PROPOSED TOWNSHIP, SITUATED IN REMAINDER OF THE FARM DWARSLOOP 248 KU, MPUMALANGA PROVINCE

1:100 RETURN PERIOD FLOODLINE DETERMINATION REPORT

DECEMBER 2020, Rev 0

PREPARED BY:

Dalimede Projects (PTY) LTD
No. 11 Pierre street, IT Park RentCo Building, Office 6,
Bendor, Polokwane, South Africa, 0699

Tel: 015 291 0775
E-mail: admin@dalimede.com

PREPARED FOR:

Nkanivo Development Consultants
456 Rosebud street
Tijger Vallei Ext 20
Pretoria, 0081

Tel: +27 65 919 4732
Cell: +27 83 277 7347
Email: info@nkanivo.co.za / nyiko@nkanivo.co.za

Contents

List of tables

List of Figures

1.0 INTRODUCTION

1.1 Study Request

Dalimede Projects (PTY) LTD was appointed by Nkanivo Development Consultants to undertake floodline assessment relating to the proposed township situated on remainder of the farm Dwarsloop 248 KU, Mpumalanga Province.

1.2 Locality

The proposed township is situated in Dwarsloop, 11km north of Bushbuckridge town along the R40 highway. 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°46'35.20"S 31° 5'20.21"E.

The locality map is shown on the figures below.

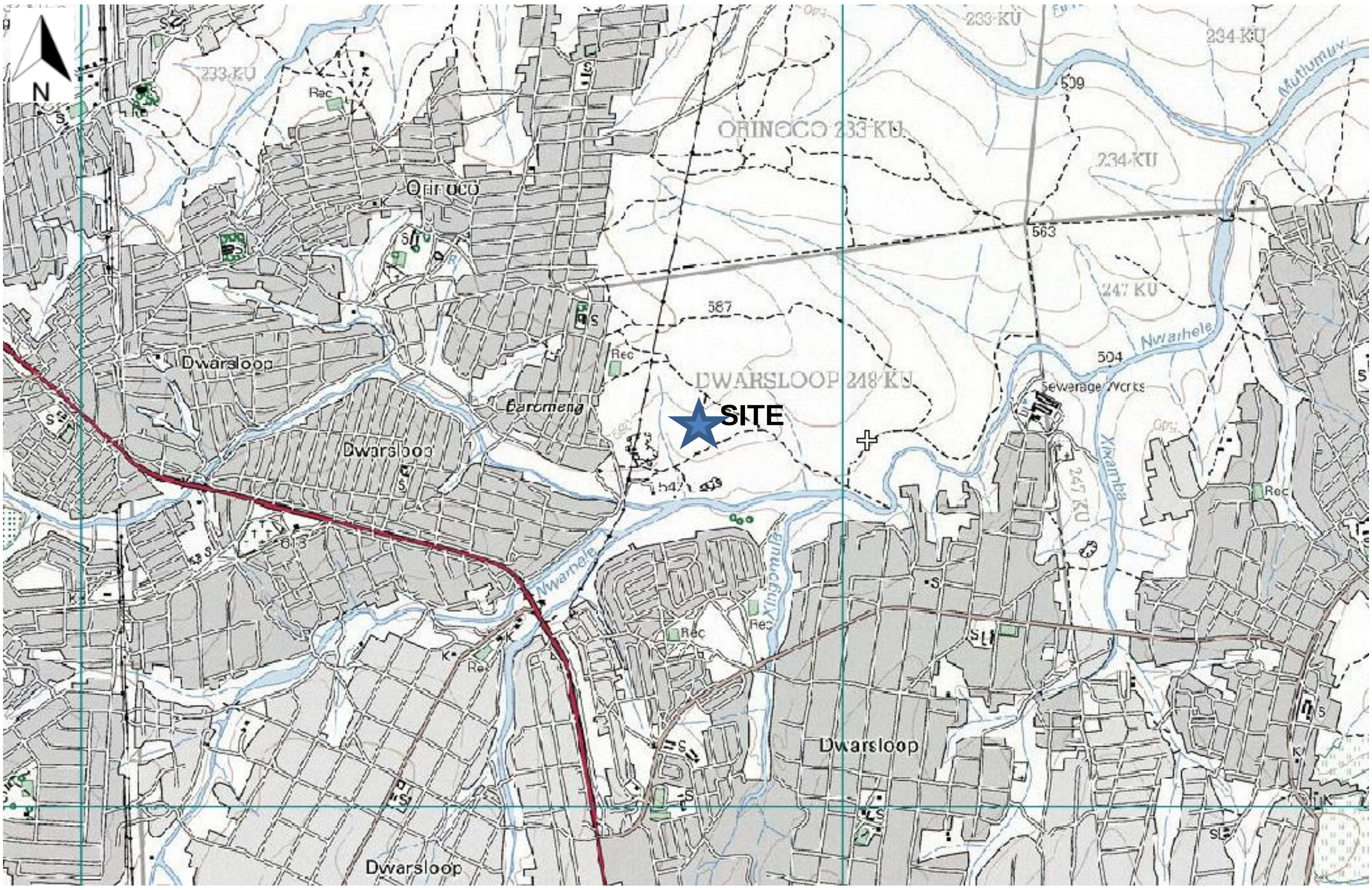

Figure 1 Location of development site

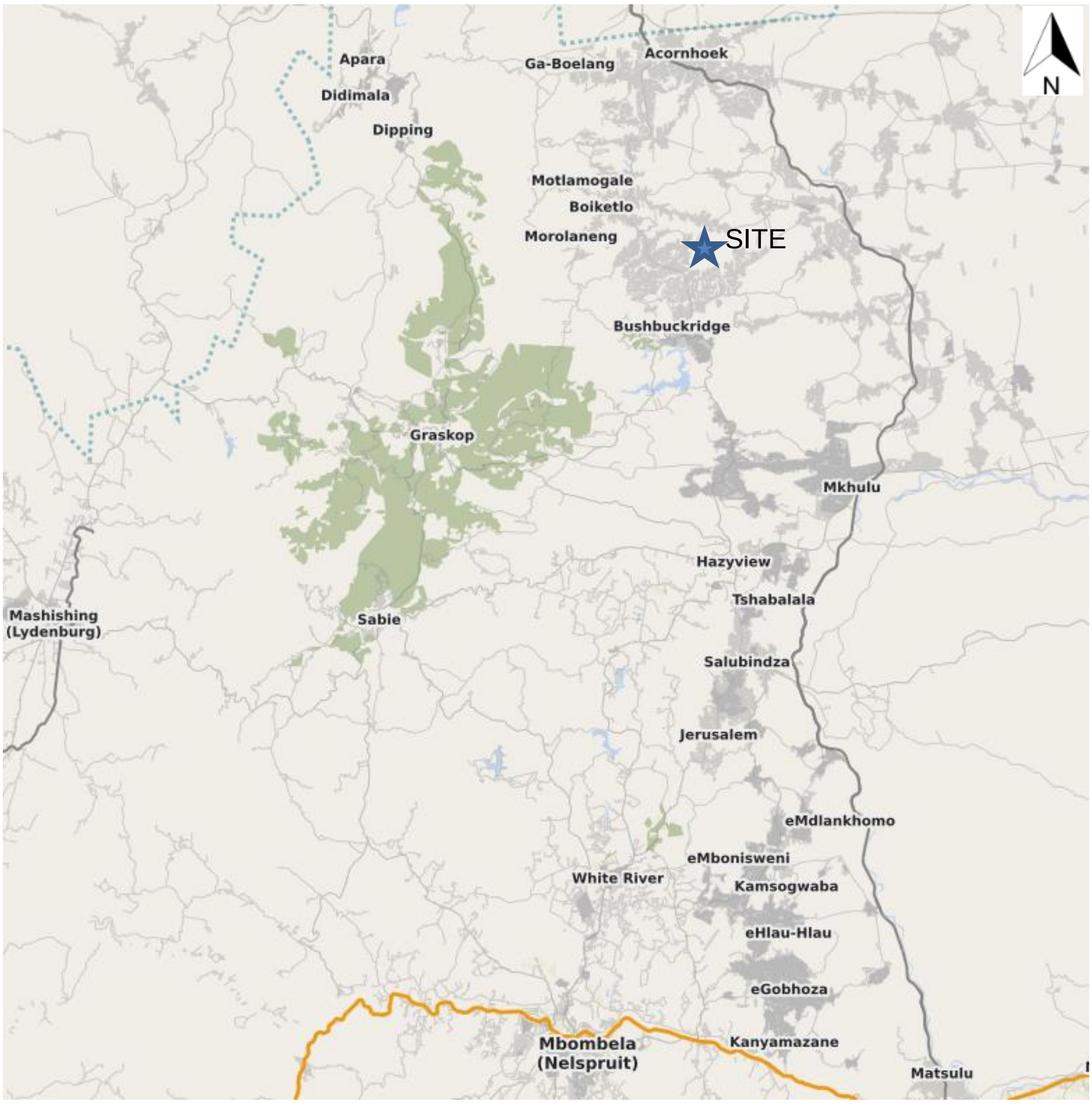

Figure 2 Project site

1.3 Background

A flood line analysis must be conducted along the streams traversing the site of proposed development.

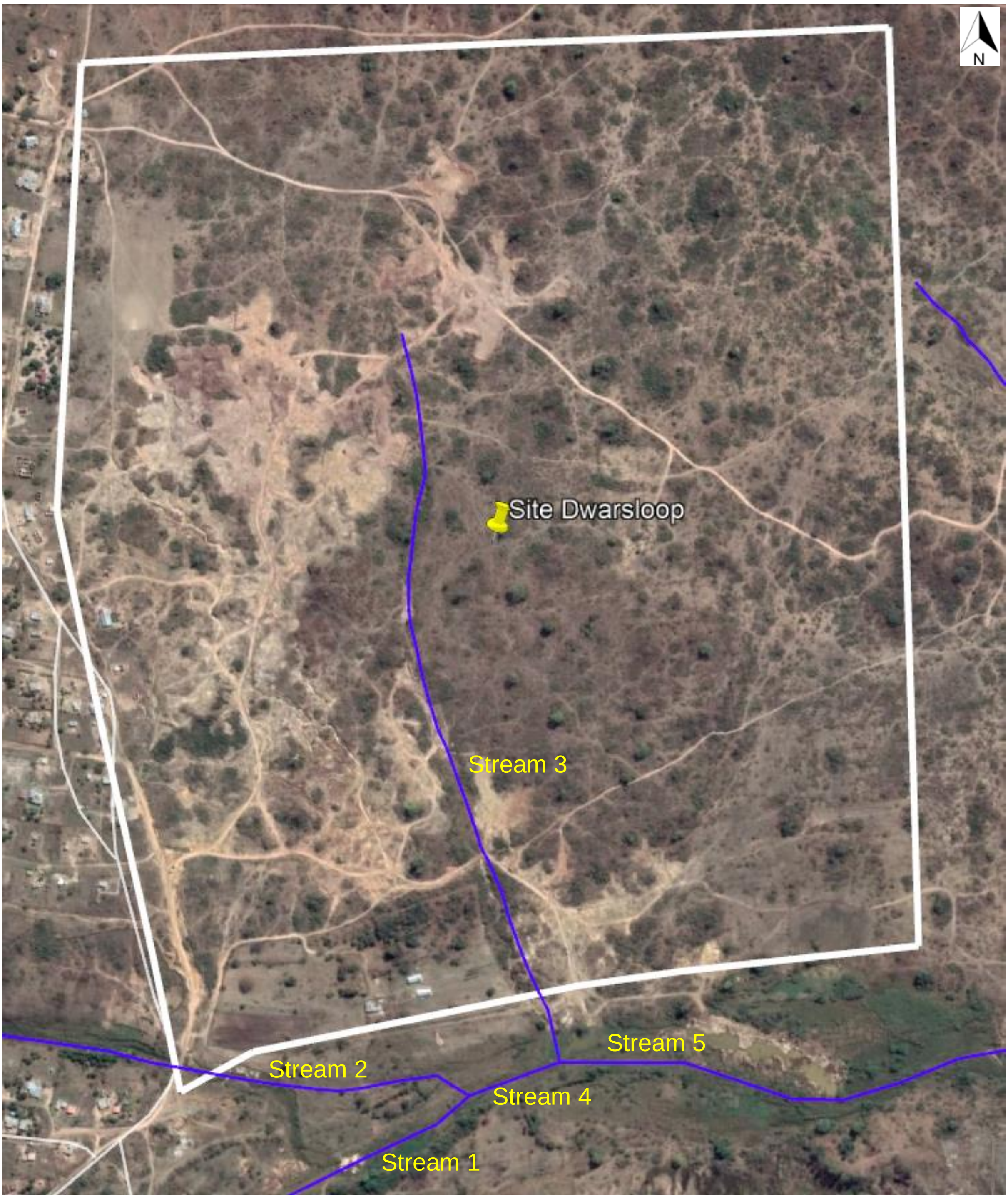

Figure 3 Streams onsite

1.4 Methodology

1.4.1 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.

Figure 4 Stream 1 onsite

1.4.2 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, 2007 with the methods detailed in SANRAL, 2013:

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

1.4.2.1 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

1.4.2.2 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	7.6	10.5	12.8	15.2	18.7	21.7	25
10	m	13.8	19.1	23.2	27.6	34.1	39.5	45.5
15	m	19.5	27.2	33	39.2	48.3	56.1	64.6
30	m	29.6	41.1	49.9	59.3	73.1	84.8	97.7
45	m	37.6	52.3	63.5	75.5	93.1	108	124.4
1	h	44.7	62.1	75.4	89.6	110.5	128.1	147.7
1.5	h	56.9	79.1	96	114.1	140.7	163.2	188
2	h	67.5	93.9	114	135.5	167	193.7	223.2
4	h	81.1	112.8	136.9	162.8	200.6	232.7	268.1
6	h	90.3	125.5	152.4	181.2	223.3	259.1	298.5
8	h	97.4	135.4	164.5	195.5	241	279.6	322.1
10	h	103.4	143.7	174.5	207.4	255.7	296.6	341.7
12	h	108.5	150.8	183.1	217.7	268.3	311.2	358.6
16	h	117.1	162.7	197.6	234.9	289.5	335.8	387
20	h	124.2	172.6	209.6	249.2	307.1	356.3	410.5
24	h	130.3	181.1	220	261.5	322.3	373.9	430.8
1	h	108.1	150.3	182.5	216.9	267.4	310.2	357.4
2	h	138.5	192.5	233.8	277.9	342.6	397.4	457.9
3	h	160.1	222.6	270.2	321.3	396	459.3	529.3
4	h	176.7	245.5	298.2	354.5	436.9	506.8	583.9
5	h	190.7	265	321.8	382.6	471.5	547	630.2
6	h	202.9	282	342.5	407.2	501.9	582.1	670.7
7	h	213.9	297.3	361	429.2	529	613.6	707

2.0 PROPOSED DEVELOPMENT

2.1 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.

2.1.1 Catchment Properties

The catchment topography is composed of flat, hilly, and mountainous areas. The topographic elevation ranges from 540m to 1152m above sea level. The landscape soils mostly ranging from high infiltration rates with rapid permeability well drained, to having slow infiltration rates with restricted permeability (Schulze, 2010). The soils are classified to have a range from low to high 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 1278mm.

Table 2 Rainfall data

Station Name	**SAWS**	**Distance**	**Record**	**Latitude**		**Longitude**		**MAP**
	Number	(km)	(Years)	(°)	(')	(°)	(')	(mm)
Onverwag (BOS)	0594828_W	0	35	24	50	31	0	1340
Bosbokrand (POL)	0595110_W	7.2	92	24	50	31	4	1024
Dunnottar	0594802_W	8	49	24	52	30	56	1582
Modderspruit	0594896_W	9.2	39	24	55	30	59	1157
Marite "Mariti"(BOS)	0594715_W	13	46	24	54	30	54	1307
Wilgeboom (BOS)	0594806_W	13	64	24	56	30	56	1331

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

There is an existing but non-functioning river gauging station X3H022 on the catchment, 1.2km upstream of township site. Data from this river gauge could not be obtained.

2.1.2 Catchment Delineation

There were three catchments that were delineated.
The catchment areas are within the Inkomati Water Management Area.

