1:100yr
Ground
Bank Sta
Elevation (m)
Station (m)
428
426
424
422
420
0
20
40
60
80
100
120
140
160


River = C Reach = 3 RS = 302
DUMPHRIES
.06
.035
.06
Legend
EG 1:100yr
WS 1:100yr
Ground
Bank Sta
Elevation (m)
Station (m)
427
426
425
424
423
422
421
420
419
0
20
40
60
80
100
120
140
160


River = C Reach = 3 RS = 301
DUMPHRIES
.06
.035
.06
Legend
EG 1:100yr
WS 1:100yr
Crit 1:100yr
Ground
Bank Sta
Elevation (m)
Station (m)
427
426
425
424
423
422
421
420
419
0
20
40
60
80
100
120
140
160


River = C Reach = 4 RS = 406
DUMPHRIES
.06
.035
.06
Legend
EG 1:100yr
WS 1:100yr
Crit 1:100yr
Ground
Bank Sta
Elevation (m)
445.6
445.4
445.2
445.0
444.8
444.6
444.4
444.2
Station (m)
0 20 40 60 80 100 120
River = C Reach = 4 RS = 405
DUMPHRIES
.06
.035
.06
Legend
EG 1:100yr
WS 1:100yr
Crit 1:100yr
Ground
Bank Sta
Elevation (m)
444.8
444.6
444.4
444.2
444.0
443.8
443.6
443.4
443.2
Station (m)
0 20 40 60 80 100 120
River = C Reach = 4 RS = 404
DUMPHRIES
.06
.035
.06
Legend
EG 1:100yr
WS 1:100yr
Crit 1:100yr
Ground
Bank Sta
Elevation (m)
443.4
443.2
443.0
442.8
442.6
442.4
442.2
442.0
441.8
441.6
Station (m)
0 20 40 60 80 100 120
River = C Reach = 4 RS = 403
DUMPHRIES
.06
.035
.06
Legend
EG 1:100yr
WS 1:100yr
Crit 1:100yr
Ground
Bank Sta
Elevation (m)
442.5
442.0
441.5
441.0
440.5
440.0
Station (m)
0 20 40 60 80 100 120


River = C Reach = 4 RS = 402
DUMPHRIES
.06
.035
.06
Legend
EG 1:100yr
WS 1:100yr
Crit 1:100yr
Ground
Bank Sta
Elevation (m)
441.0
440.5
440.0
439.5
439.0
438.5
0
20
40
60
80
100
120
Station (m)


River = C Reach = 4 RS = 401
DUMPHRIES
.06
.035
.06
Legend
EG 1:100yr
WS 1:100yr
Crit 1:100yr
Ground
Bank Sta
Elevation (m)
440.5
440.0
439.5
439.0
438.5
438.0
437.5
437.0
0
20
40
60
80
100
120
Station (m)