Catchments in the table below was delineated to cover the streams within the project boundary and was 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	57.041	Catchment	X32E
C2	12.500	Catchment	X32E
C3	0.594	Catchment	X32E

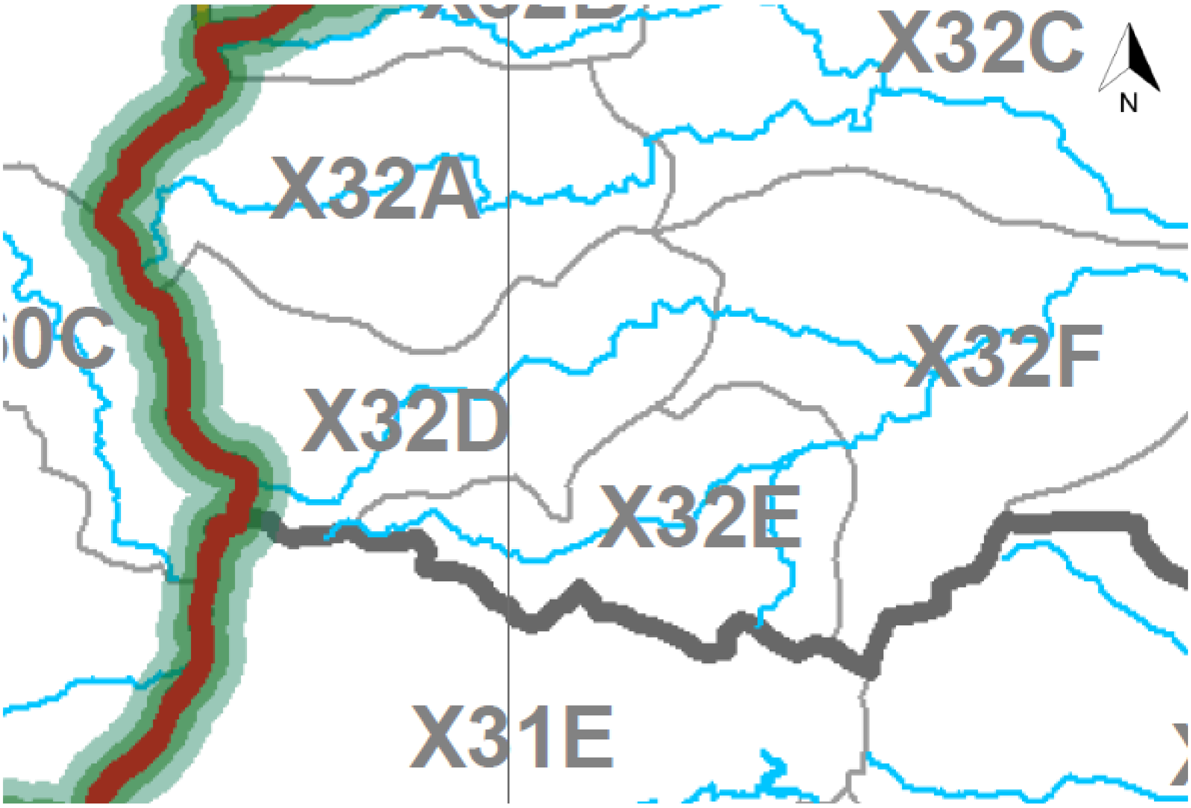

Figure 5 Quaternary catchments

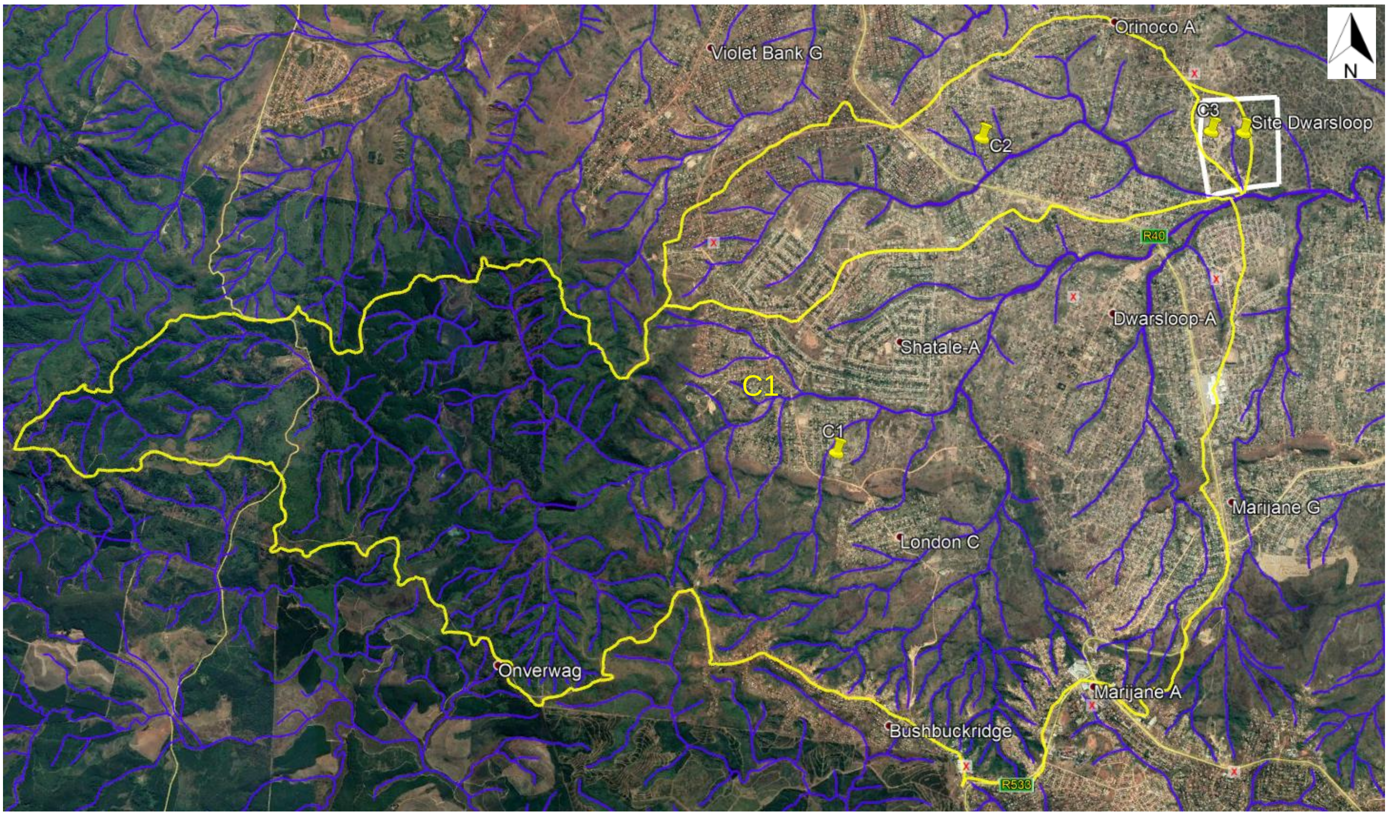

Figure 6 Catchments (yellow line boundary)

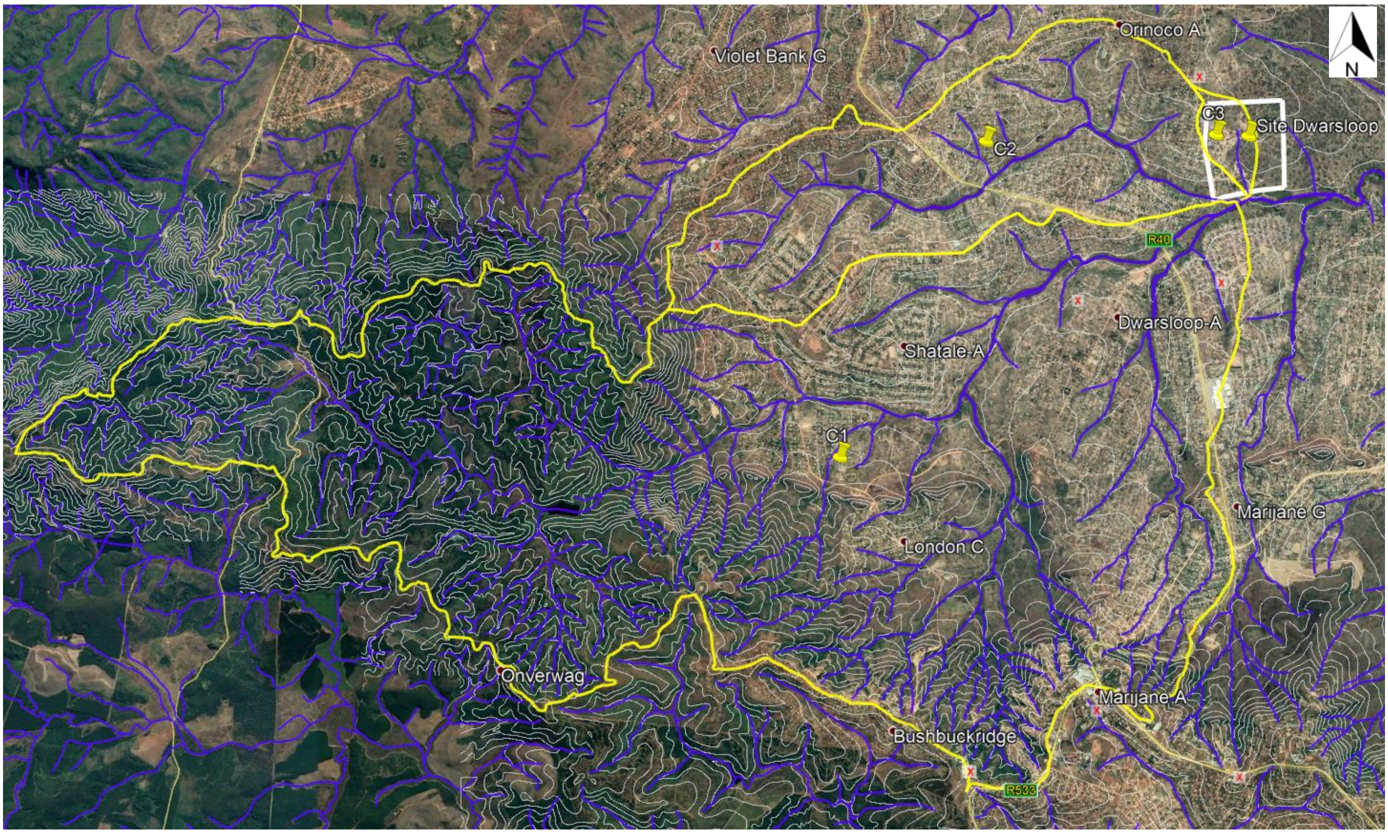

Figure 7 Catchment delineation (yellow line boundaries)

Table 4 Catchment Characteristic

Characteristic	**Rural Distribution**	**Urban Distribution**	**Lakes Distribution**	**Total**
Catchment	**%**	**%**	**%**	**(%)**
C1	89%	11%	0%	100%
C2	82%	18%	0%	100%
C3	100%	0%	0%	100%

Table 5 Rural area - Surface slope

Rural area - Surface slope	**Lakes and pans (<3%) Distribution**	**Flat area (3 to 10%) Distribution**	**Hilly (10 to 30%) Distribution**	**Steep areas (>30%) Distribution**	**Total**
Catchment	**(%)**	**(%)**	**(%)**	**(%)**	**(%)**
C1	5%	34%	45%	16%	100%
C2	8%	74%	18%	0%	100%
C3	9%	91%	0%	0%	100%

Table 6 Rural area – Permeability

Rural area - Permeability	**Very permeable Distribution**	**Permeable Distribution**	**Semi-permeable Distribution**	**Impermeable Distribution**	**Total**
Catchment	**(%)**	**(%)**	**(%)**	**(%)**	**(%)**
C1	8%	42%	45%	5%	100%
C2	12%	47%	40%	1%	100%
C3	15%	60%	25%	0%	100%

Table 7 Rural area - Vegetation

Rural area - Vegetation	**Thick bush & forests Distribution**	**Light bush & cultivated land Distribution**	**Grasslands Distribution**	**Bare Distribution**	**Total**
Catchment					**(%)**
C1	50%	6%	6%	38%	100.0%
C2	3%	12%	10%	75%	100.0%
C3	7%	48%	7%	38%	100.0%

Table 8 Urban

Urban	**C1**	**C2**
Lawns		
Sandy, flat	12%	11%
Sandy, steep		
Heavy soil, flat	6%	7%
Heavy soil, steep		
Residential areas		
Houses	55%	54%
Flats	4%	3%
Industry		
Light industry		
Heavy industry		
Business		
City centre		
Suburban	3%	1%
Streets	20%	24%
Maximum flood		
Total	**100%**	**100%**

Table 9 Run-off factors

Catchment	**Run-off factor**			
	Rural (C_R)	**Urban (C_U)**	**Lakes (C_L)**	**Combined (C)**
C1	0.492	0.536	0	**0.497**
C2	0.527	0.549	0	**0.531**
C3	0.429	0	0	**0.429**

Table 10 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	57.041	19.067	366.9	45	0	1278	29
C2	12.500	8.414	91.4	45	0	1278	29
C3	0.594	1.534	56.4	45	0	1278	29

Table 11 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	57.041	19.067	366.9	0.02565613	2.6302737	2.57%	1278	0.497
C2	12.500	8.414	91.4	0.01447869	1.74609857	1.45%	1278	0.531
C3	0.594	1.534	56.4	0.04904112	0.294370559	4.90%	1278	0.429

Flood magnitudes

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

Table 12 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	158.86	224.94	295.12	375.89	497.3	620.99	110.53	197	271.48	352.44	462.57	557.57
C2	54.08	76.98	101.59	130.42	175.31	222.67	38.24	67.8	92.99	120.22	157.18	188.8
C3	6.317	9.168	12.32	16.09	22.06	28.54	4.761	8.567	11.91	15.58	20.58	24.97

Table 13 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	23.94	74.34	120.52	172.43	249.42	313.79
C2	7.584	23.56	38.19	54.64	79.03	99.43
C3	1.241	3.854	6.248	8.939	12.93	16.27

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

Table 14 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 $15km^2$	1:2 to 1:200
Unit Hydrograph method	$15km^2$ to $5,000km^2$	1:2 to 1:100
Standard Design Flood method	No limitation	1:2 to 1:200
SCS-SA method	Less than $30km^2$	1:2 to 1:100
Empirical methods	No limitation (larger areas)	1:10 to 1:100

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 method with the highest magnitude of the peak flow was used for the 1:100 return flood for a sub-catchment. However, for C1 the Rational methods were not used as the catchment area is beyond the recommended maximum area, hence the SDF method flow was selected.

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

Table 15 Catchment generated estimated 1:100 peak flow

C1	Catchment, estimated 100year peak flow =	313.79	m^3/s
C2	Catchment, estimated 100year peak flow =	222.67	m^3/s
C3	Catchment, estimated 100year peak flow =	28.54	m^3/s

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

Table 16 Stream Peak flows estimates

Stream - Reach	Flow (m^3/s)
Stream 1	313.79
Stream 2	222.67
Stream 4	536.46
Stream 3	28.54
Stream 5	565.00

2.2 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.

2.2.1 Cross section profile

Cross sectional data was generated using GIS and CAD software, as well as the contour lines that were obtained from Messers Windus M & Associates Surveys. Sections shown in Annexure 5 were used to approximate the geometry for the river.

2.2.2 Flood profiles

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

3.0 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.

4.0 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

Branch Offices
Polokwane, Limpopo

DALIMEDE PROJECTS (PTY) LTD
No. 11 Pierre street,
IT Park RentCo Building, Office 6,
Bendor, Polokwane, South Africa, 0699
Tel: 015 291 0775, Cell: 079 368 8414,
E-mail: admin@dalimede.com

FLOOD LINE CERTIFICATE

Dalimede Projects (PTY) LTD was appointed by Nkanivo Development Consultants to undertake floodline assessment relating to the proposed township situated on remainder of the farm Dwarsloop 248 KU, Mpumalanga Province.

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

Site:	*Remainder of the farm Dwarsloop 248 KU*
Township Name:	*Dwarsloop, Bushbuckridge*
Co-ordinates:	*24°46'35.20"S 31° 5'20.21"E*
Municipality:	*Bushbuckridge Local Municipality, in Ehlanzeni District Municipality*

In terms of section 114 of the National Water Act, Act 36 of 1998 the above-mentioned property is 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	.../.../...	....	....

CLIENT

Nkanivo Development Consultants
456 Rosebud street
Tijger Vallei Ext 20
Pretoria, 0081

Tel: +27 65 919 4732
Cell: +27 83 277 7347
Email: info@nkanivo.co.za / nyiko@nkanivo.co.za

CONSULTANT

Dalimede Projects (PTY) LTD
No. 11 Pierre street, IT Park RentCo Building, Office 6,
Bendor, Polokwane, South Africa, 0699

Tel: 015 291 0775, Cell: 079 368 8414,
E-mail: admin@dalimede.com
GPS; Lat: -23.894692 Long: 29.479758

DRAWING STATUS

FOR INFORMATION

PROJECT TITLE

Proposed township situated on remainder of the farm Dwarsloop 248 KU, Mpumalanga Province.

PROJECT LOCATION

The proposed township is situated in Dwarsloop, 11km north of Bushbuckridge town along the R40 highway. Bushbuckridge is in turn 100km north from Nelspruit. GPS coordinates of site are 24°46'35.20"S 31° 5'20.21"E

DRAWING DESCRIPTION

FLOODLINE DELINEATION 1:100 RETURN PERIOD

SCALE	DATE	DESIGNED	DRAWN	CHECKED
As Shown	Dec 2020	LM	HM	CM

DRAWING No.	REVISION
DWARSLOOP/FL/01	A

NOTES

KEY

FLOODLINE

CROSS SECTION

STREAM / RIVER

REVISIONS

REV	DATE	SIGN	DESCRIPTION
0	.../.../...	....	....

CLIENT

Nkanivo Development Consultants

Nkanivo Development Consultants
456 Rosebud street
Tijger Vallei Ext 20
Pretoria, 0081

Tel: +27 65 919 4732
Cell: +27 83 277 7347
Email: info@nkanivo.co.za / nyiko@nkanivo.co.za

CONSULTANT

DALIMEDE PROJECTS (PTY) LTD

Dalimede Projects (PTY) LTD
No. 11 Pierre street, IT Park RentCo Building, Office 6,
Bendor, Polokwane, South Africa, 0699

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DRAWING DESCRIPTION

FLOODLINE DELINEATION 1:100 RETURN PERIOD

SCALE	DATE	DESIGNED	DRAWN	CHECKED
As Shown	Dec 2020	LM	HM	CM

DRAWING No.	REVISION
DWARSLOOP/FL/02	A

ANNEXURE 3: HEC-RAS PROGRAMME MODELLING RESULTS

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

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	108	1:100	313.79	538.50	542.76		542.84	0.001271	1.60	295.77	185.25	0.33
1	107	1:100	313.79	538.50	542.73		542.83	0.001596	1.71	275.26	184.50	0.36
1	106	1:100	313.79	538.76	542.66		542.79	0.001835	1.90	255.34	185.55	0.39
1	105	1:100	313.79	538.52	542.61		542.75	0.001949	1.96	249.55	184.79	0.40
1	104	1:100	313.79	538.08	542.61		542.71	0.001085	1.68	278.47	155.71	0.31
1	103	1:100	313.79	538.02	542.59		542.69	0.000957	1.62	275.10	134.25	0.29
1	102	1:100	313.79	538.31	542.59		542.67	0.000744	1.46	306.47	135.87	0.26
1	101	1:100	313.79	538.50	542.35		542.62	0.002187	2.47	156.63	69.68	0.45

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

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	1:100	222.67	541.00	543.11		543.42	0.008946	3.03	103.11	91.19	0.80
2	209	1:100	222.67	541.00	543.03		543.29	0.005928	2.72	115.25	95.79	0.67
2	208	1:100	222.67	540.63	542.65	542.58	543.09	0.015440	3.54	84.55	84.61	1.02
2	207	1:100	222.67	540.09	542.61		542.88	0.005080	2.73	116.22	90.21	0.63
2	206	1:100	222.67	539.97	542.59		542.79	0.003238	2.38	140.44	105.18	0.51
2	205	1:100	222.67	539.50	542.62		542.72	0.001392	1.74	204.85	128.36	0.34
2	204	1:100	222.67	539.50	542.58		542.69	0.001589	1.84	179.12	87.41	0.36
2	203	1:100	222.67	539.50	542.58		542.65	0.000988	1.58	219.86	105.32	0.30
2	202	1:100	222.67	539.25	542.55		542.63	0.000810	1.51	197.51	68.95	0.27
2	201	1:100	222.67	538.85	542.48		542.61	0.001047	1.85	158.06	48.69	0.32

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

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	316	1:100	28.54	551.09	552.27	552.27	552.35	0.010556	1.66	37.21	243.59	0.72
3	315	1:100	28.54	550.31	551.12	551.12	551.30	0.012743	2.05	19.61	73.98	0.83
3	314	1:100	28.54	549.39	550.01	550.01	550.26	0.041051	2.59	14.13	43.02	1.36
3	313	1:100	28.54	548.65	549.27	549.27	549.40	0.025171	2.02	22.56	95.11	1.06
3	312	1:100	28.54	546.98	548.34	548.34	548.49	0.012558	2.00	23.93	90.51	0.81
3	311	1:100	28.54	545.87	547.30	547.30	547.42	0.008424	1.75	29.37	142.57	0.68
3	310	1:100	28.54	544.89	546.15	546.15	546.51	0.018185	2.67	10.68	14.78	1.00
3	309	1:100	28.54	543.93	545.10	545.10	545.47	0.018119	2.69	10.61	14.48	1.00
3	308	1:100	28.54	542.96	544.14	544.14	544.51	0.017634	2.69	10.67	15.21	0.99
3	307	1:100	28.54	542.00	543.17	543.17	543.53	0.017872	2.66	10.79	15.73	0.99
3	306	1:100	28.54	541.04	542.19	542.19	542.56	0.017982	2.68	10.79	16.14	0.99
3	305	1:100	28.54	540.28	541.84		541.87	0.001145	0.88	48.12	68.14	0.27
3	304	1:100	28.54	539.28	541.85		541.86	0.000185	0.50	86.64	71.77	0.12
3	303	1:100	28.54	538.65	541.85		541.85	0.000051	0.33	119.98	60.09	0.07
3	302	1:100	28.54	538.20	541.85		541.85	0.000040	0.30	119.70	54.36	0.06
3	301	1:100	28.54	538.00	541.85		541.85	0.000022	0.27	153.63	63.58	0.05

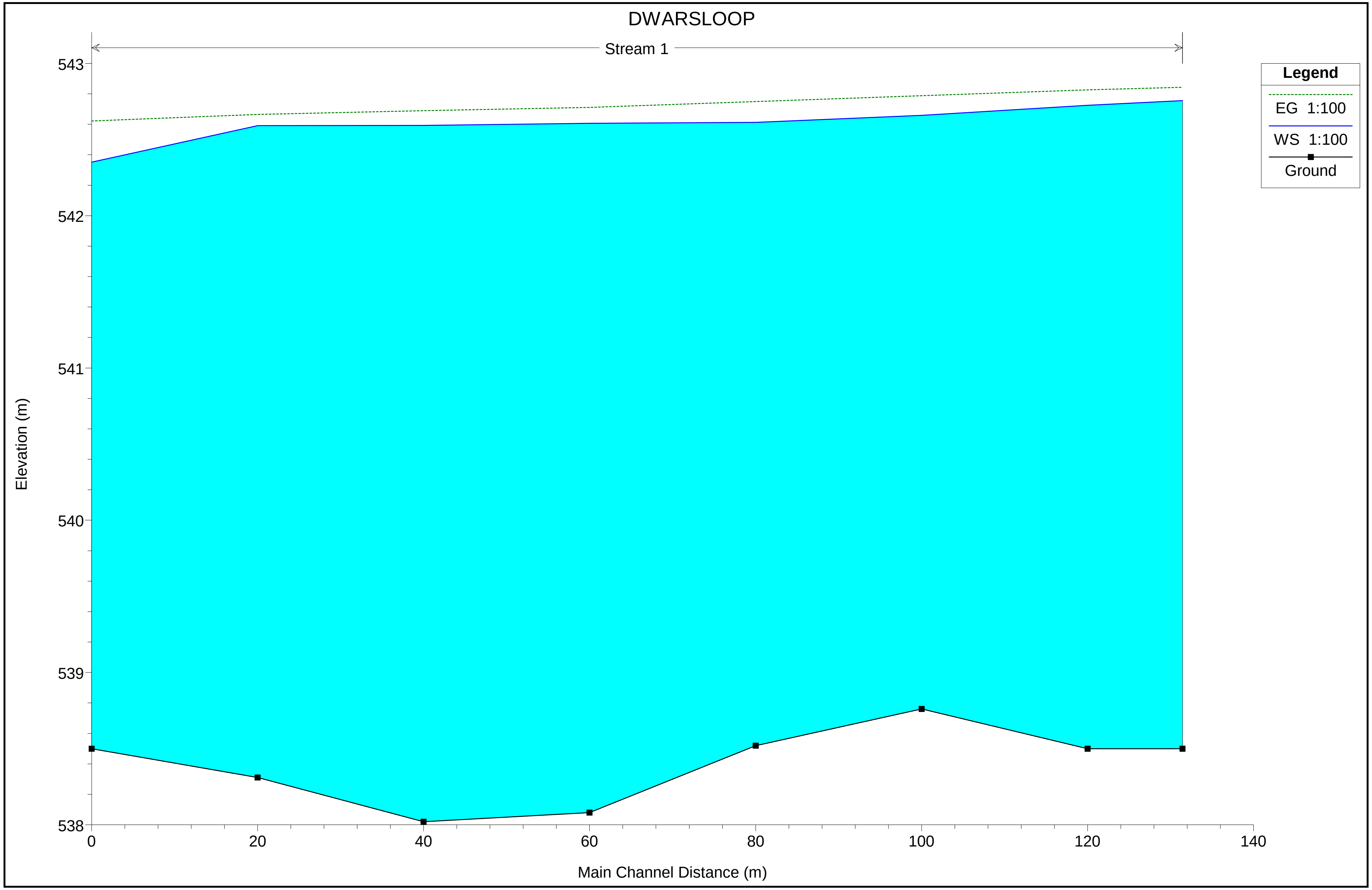
HEC-RAS Plan: Current mode River: Stream Reach: 4 Profile: 1:100

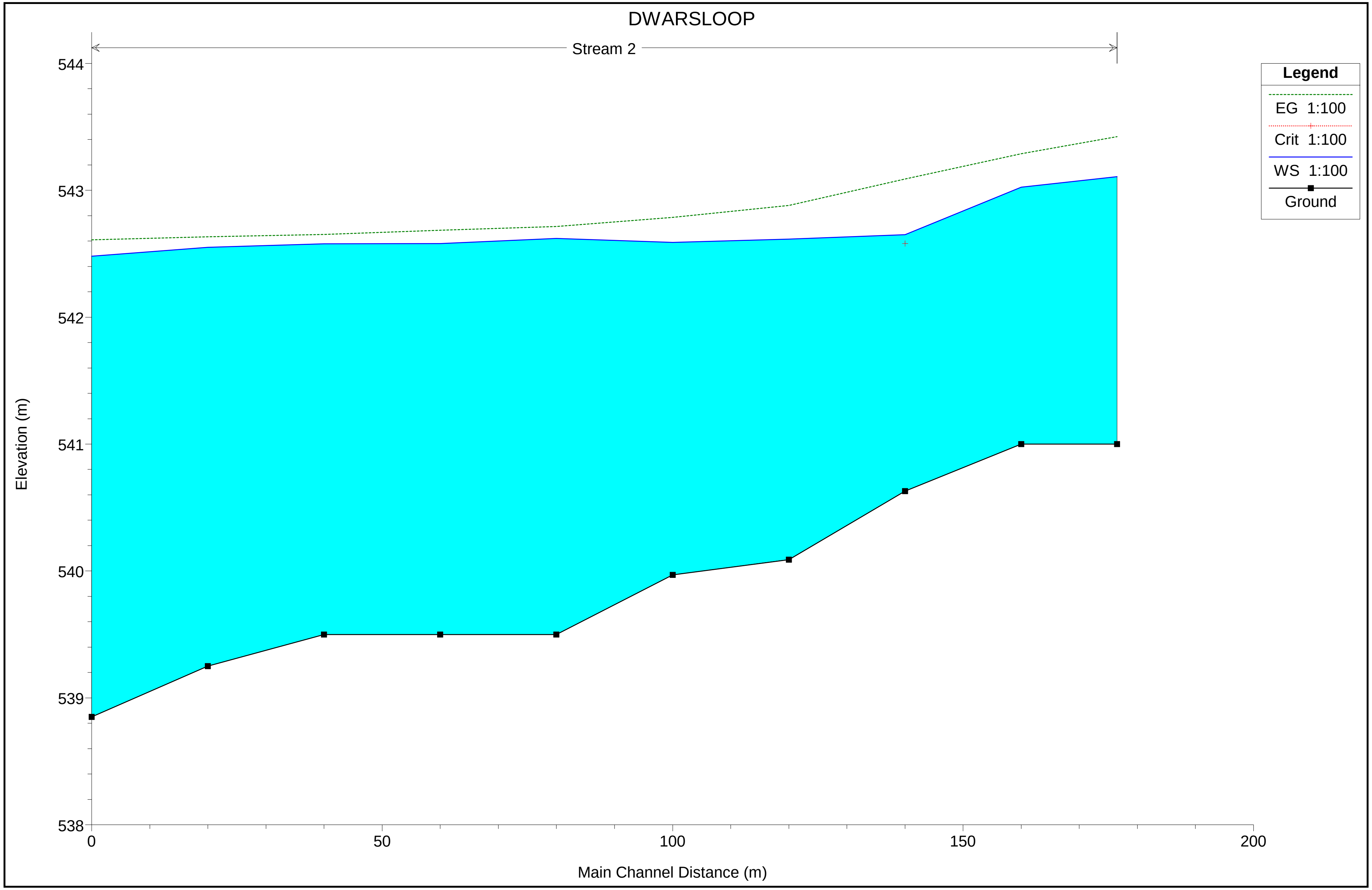
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
4	415	1:100	536.46	538.89	541.92		542.46	0.005205	3.55	189.83	90.15	0.68
4	414	1:100	536.46	538.50	542.05		542.31	0.002156	2.50	275.29	114.54	0.45
4	413	1:100	536.46	538.50	542.06		542.25	0.001673	2.18	324.92	140.63	0.39
4	412	1:100	536.46	538.33	542.07		542.21	0.001389	1.93	395.80	193.42	0.36
4	411	1:100	536.46	538.04	542.05		542.18	0.001338	1.88	401.91	192.97	0.35
4	410	1:100	536.46	537.99	542.03		542.15	0.001153	1.83	426.03	201.42	0.33
4	409	1:100	536.46	537.58	542.01		542.13	0.000939	1.78	448.07	199.09	0.30
4	408	1:100	536.46	537.50	541.99		542.11	0.000982	1.83	436.22	193.37	0.31
4	407	1:100	536.46	537.50	541.95		542.09	0.001073	1.93	416.81	191.36	0.32
4	406	1:100	536.46	537.50	541.91		542.06	0.001155	2.00	414.68	205.71	0.33
4	405	1:100	536.46	537.50	541.89		542.04	0.001131	2.04	423.06	199.91	0.33
4	404	1:100	536.46	537.50	541.85		542.01	0.001303	2.16	398.00	196.24	0.36
4	403	1:100	536.46	537.50	541.83		541.98	0.001196	2.07	411.29	206.51	0.34
4	402	1:100	536.46	537.50	541.77		541.95	0.001382	2.17	340.36	146.99	0.36
4	401	1:100	536.46	537.50	541.48		541.89	0.002670	2.95	213.95	92.40	0.50

HEC-RAS Plan: Current mode River: Stream Reach: 5 Profile: 1:100

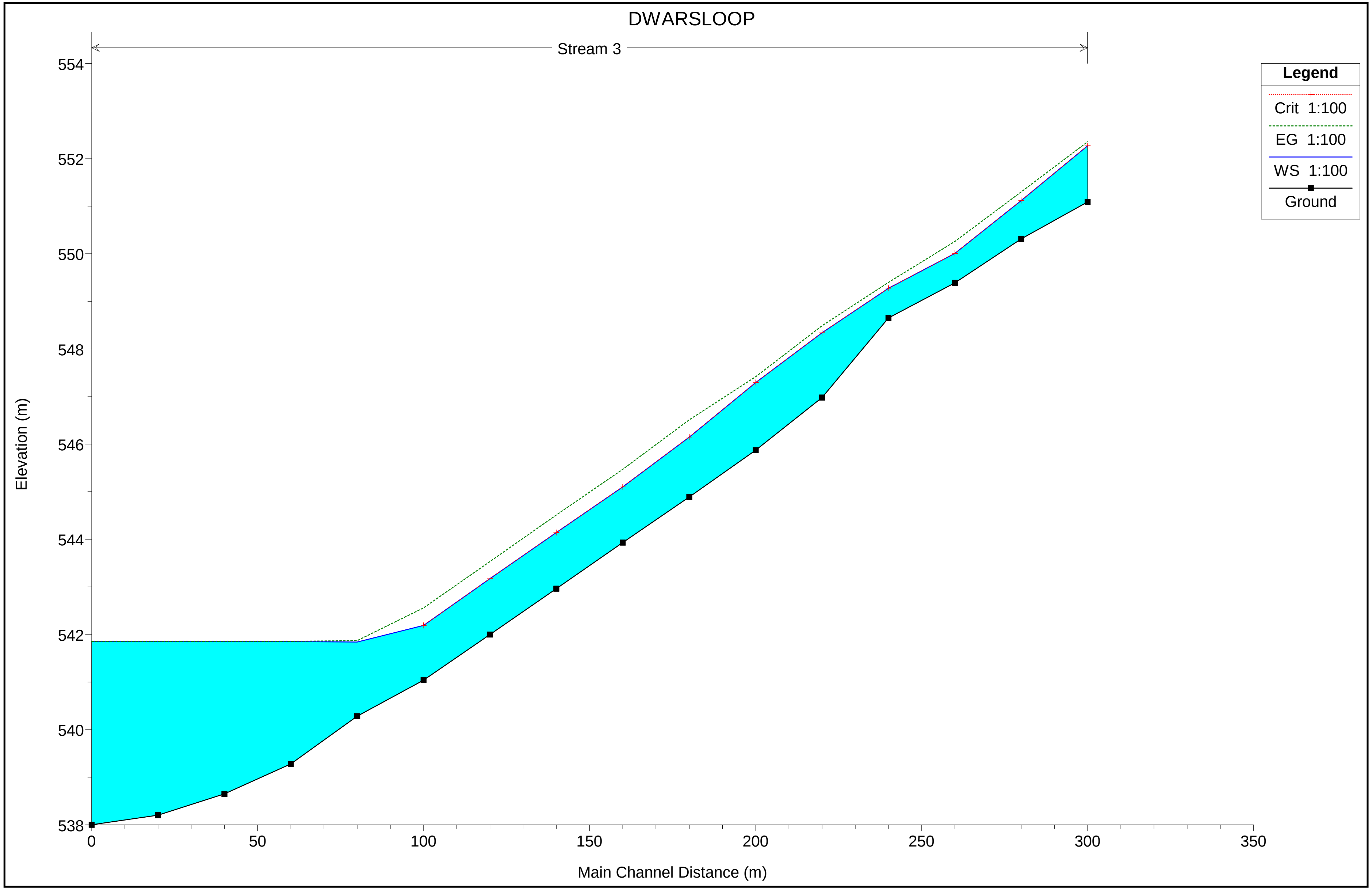
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
5	511	1:100	565.00	537.30	541.46		541.78	0.002287	2.67	276.61	142.33	0.46
5	510	1:100	565.00	537.09	541.43		541.75	0.002228	2.66	271.43	148.82	0.46
5	509	1:100	565.00	537.00	541.33		541.70	0.002718	2.79	254.09	152.12	0.50
5	508	1:100	565.00	537.58	540.78	540.78	541.56	0.009773	4.07	168.32	129.68	0.89
5	507	1:100	565.00	537.29	540.42	540.42	541.20	0.010167	4.09	165.98	123.37	0.90
5	506	1:100	565.00	536.86	540.16	539.90	540.78	0.006839	3.62	186.76	123.24	0.75
5	505	1:100	565.00	536.50	540.23		540.61	0.003504	2.90	242.79	141.33	0.55
5	504	1:100	565.00	536.50	540.15		540.54	0.003842	2.90	238.71	138.85	0.57
5	503	1:100	565.00	536.57	540.06		540.46	0.004255	2.93	231.80	138.43	0.60
5	502	1:100	565.00	536.50	539.76	539.49	540.33	0.007104	3.47	189.06	121.55	0.75
5	501	1:100	565.00	536.30	539.44	539.36	540.15	0.010007	3.85	166.98	116.46	0.88

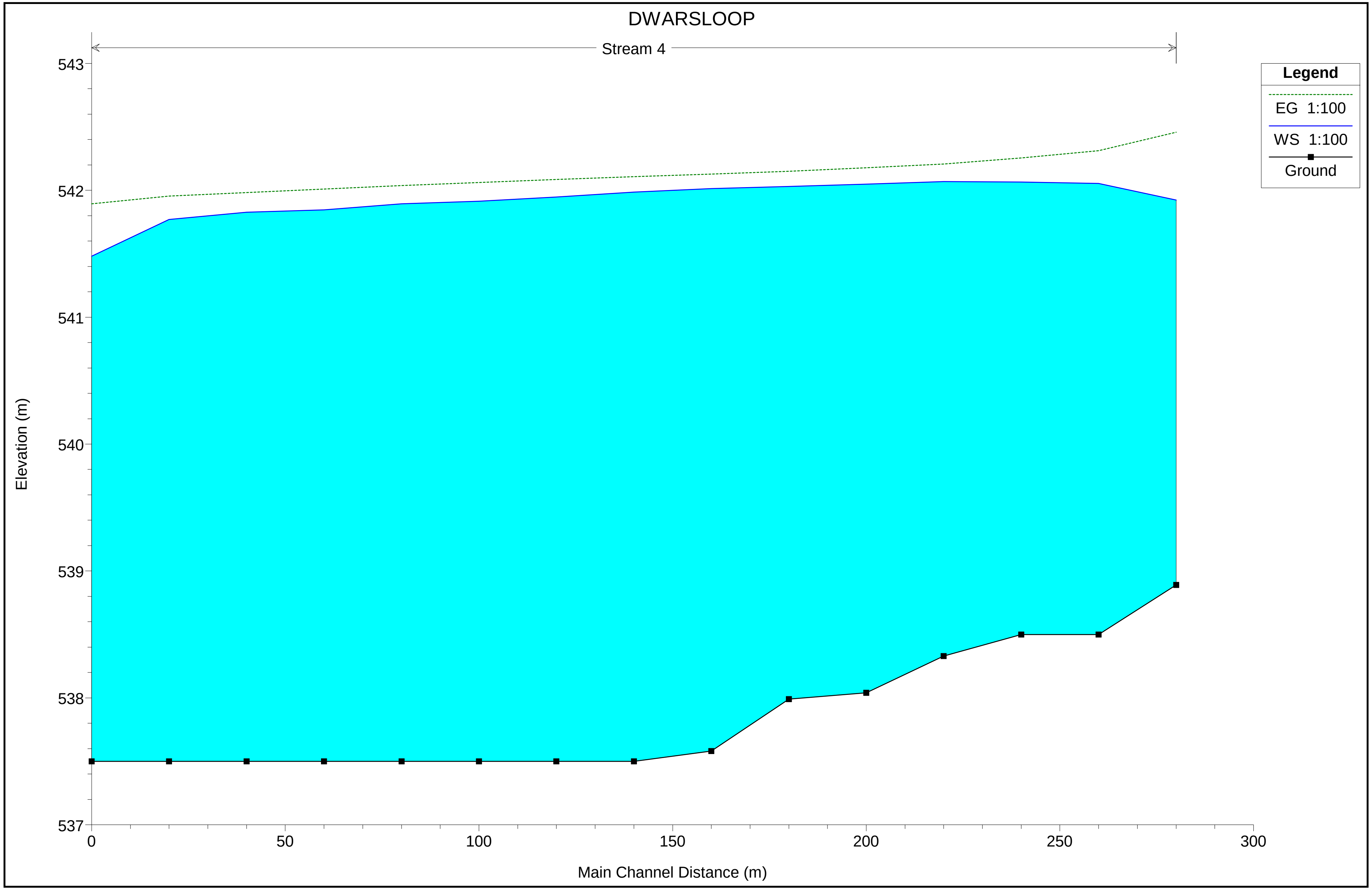
ANNEXURE 4: LONGITUDINAL FLOW PROFILE FOR THE FLOOD PEAK

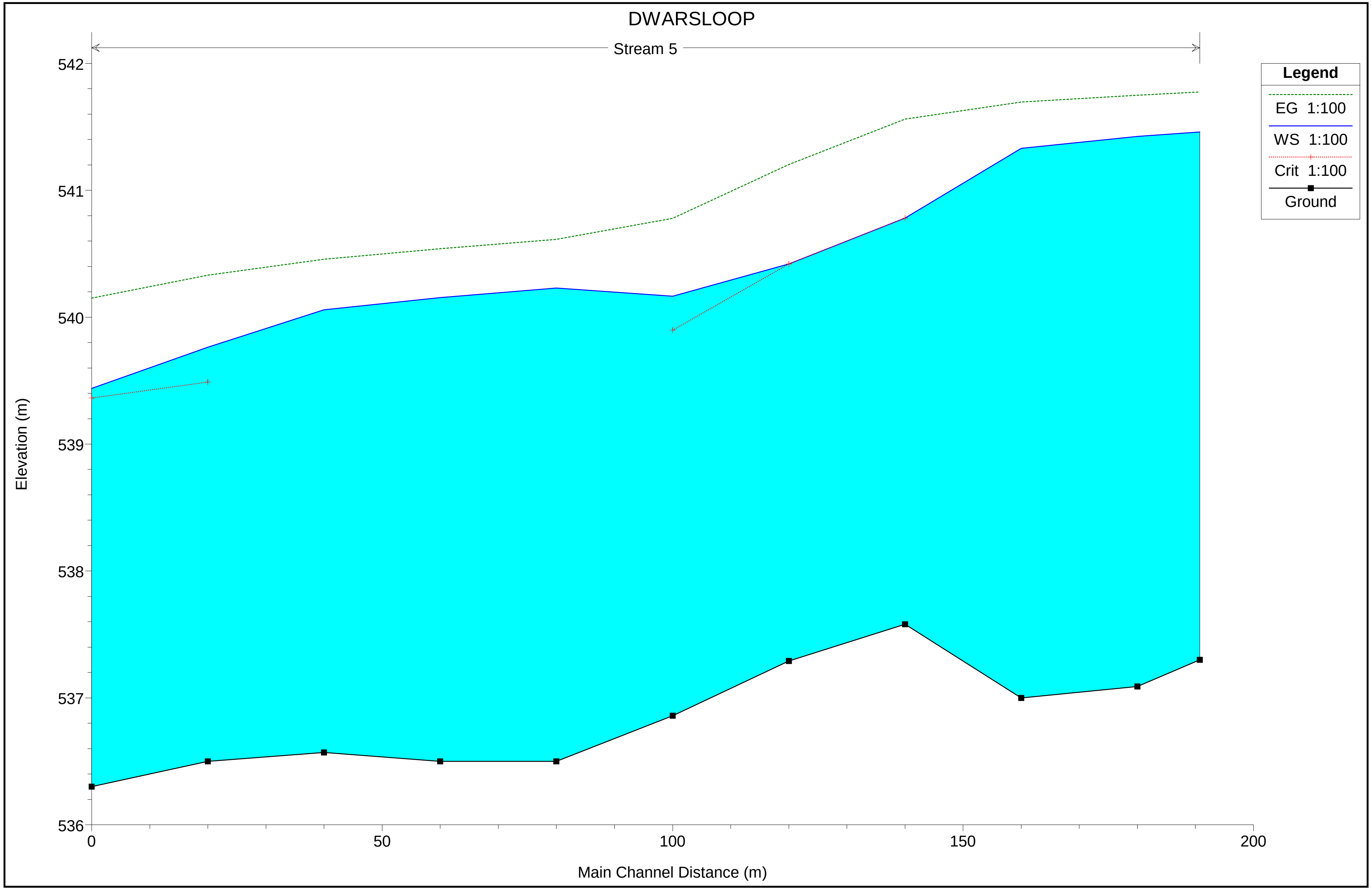

DWARSLOOP
Stream 1
Legend
EG 1:100
WS 1:100
Ground
Elevation (m)
543
542
541
540
539
538
0
20
40
60
80
100
120
140
Main Channel Distance (m)



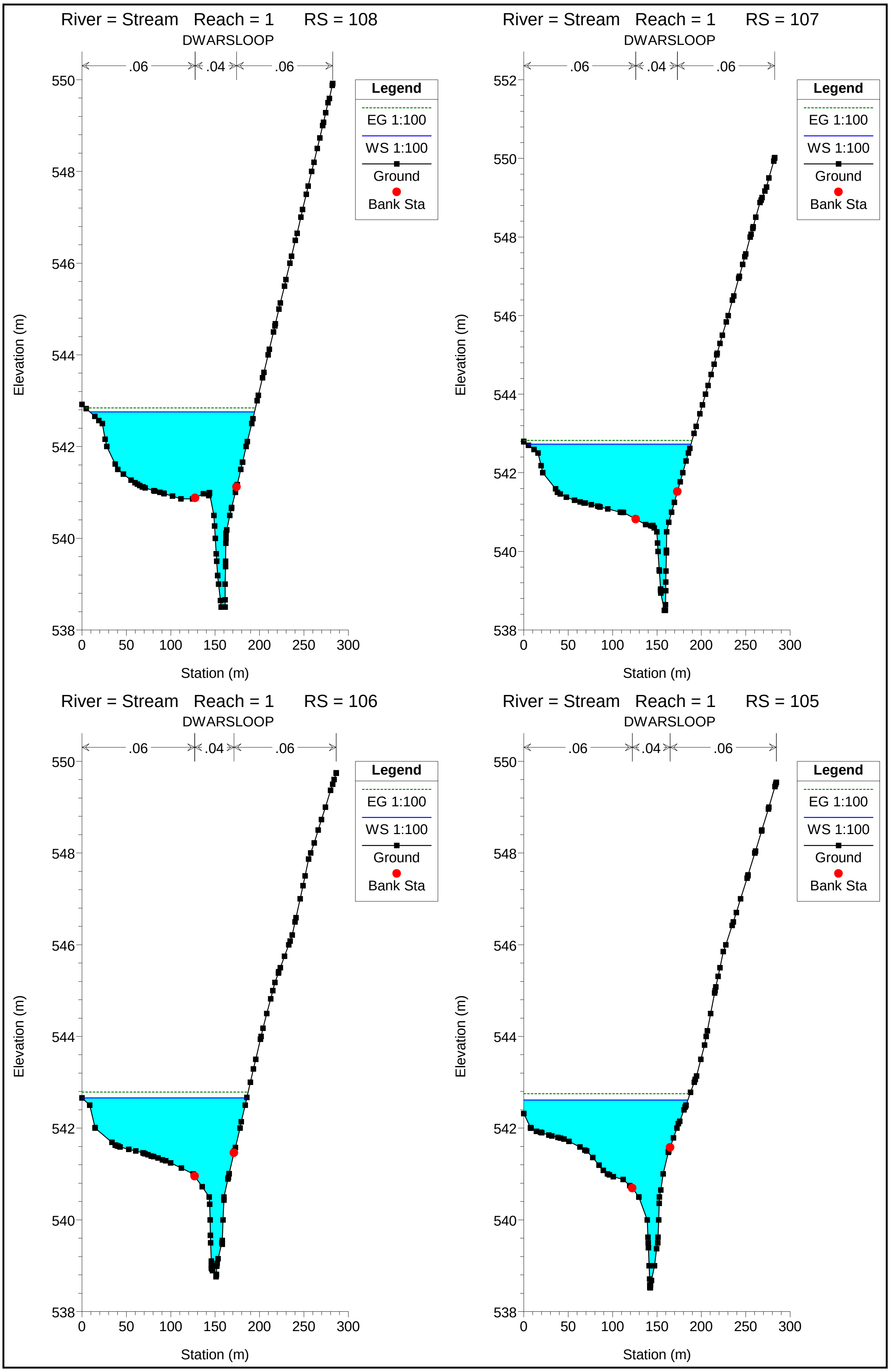
DWARSLOOP
Stream 2
Legend
EG 1:100
Crit 1:100
WS 1:100
Ground
Elevation (m)
544
543
542
541
540
539
538
0
50
100
150
200
Main Channel Distance (m)

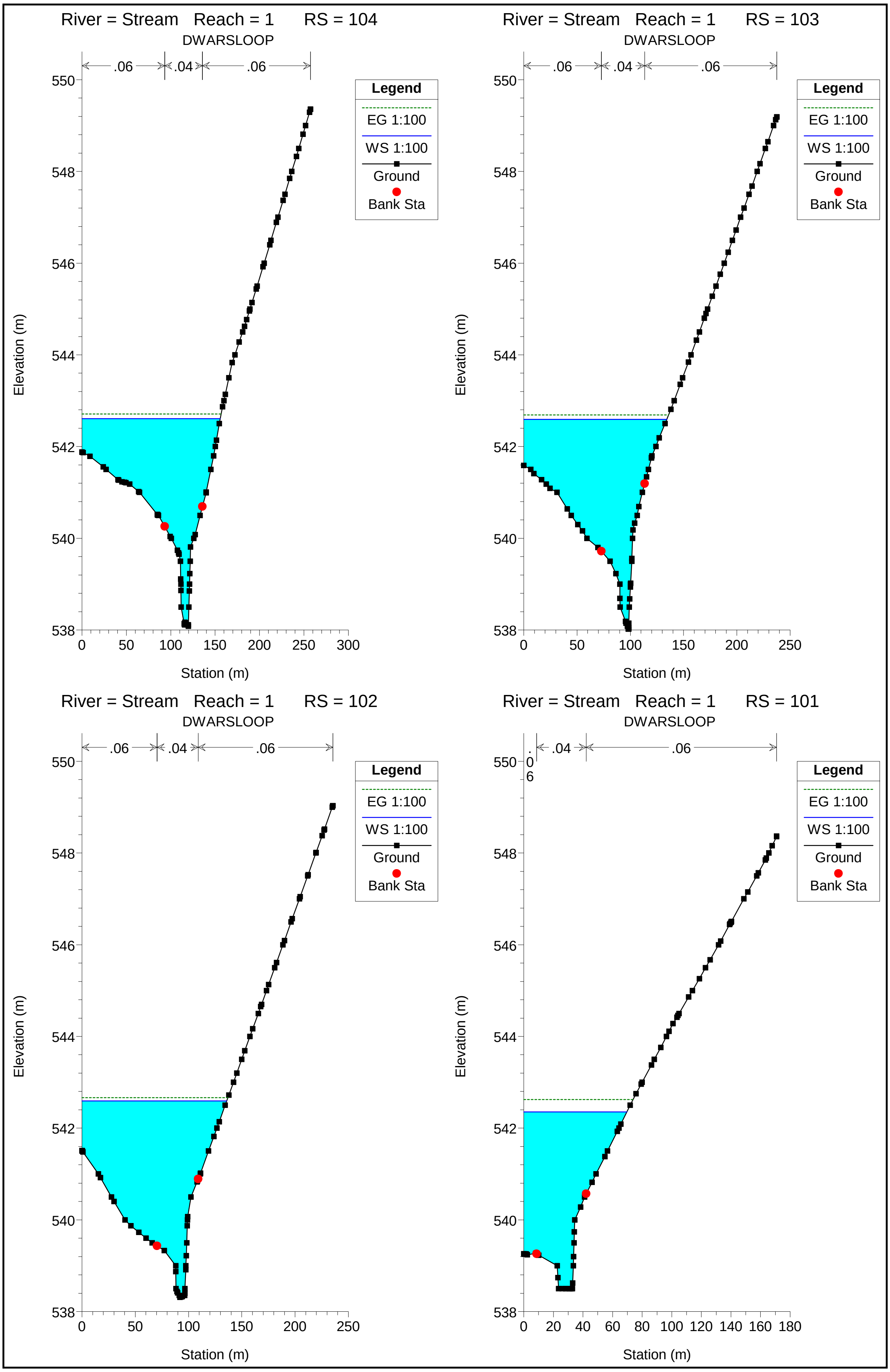

DWARSLOOP
Stream 3
Legend
Crit 1:100
EG 1:100
WS 1:100
Ground
554
552
550
548
546
544
542
540
538
Elevation (m)
0
50
100
150
200
250
300
350
Main Channel Distance (m)

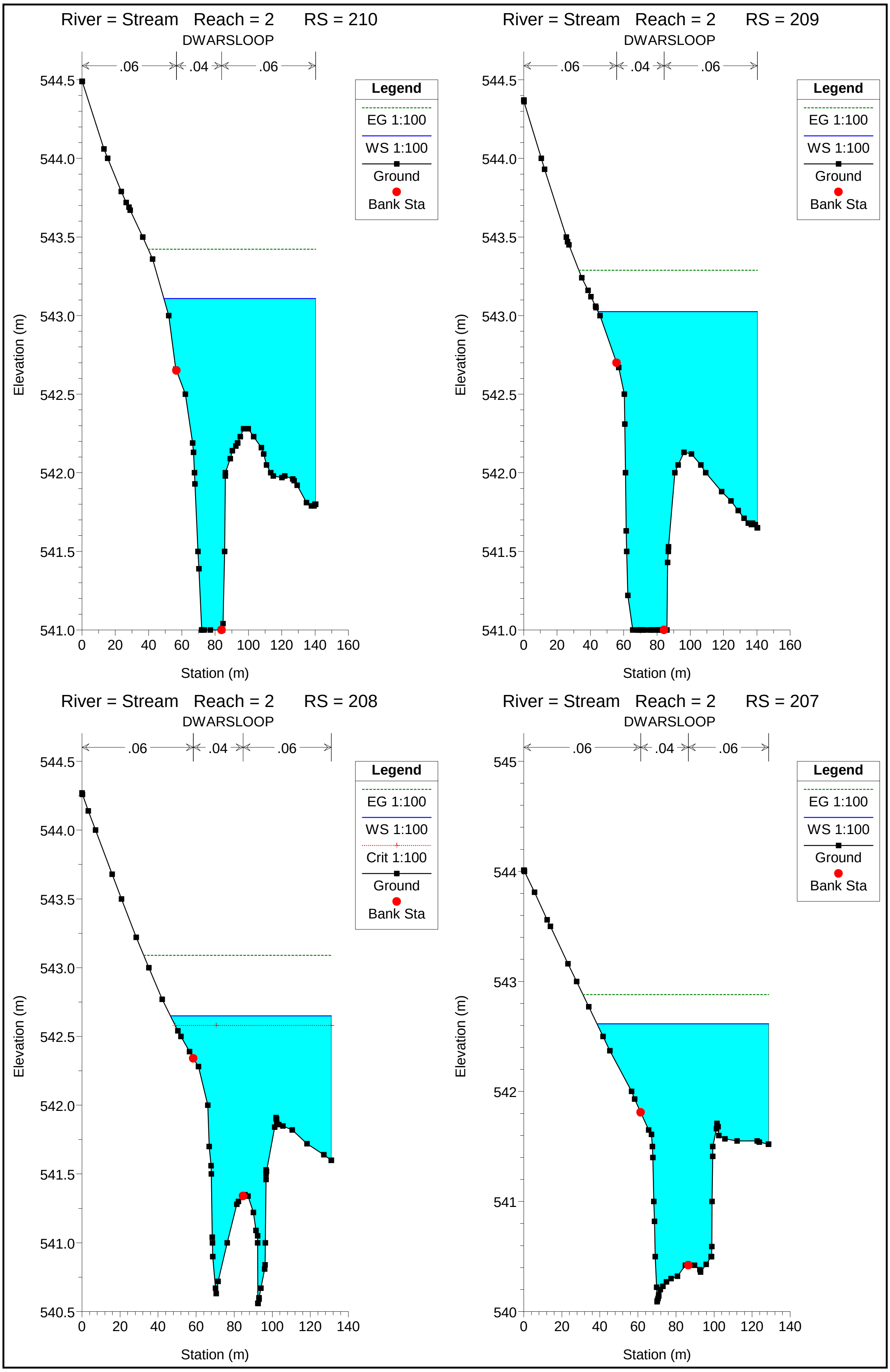

DWARSLOOP
Stream 4
Legend
EG 1:100
WS 1:100
Ground
Elevation (m)
543
542
541
540
539
538
537
0
50
100
150
200
250
300
Main Channel Distance (m)

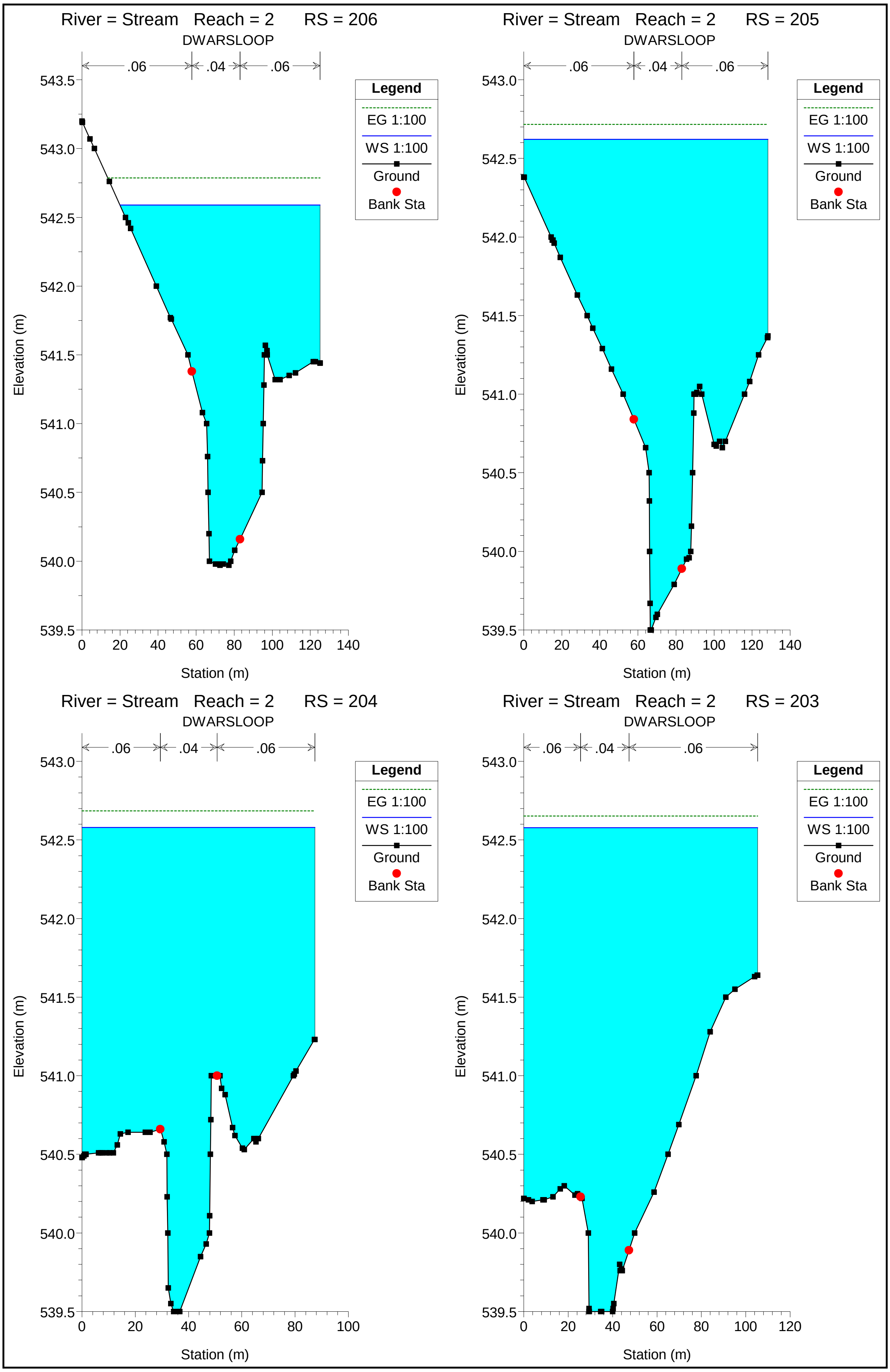

DWARSLOOP
Stream 5
Legend
EG 1:100
WS 1:100
Crit 1:100
Ground
Elevation (m)
542
541
540
539
538
537
536
0
50
100
150
200
Main Channel Distance (m)

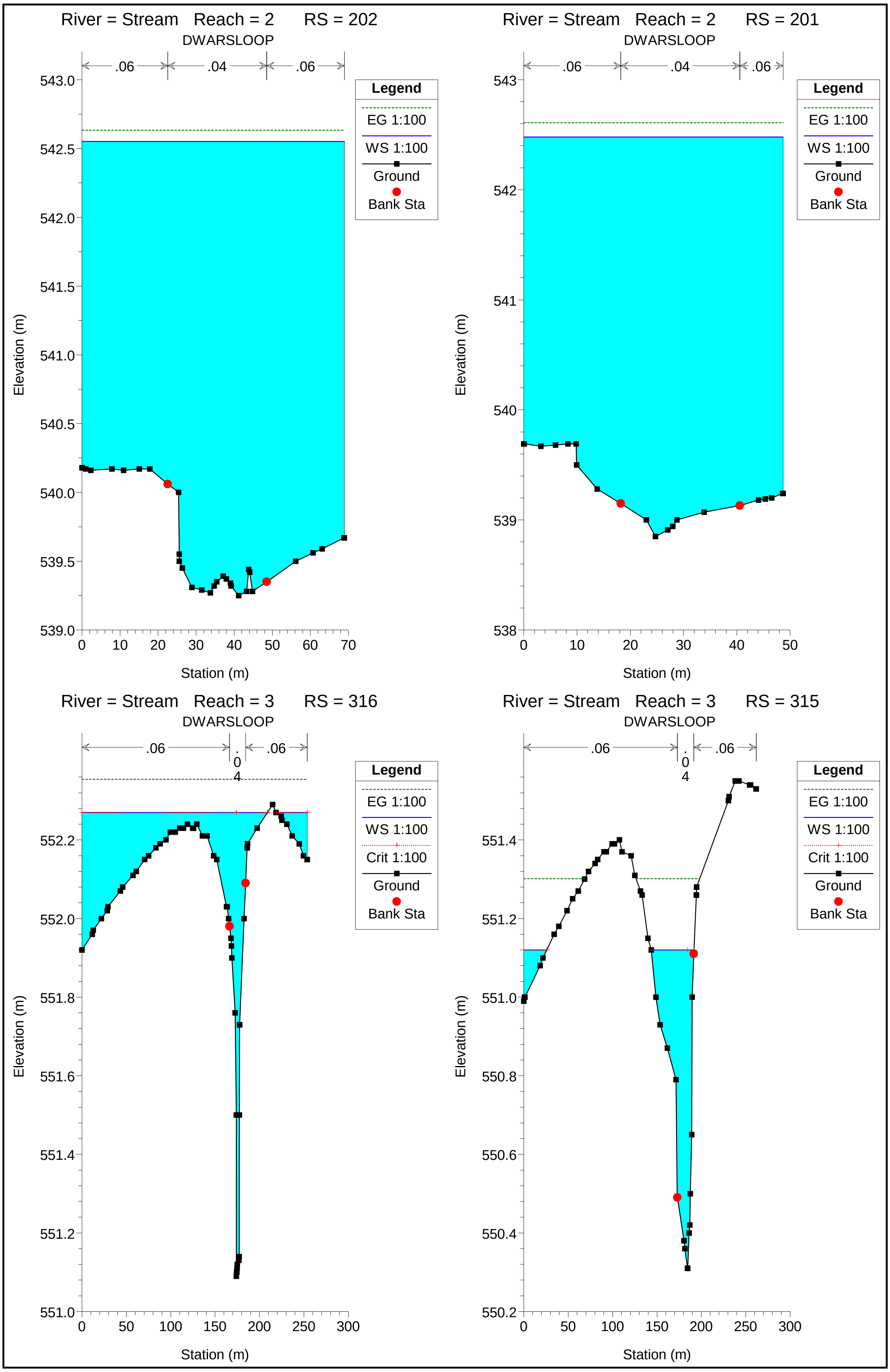
ANNEXURE 5: FLOW CROSS SECTIONS FOR THE FLOOD PEAK

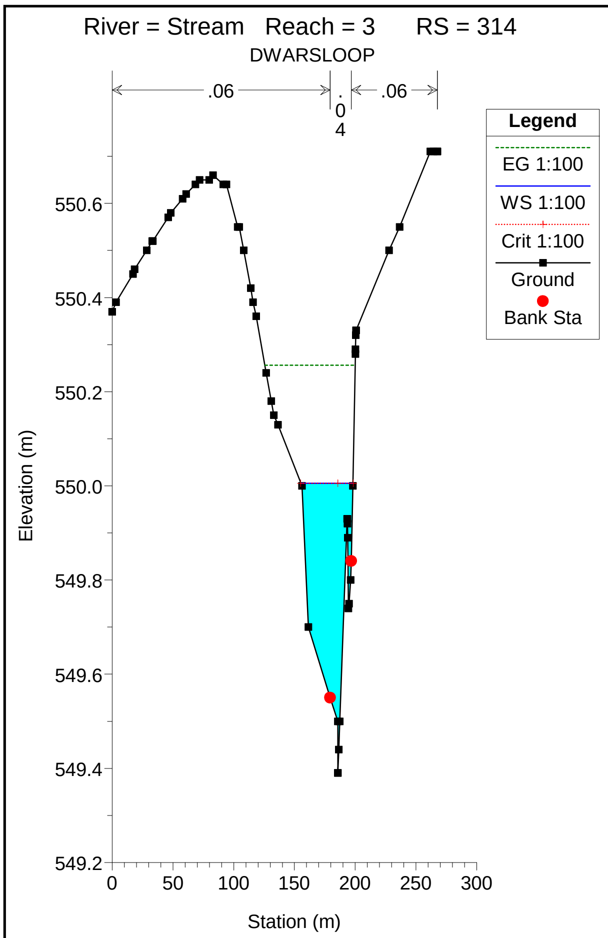

River = Stream Reach = 1 RS = 108
DWARSLOOP
.06
.04
.06
Legend
EG 1:100
WS 1:100
Ground
Bank Sta
Elevation (m)
Station (m)
River = Stream Reach = 1 RS = 107
DWARSLOOP
River = Stream Reach = 1 RS = 106
DWARSLOOP
River = Stream Reach = 1 RS = 105
DWARSLOOP

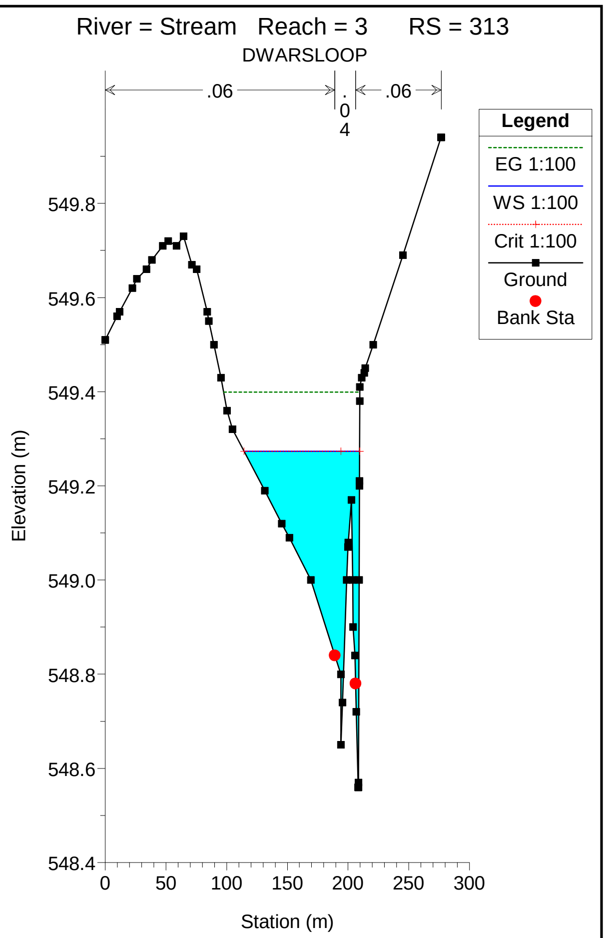

River = Stream Reach = 1 RS = 104
DWARSLOOP
.06
.04
.06
Legend
EG 1:100
WS 1:100
Ground
Bank Sta
Elevation (m)
550
548
546
544
542
540
538
0
50
100
150
200
250
300
Station (m)
River = Stream Reach = 1 RS = 103
DWARSLOOP
.06
.04
.06
Legend
EG 1:100
WS 1:100
Ground
Bank Sta
Elevation (m)
550
548
546
544
542
540
538
0
50
100
150
200
250
Station (m)
River = Stream Reach = 1 RS = 102
DWARSLOOP
.06
.04
.06
Legend
EG 1:100
WS 1:100
Ground
Bank Sta
Elevation (m)
550
548
546
544
542
540
538
0
50
100
150
200
250
Station (m)
River = Stream Reach = 1 RS = 101
DWARSLOOP
.06
.04
.06
Legend
EG 1:100
WS 1:100
Ground
Bank Sta
Elevation (m)
550
548
546
544
542
540
538
0
20
40
60
80
100
120
140
160
180
Station (m)

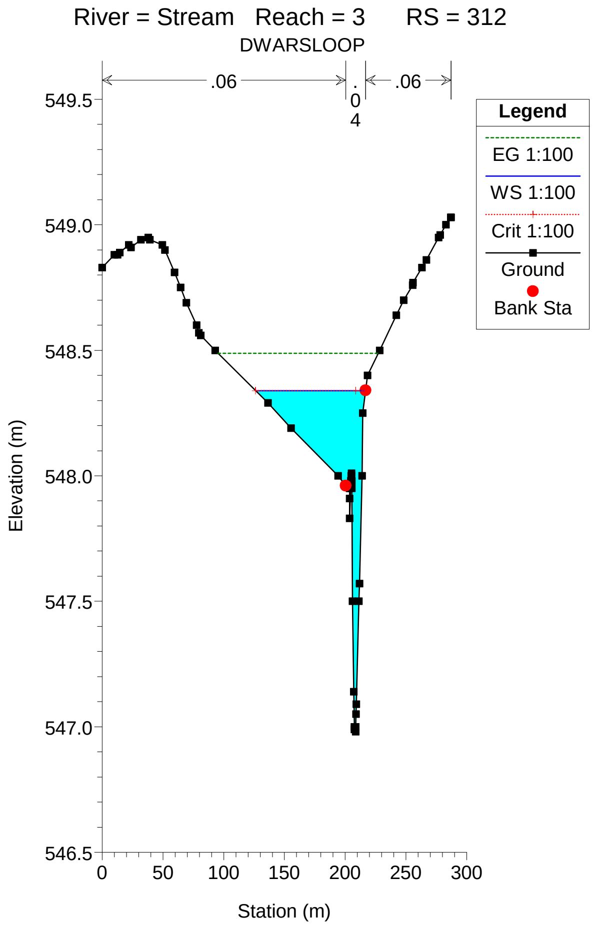

River = Stream Reach = 2 RS = 210
DWARSLOOP
.06 .04 .06
Legend
EG 1:100
WS 1:100
Ground
Bank Sta
Elevation (m)
Station (m)
River = Stream Reach = 2 RS = 209
DWARSLOOP
.06 .04 .06
Legend
EG 1:100
WS 1:100
Ground
Bank Sta
Elevation (m)
Station (m)
River = Stream Reach = 2 RS = 208
DWARSLOOP
.06 .04 .06
Legend
EG 1:100
WS 1:100
Crit 1:100
Ground
Bank Sta
Elevation (m)
Station (m)
River = Stream Reach = 2 RS = 207
DWARSLOOP
.06 .04 .06
Legend
EG 1:100
WS 1:100
Ground
Bank Sta
Elevation (m)
Station (m)

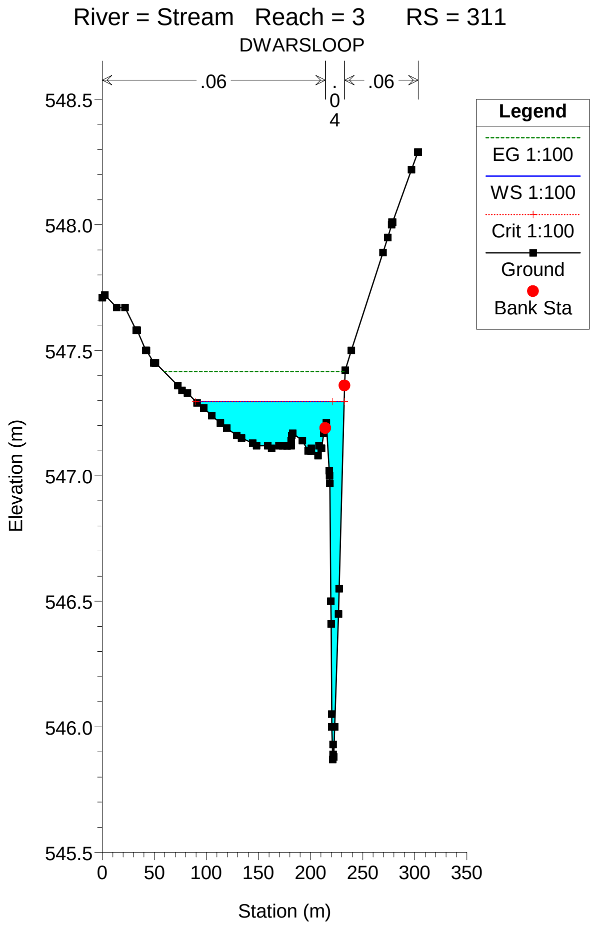

River = Stream Reach = 2 RS = 206
DWARSLOOP
.06
.04
.06
Legend
EG 1:100
WS 1:100
Ground
Bank Sta
Elevation (m)
543.5
543.0
542.5
542.0
541.5
541.0
540.5
540.0
539.5
0
20
40
60
80
100
120
140
Station (m)
River = Stream Reach = 2 RS = 205
DWARSLOOP
.06
.04
.06
Legend
EG 1:100
WS 1:100
Ground
Bank Sta
Elevation (m)
543.0
542.5
542.0
541.5
541.0
540.5
540.0
539.5
0
20
40
60
80
100
120
140
Station (m)
River = Stream Reach = 2 RS = 204
DWARSLOOP
.06
.04
.06
Legend
EG 1:100
WS 1:100
Ground
Bank Sta
Elevation (m)
543.0
542.5
542.0
541.5
541.0
540.5
540.0
539.5
0
20
40
60
80
100
Station (m)
River = Stream Reach = 2 RS = 203
DWARSLOOP
.06
.04
.06
Legend
EG 1:100
WS 1:100
Ground
Bank Sta
Elevation (m)
543.0
542.5
542.0
541.5
541.0
540.5
540.0
539.5
0
20
40
60
80
100
120
Station (m)

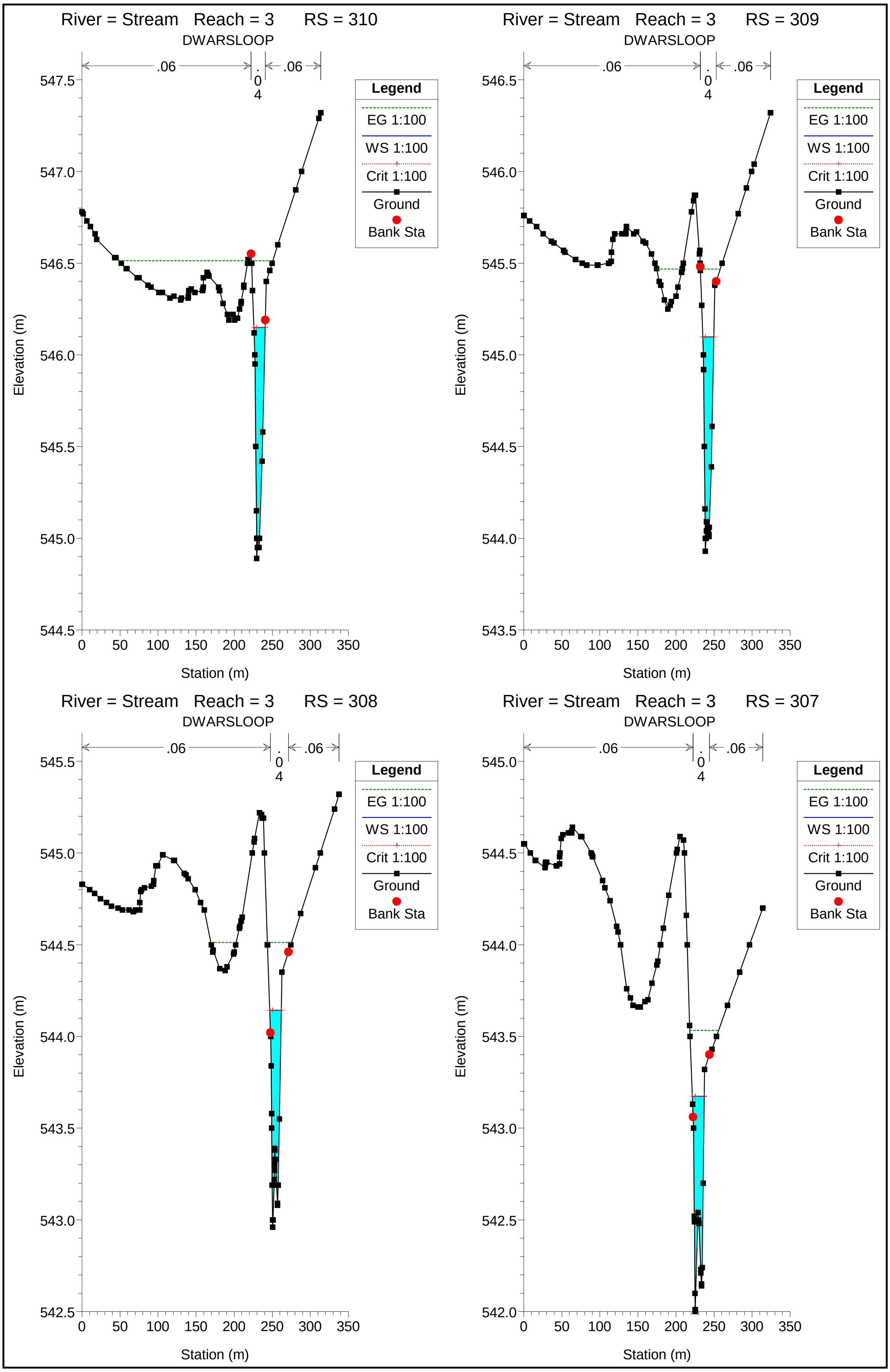

River = Stream Reach = 2 RS = 202
DWARSLOOP
.06 .04 .06
Legend
EG 1:100
WS 1:100
Ground
Bank Sta
Elevation (m)
543.0
542.5
542.0
541.5
541.0
540.5
540.0
539.5
539.0
0 10 20 30 40 50 60 70
Station (m)
River = Stream Reach = 2 RS = 201
DWARSLOOP
.06 .04 .06
Legend
EG 1:100
WS 1:100
Ground
Bank Sta
Elevation (m)
543
542
541
540
539
538
0 10 20 30 40 50
Station (m)
River = Stream Reach = 3 RS = 316
DWARSLOOP
.06 .04 .06
Legend
EG 1:100
WS 1:100
Crit 1:100
Ground
Bank Sta
Elevation (m)
552.2
552.0
551.8
551.6
551.4
551.2
551.0
0 50 100 150 200 250 300
Station (m)
River = Stream Reach = 3 RS = 315
DWARSLOOP
.06 .04 .06
Legend
EG 1:100
WS 1:100
Crit 1:100
Ground
Bank Sta
Elevation (m)
551.4
551.2
551.0
550.8
550.6
550.4
550.2
0 50 100 150 200 250 300
Station (m)

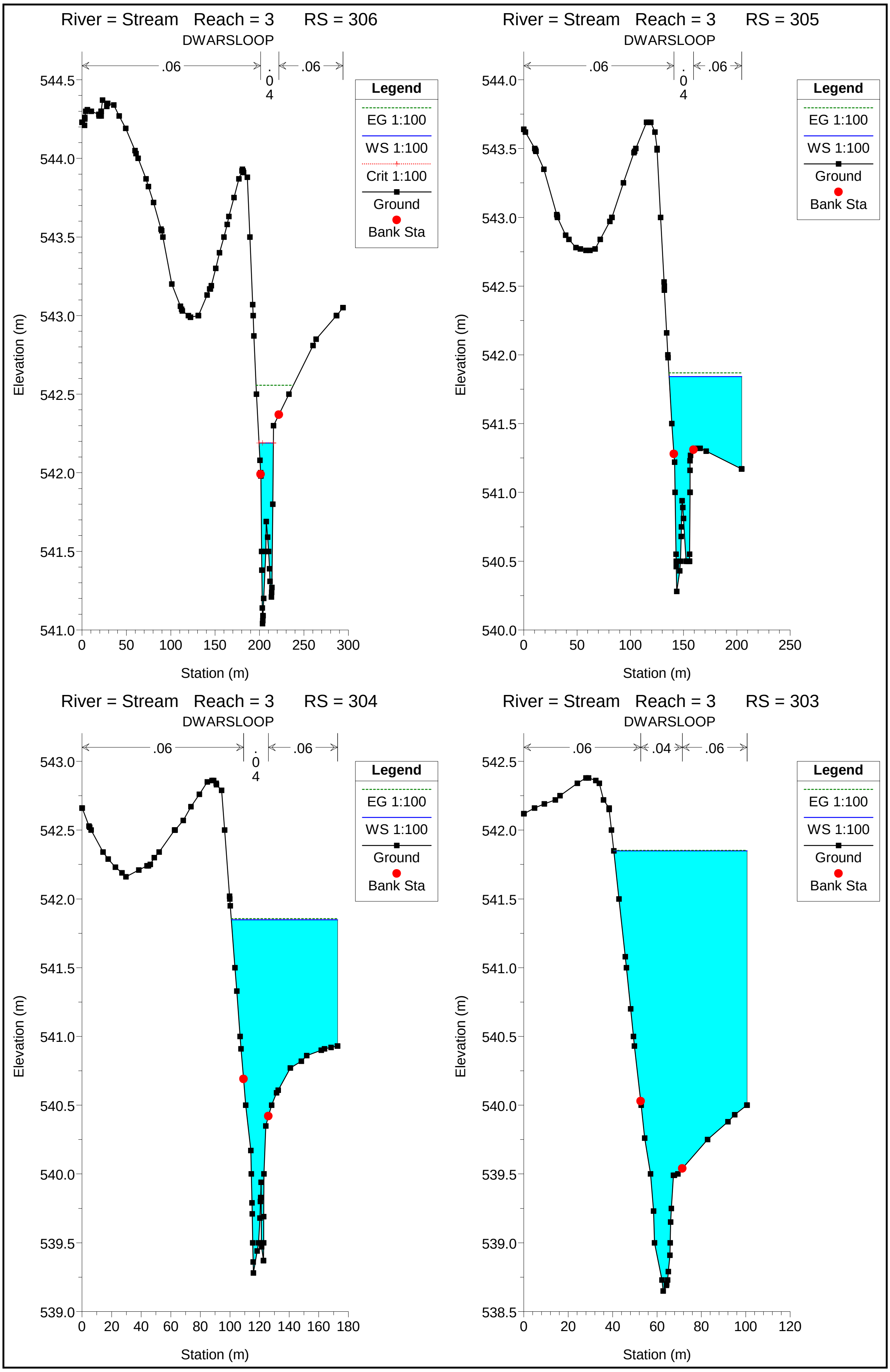

River = Stream Reach = 3 RS = 314
DWARSLOOP
.06
.04
.06
Elevation (m)
549.2
549.4
549.6
549.8
550.0
550.2
550.4
550.6
Station (m)
0
50
100
150
200
250
300
Legend
EG 1:100
WS 1:100
Crit 1:100
Ground
Bank Sta

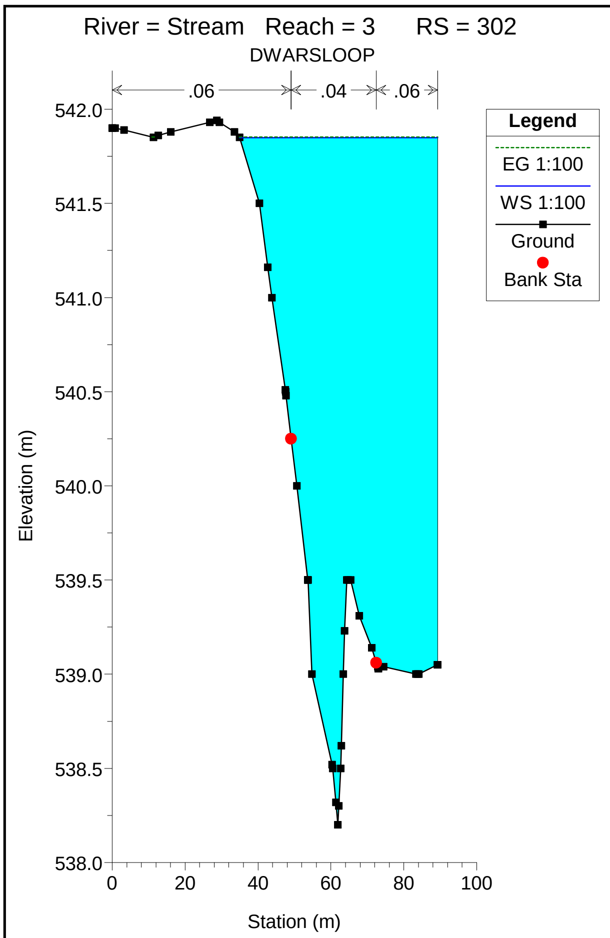

River = Stream Reach = 3 RS = 313
DWARSLOOP
.06
.04
.06
Elevation (m)
548.4
548.6
548.8
549.0
549.2
549.4
549.6
549.8
Station (m)
0
50
100
150
200
250
300
Legend
EG 1:100
WS 1:100
Crit 1:100
Ground
Bank Sta

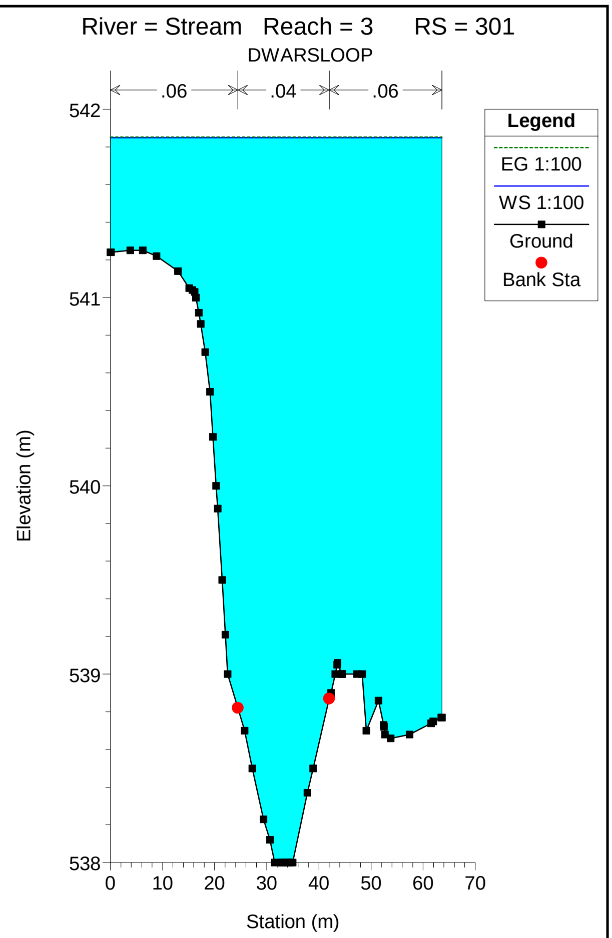

River = Stream Reach = 3 RS = 312
DWARSLOOP
.06
.04
.06
Elevation (m)
546.5
547.0
547.5
548.0
548.5
549.0
549.5
Station (m)
0
50
100
150
200
250
300
Legend
EG 1:100
WS 1:100
Crit 1:100
Ground
Bank Sta

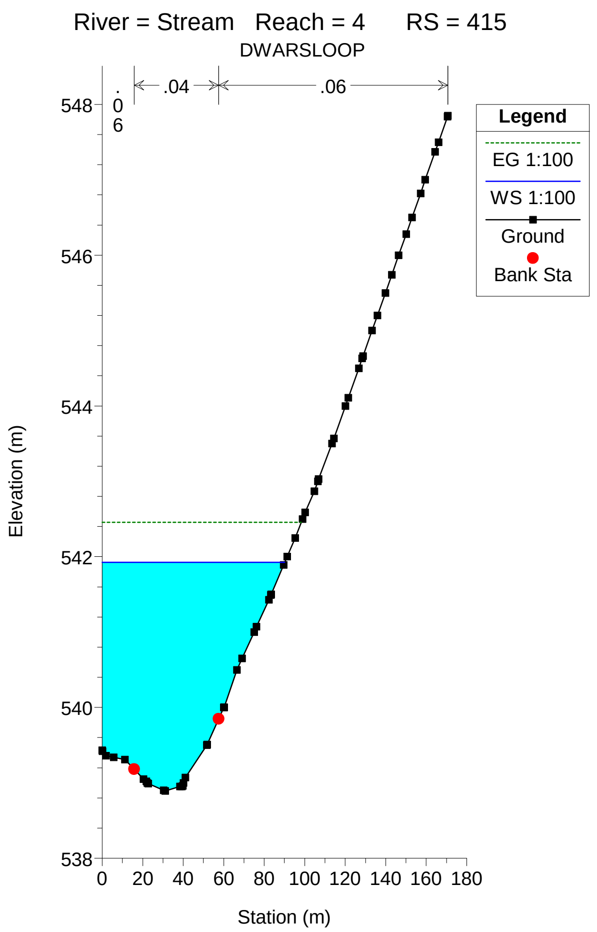

River = Stream Reach = 3 RS = 311
DWARSLOOP
.06
.04
.06
Elevation (m)
545.5
546.0
546.5
547.0
547.5
548.0
548.5
Station (m)
0
50
100
150
200
250
300
350
Legend
EG 1:100
WS 1:100
Crit 1:100
Ground
Bank Sta

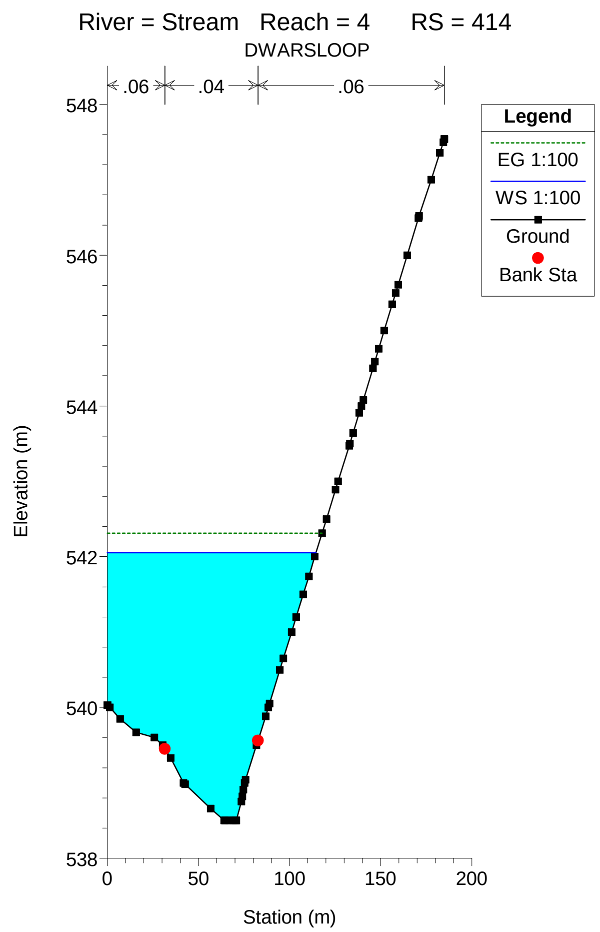

River = Stream Reach = 3 RS = 310
DWARSLOOP
Legend
EG 1:100
WS 1:100
Crit 1:100
Ground
Bank Sta
Elevation (m)
Station (m)
River = Stream Reach = 3 RS = 309
DWARSLOOP
River = Stream Reach = 3 RS = 308
DWARSLOOP
River = Stream Reach = 3 RS = 307
DWARSLOOP

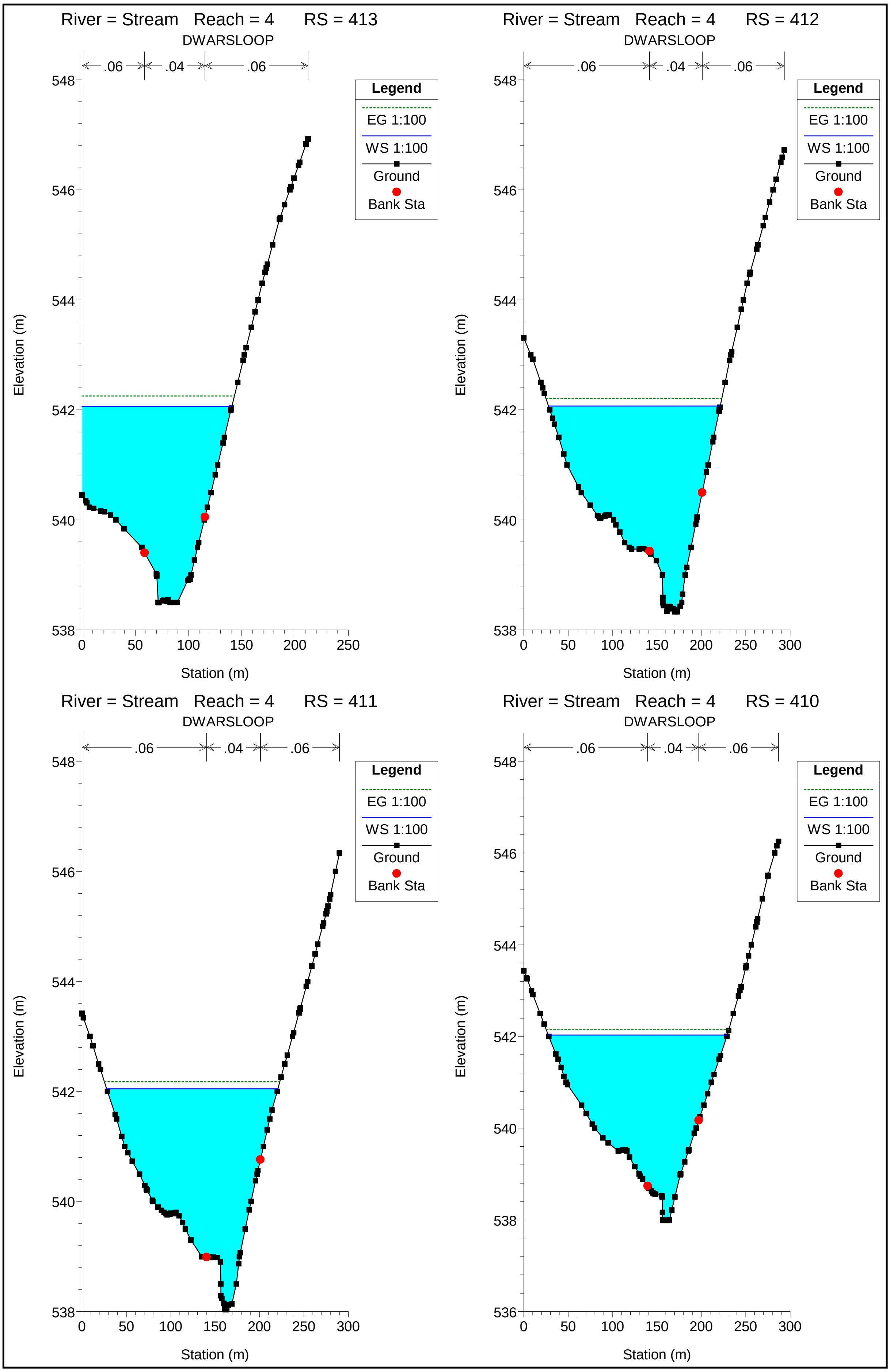

River = Stream Reach = 3 RS = 306
DWARSLOOP
.06
.04
.06
Legend
EG 1:100
WS 1:100
Crit 1:100
Ground
Bank Sta
Elevation (m)
Station (m)
River = Stream Reach = 3 RS = 305
DWARSLOOP
.06
.04
.06
Legend
EG 1:100
WS 1:100
Ground
Bank Sta
Elevation (m)
Station (m)
River = Stream Reach = 3 RS = 304
DWARSLOOP
.06
.04
.06
Legend
EG 1:100
WS 1:100
Ground
Bank Sta
Elevation (m)
Station (m)
River = Stream Reach = 3 RS = 303
DWARSLOOP
.06
.04
.06
Legend
EG 1:100
WS 1:100
Ground
Bank Sta
Elevation (m)
Station (m)

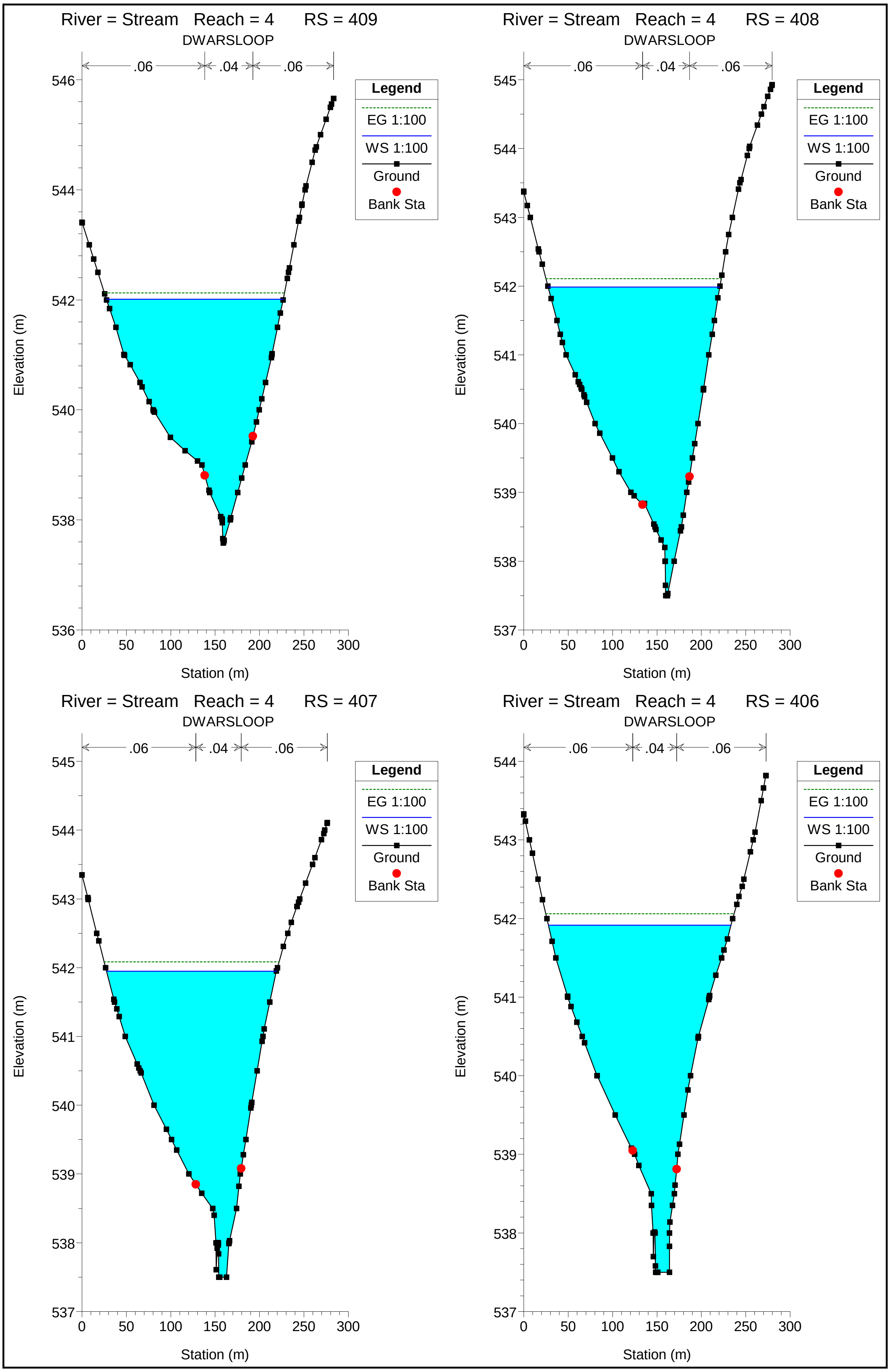

River = Stream Reach = 3 RS = 302
DWARSLOOP
.06 .04 .06
Legend
EG 1:100
WS 1:100
Ground
Bank Sta
Elevation (m)
542.0
541.5
541.0
540.5
540.0
539.5
539.0
538.5
538.0
0 20 40 60 80 100
Station (m)

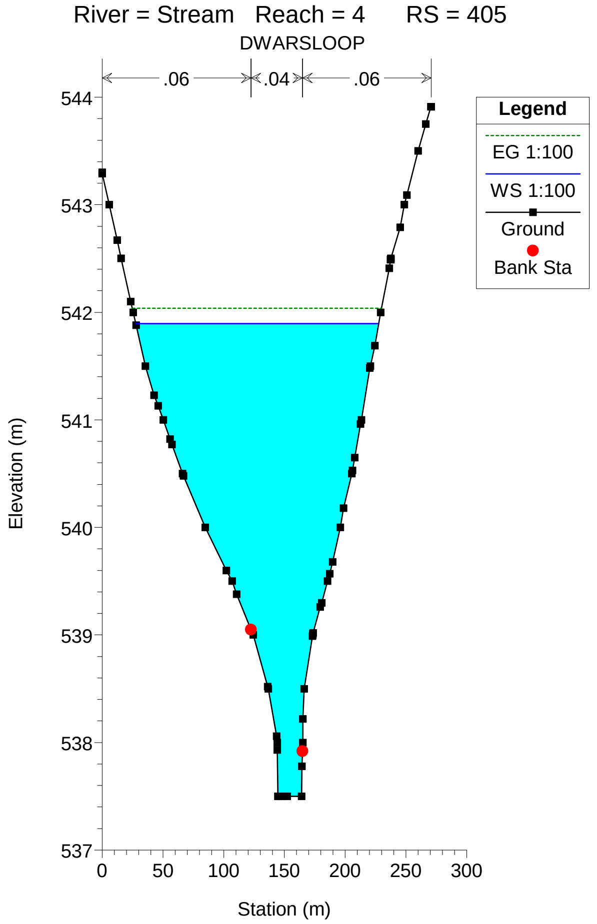

River = Stream Reach = 3 RS = 301
DWARSLOOP
.06 .04 .06
Legend
EG 1:100
WS 1:100
Ground
Bank Sta
Elevation (m)
542
541
540
539
538
0 10 20 30 40 50 60 70
Station (m)

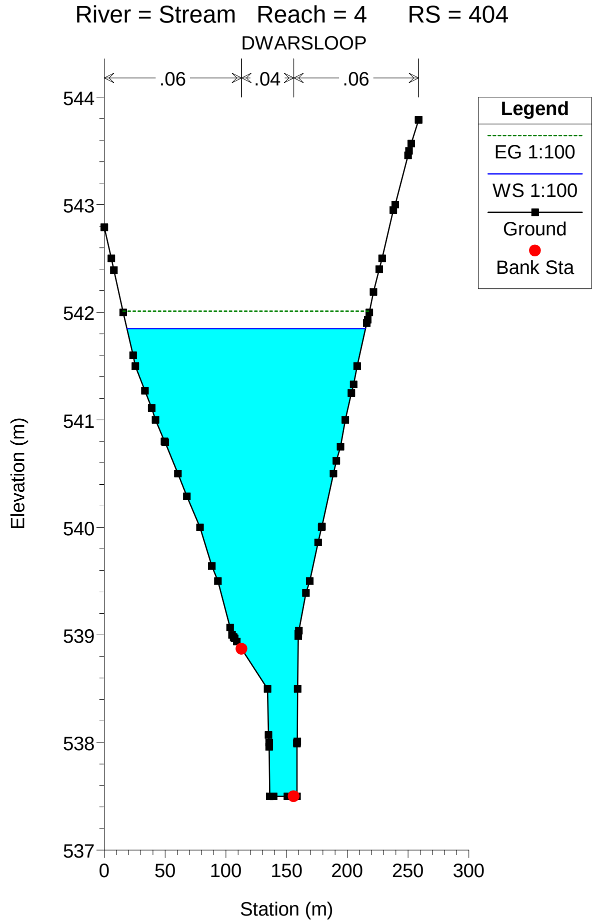

River = Stream Reach = 4 RS = 415
DWARSLOOP
.06 .04 .06
Legend
EG 1:100
WS 1:100
Ground
Bank Sta
Elevation (m)
548
546
544
542
540
538
0 20 40 60 80 100 120 140 160 180
Station (m)

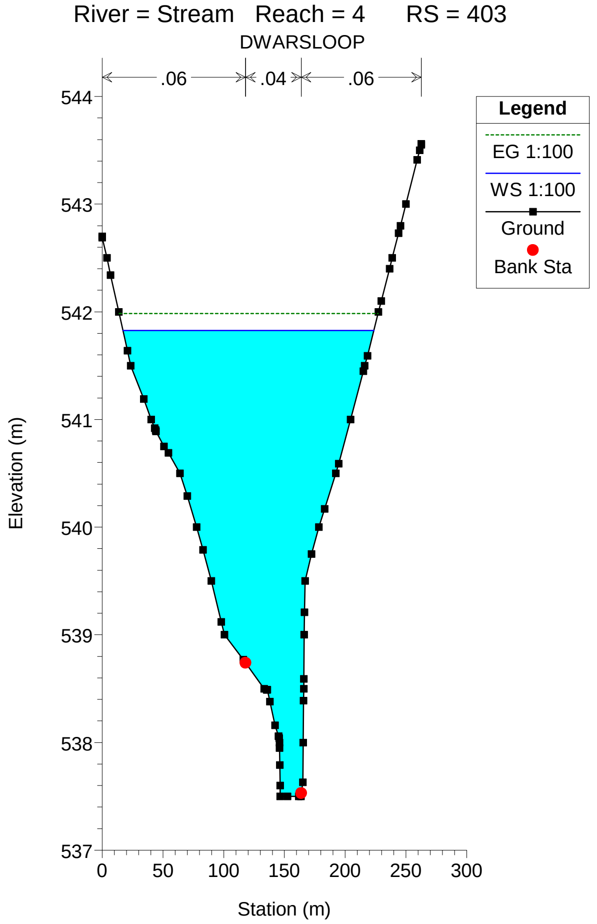

River = Stream Reach = 4 RS = 414
DWARSLOOP
.06 .04 .06
Legend
EG 1:100
WS 1:100
Ground
Bank Sta
Elevation (m)
548
546
544
542
540
538
0 50 100 150 200
Station (m)

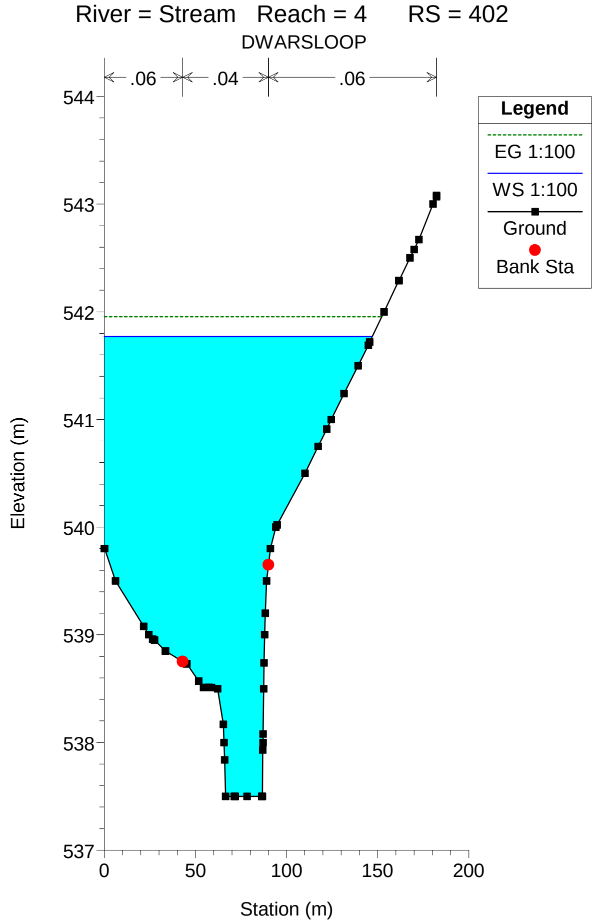

River = Stream Reach = 4 RS = 413
DWARSLOOP
.06 .04 .06
Legend
EG 1:100
WS 1:100
Ground
Bank Sta
Elevation (m)
Station (m)
548
546
544
542
540
538
0 50 100 150 200 250
River = Stream Reach = 4 RS = 412
DWARSLOOP
.06 .04 .06
Legend
EG 1:100
WS 1:100
Ground
Bank Sta
Elevation (m)
Station (m)
548
546
544
542
540
538
0 50 100 150 200 250 300
River = Stream Reach = 4 RS = 411
DWARSLOOP
.06 .04 .06
Legend
EG 1:100
WS 1:100
Ground
Bank Sta
Elevation (m)
Station (m)
548
546
544
542
540
538
0 50 100 150 200 250 300
River = Stream Reach = 4 RS = 410
DWARSLOOP
.06 .04 .06
Legend
EG 1:100
WS 1:100
Ground
Bank Sta
Elevation (m)
Station (m)
548
546
544
542
540
538
536
0 50 100 150 200 250 300

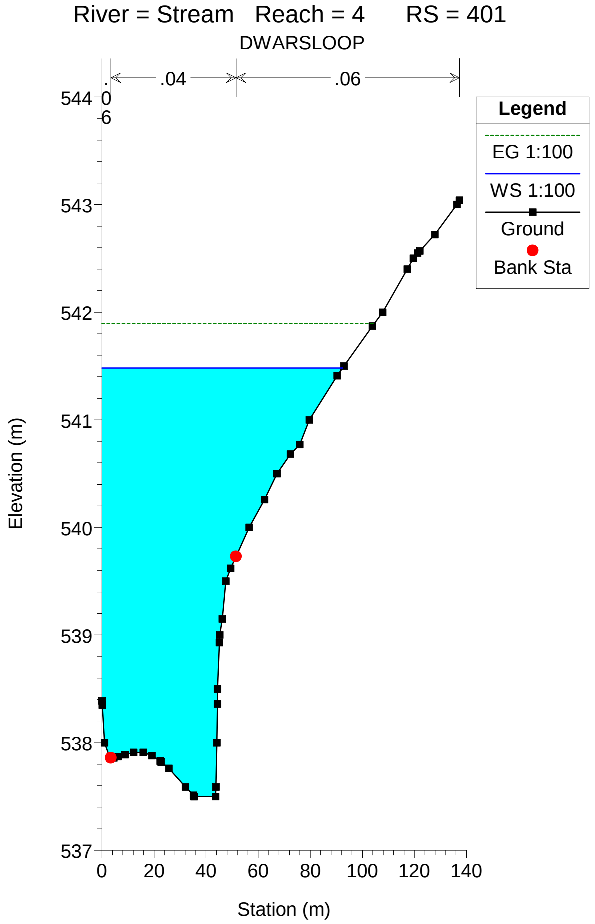

River = Stream Reach = 4 RS = 409
DWARSLOOP
.06
.04
.06
Legend
EG 1:100
WS 1:100
Ground
Bank Sta
Elevation (m)
Station (m)
536
538
540
542
544
546
0
50
100
150
200
250
300
River = Stream Reach = 4 RS = 408
DWARSLOOP
.06
.04
.06
Legend
EG 1:100
WS 1:100
Ground
Bank Sta
Elevation (m)
Station (m)
537
538
539
540
541
542
543
544
545
0
50
100
150
200
250
300
River = Stream Reach = 4 RS = 407
DWARSLOOP
.06
.04
.06
Legend
EG 1:100
WS 1:100
Ground
Bank Sta
Elevation (m)
Station (m)
537
538
539
540
541
542
543
544
545
0
50
100
150
200
250
300
River = Stream Reach = 4 RS = 406
DWARSLOOP
.06
.04
.06
Legend
EG 1:100
WS 1:100
Ground
Bank Sta
Elevation (m)
Station (m)
537
538
539
540
541
542
543
544
0
50
100
150
200
250
300

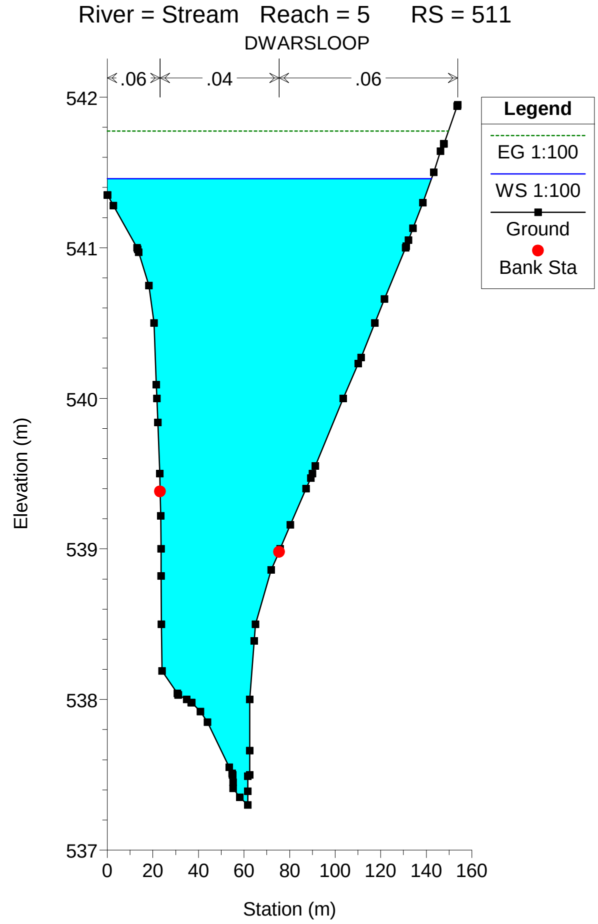

River = Stream Reach = 4 RS = 405
DWARSLOOP
.06
.04
.06
Legend
EG 1:100
WS 1:100
Ground
Bank Sta
Elevation (m)
Station (m)
537
538
539
540
541
542
543
544
0
50
100
150
200
250
300

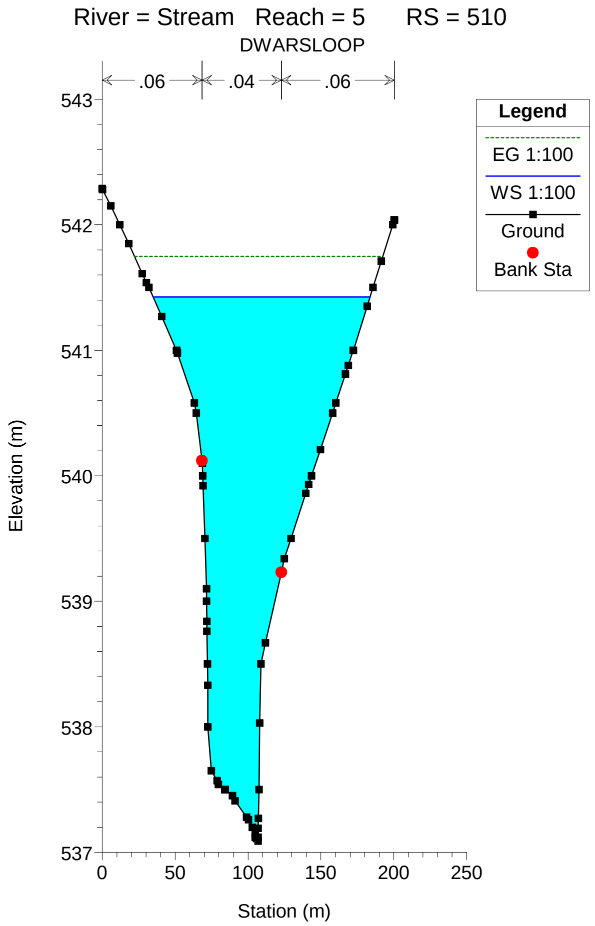

River = Stream Reach = 4 RS = 404
DWARSLOOP
.06
.04
.06
Legend
EG 1:100
WS 1:100
Ground
Bank Sta
Elevation (m)
Station (m)
537
538
539
540
541
542
543
544
0
50
100
150
200
250
300

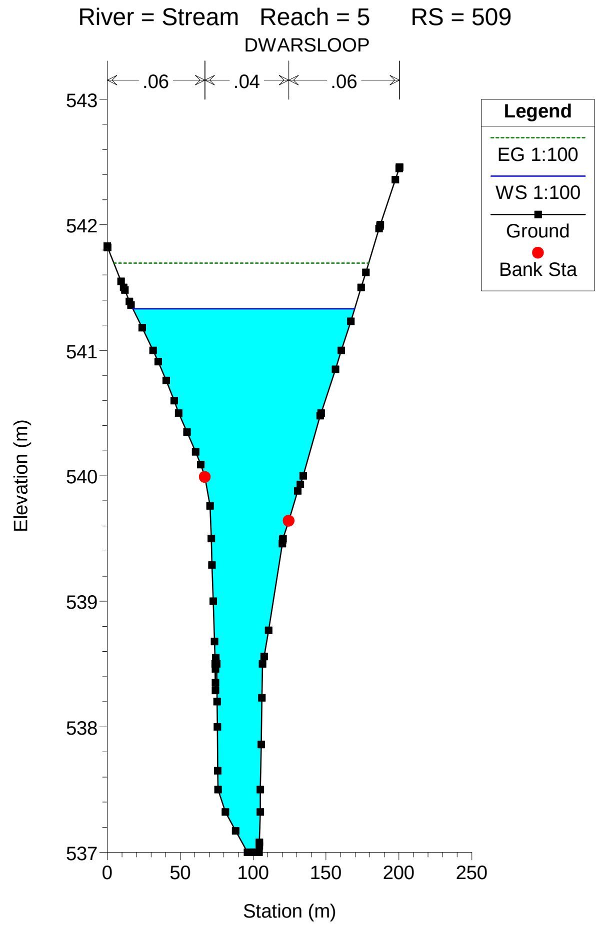

River = Stream Reach = 4 RS = 403
DWARSLOOP
.06
.04
.06
Legend
EG 1:100
WS 1:100
Ground
Bank Sta
Elevation (m)
Station (m)
537
538
539
540
541
542
543
544
0
50
100
150
200
250
300

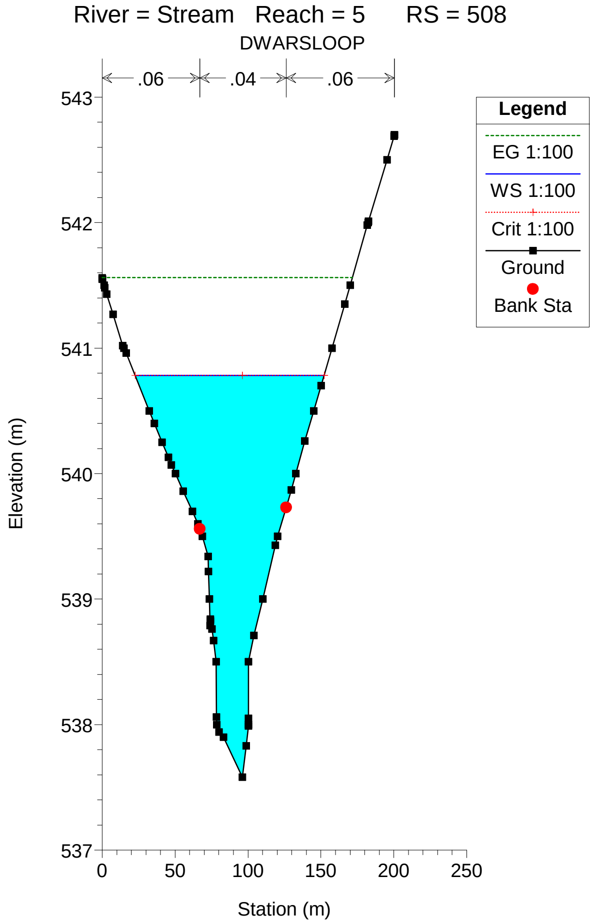

River = Stream Reach = 4 RS = 402
DWARSLOOP
.06
.04
.06
Legend
EG 1:100
WS 1:100
Ground
Bank Sta
Elevation (m)
Station (m)
537
538
539
540
541
542
543
544
0
50
100
150
200

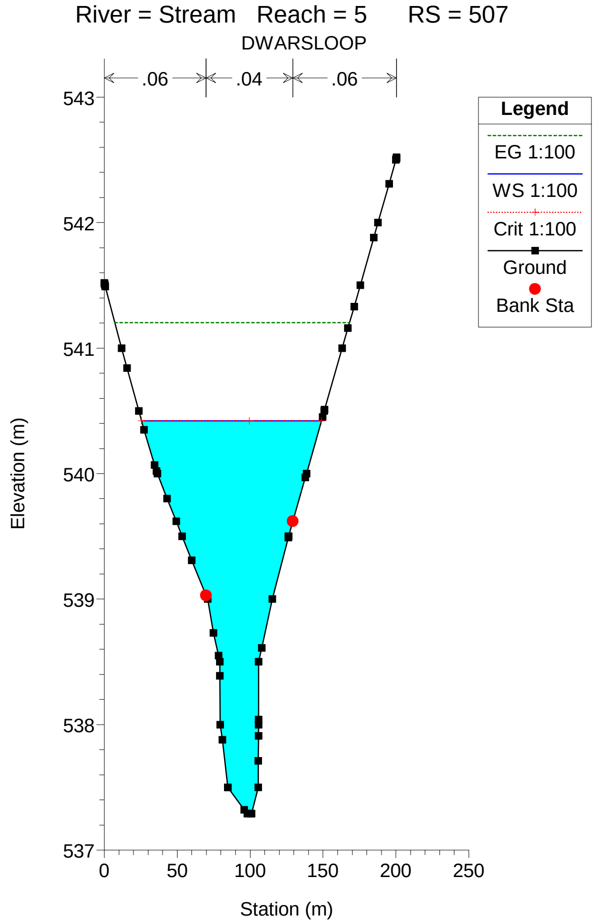

River = Stream Reach = 4 RS = 401
DWARSLOOP
.04
.06
.06
Legend
EG 1:100
WS 1:100
Ground
Bank Sta
Elevation (m)
544
543
542
541
540
539
538
537
0 20 40 60 80 100 120 140
Station (m)

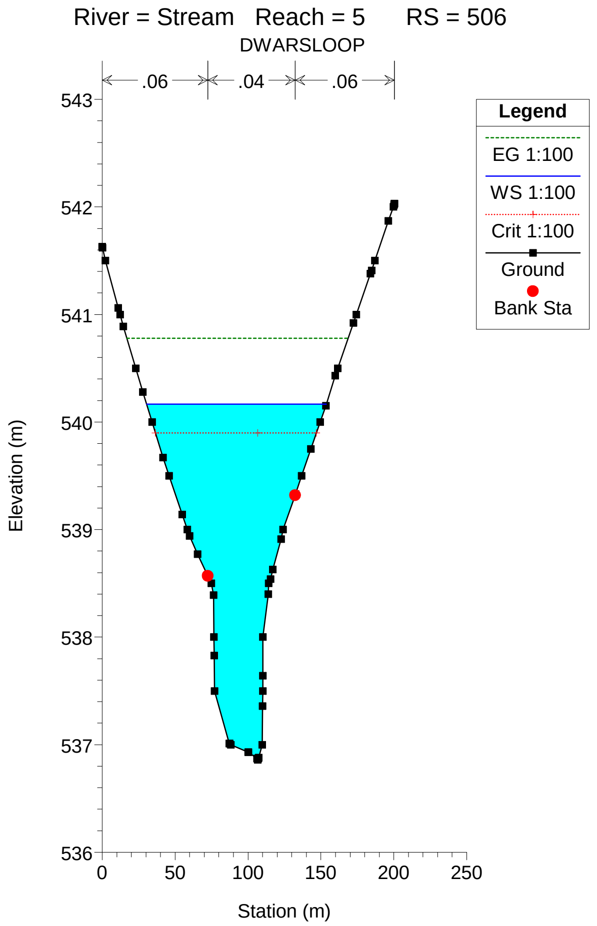

River = Stream Reach = 5 RS = 511
DWARSLOOP
.06
.04
.06
Legend
EG 1:100
WS 1:100
Ground
Bank Sta
Elevation (m)
542
541
540
539
538
537
0 20 40 60 80 100 120 140 160
Station (m)

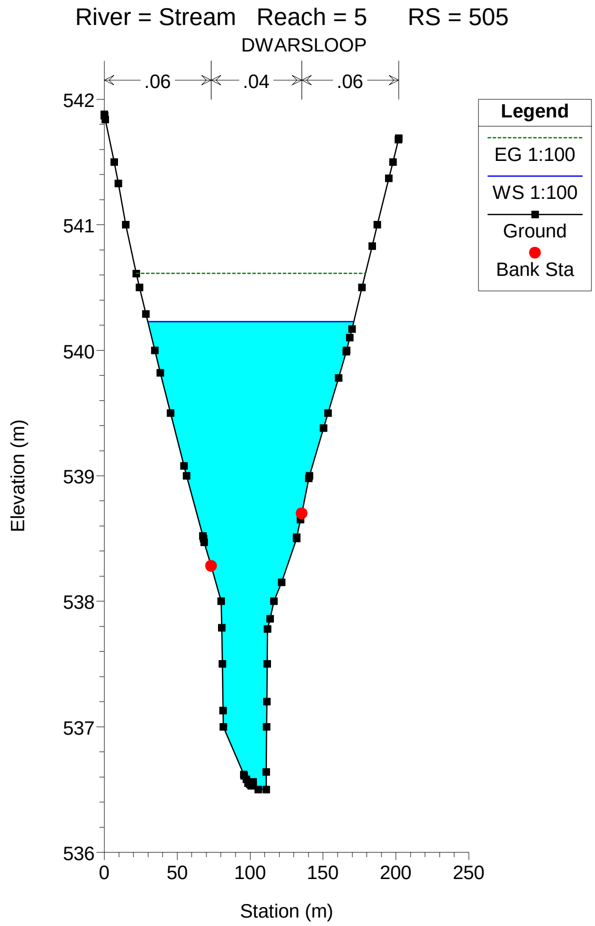

River = Stream Reach = 5 RS = 510
DWARSLOOP
.06
.04
.06
Legend
EG 1:100
WS 1:100
Ground
Bank Sta
Elevation (m)
543
542
541
540
539
538
537
0 50 100 150 200 250
Station (m)

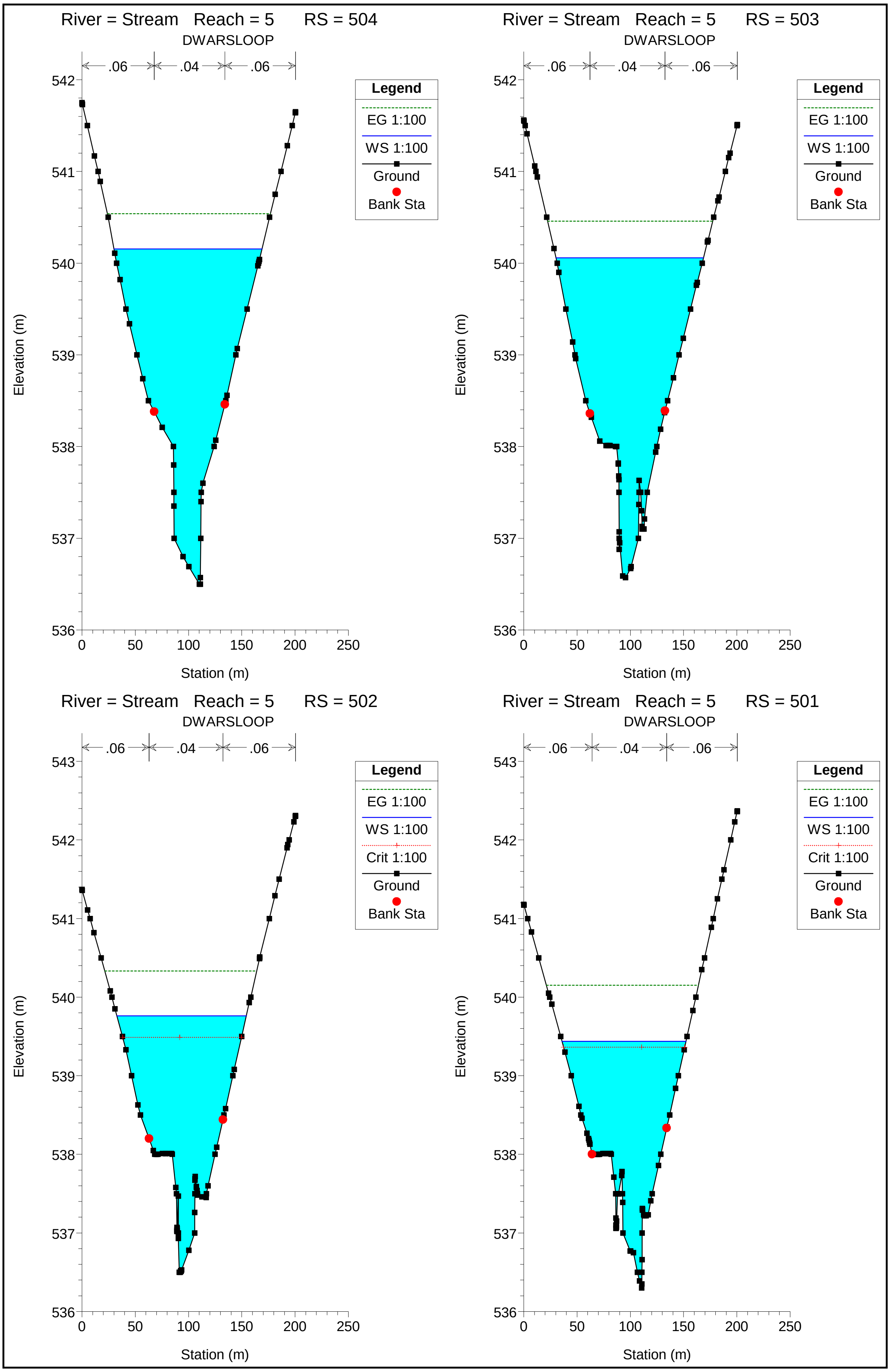

River = Stream Reach = 5 RS = 509
DWARSLOOP
.06
.04
.06
Legend
EG 1:100
WS 1:100
Ground
Bank Sta
Elevation (m)
543
542
541
540
539
538
537
0 50 100 150 200 250
Station (m)


River = Stream Reach = 5 RS = 508
DWARSLOOP
.06 .04 .06
Legend
EG 1:100
WS 1:100
Crit 1:100
Ground
Bank Sta
Elevation (m)
543
542
541
540
539
538
537
0 50 100 150 200 250
Station (m)


River = Stream Reach = 5 RS = 507
DWARSLOOP
.06 .04 .06
Legend
EG 1:100
WS 1:100
Crit 1:100
Ground
Bank Sta
Elevation (m)
543
542
541
540
539
538
537
0 50 100 150 200 250
Station (m)


River = Stream Reach = 5 RS = 506
DWARSLOOP
.06 .04 .06
Legend
EG 1:100
WS 1:100
Crit 1:100
Ground
Bank Sta
Elevation (m)
543
542
541
540
539
538
537
536
0 50 100 150 200 250
Station (m)


River = Stream Reach = 5 RS = 505
DWARSLOOP
.06 .04 .06
Legend
EG 1:100
WS 1:100
Ground
Bank Sta
Elevation (m)
542
541
540
539
538
537
536
0 50 100 150 200 250
Station (m)



River = Stream Reach = 5 RS = 504
DWARSLOOP
.06 .04 .06
Legend
EG 1:100
WS 1:100
Ground
Bank Sta
Elevation (m)
542
541
540
539
538
537
536
0 50 100 150 200 250
Station (m)
River = Stream Reach = 5 RS = 503
DWARSLOOP
.06 .04 .06
Legend
EG 1:100
WS 1:100
Ground
Bank Sta
Elevation (m)
542
541
540
539
538
537
536
0 50 100 150 200 250
Station (m)
River = Stream Reach = 5 RS = 502
DWARSLOOP
.06 .04 .06
Legend
EG 1:100
WS 1:100
Crit 1:100
Ground
Bank Sta
Elevation (m)
543
542
541
540
539
538
537
536
0 50 100 150 200 250
Station (m)
River = Stream Reach = 5 RS = 501
DWARSLOOP
.06 .04 .06
Legend
EG 1:100
WS 1:100
Crit 1:100
Ground
Bank Sta
Elevation (m)
543
542
541
540
539
538
537
536
0 50 100 150 200 250
Station (m)