PLANS AND DOCUMENTS
referred to in the PDA
DEVELOPMENT APPROVAL

Approval no: DEV2012/284

Date: 22 June 2017

Queensland Government

Teviot Village

Concept Stormwater Management Plan and Flood Investigation

Prepared by Calibre Consulting
Prepared for Villa Green Ltd

December 2016

16-002518-02A
Original
Water & Environment

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DOCUMENT CONTROL
16-002518-02A

Issue	Date	Issue Details	Author	Checked	Approved
A	13.12.16	Original Issue	KO	MS (RPEQ 9485)	

EXECUTIVE SUMMARY

Calibre Consulting (Qld) Pty Ltd has been commissioned by Villa Green Ltd (the Client) to prepare a *Concept Stormwater Management Plan and Flood Investigation* to support the proposed 1,502 lot Teviot Village Development located at Pub Lane, Greenbank. The proposed development is located within the Greenbank Priority Development Area (PDA) of the Logan City Council (LCC) planning scheme (2015).

Design strategies from the following previously approved stormwater management plans by BMD and Hydrology & Water Management Consulting for the site were generally maintained throughout this investigation.

The stormwater management analyses demonstrated that the proposed development will not adversely impact downstream properties with regards to peak flows for the 63% to the 1% Annual Exceedance Probability (AEP) storm events.

This is achieved by incorporating flood storage upstream of the proposed crossings to mitigate peak flows. Appropriately sized drainage infrastructure is proposed to be provided for upstream external catchment flows (1% AEP). One-dimensional HEC-RAS flood modelling demonstrated that increases in 1% AEP flood levels are generally constrained within the site.

Flood immunity levels for habitable floors and waterway crossings have also been nominated.

For stormwater quality, a strategy comprising bioretention basins and bioretention pods is proposed. ‘At-source’ stormwater quality treatment through bioretention pods located within the road verges throughout the development have been adopted in combination with ‘end-of-line’ bioretention basins adjacent to the waterways.

The stormwater drainage network will be designed to convey the ‘first flush’ of site runoff to end-of-line bioretention basins to complete the stormwater treatment train. MUSIC modelling demonstrates the effectiveness of this stormwater treatment train in achieving the required water quality objectives under the *State Planning Policy* (SPP, 2016) and the SEQ Water *Development Guidelines*.

Waterway stability management is addressed by managing 63% AEP flows and flooding along the drainage corridors.

It is recommended that this *Concept Stormwater Management Plan and Flood Investigation* be approved and the management strategies presented within this report be incorporated into future design development. Future design may result in changes to the concepts, however the design objectives are to be maintained.

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1 INTRODUCTION

Calibre Consulting (Qld) Pty Ltd has been commissioned by Villa Green Ltd (the Client) to prepare a *Concept Stormwater Management Plan and Flood Investigation Report* to support the proposed Teviot Village Development located at Pub Lane, Greenbank. The proposed development is located within the Greenbank Priority Development Area (PDA) of the Logan City Council (LCC) planning scheme (2015).

The development area encompassed by the proposal involves the creation of 1,502 urban residential allotments with associated community facilities, roads and open space areas. Refer to **Appendix A** for an extract of the conceptual site layout drawings, herein referred to as "the site".

This report provides stormwater management analyses to demonstrate that the proposed development will not adversely impact downstream properties with regards to stormwater quantity for the 63% to the 1% Annual Exceedance Probability (AEP) storm events. Additionally, one-dimensional hydraulic flood investigations of the 1% AEP storm event under existing and post-development conditions have been undertaken to determine flood immunity levels and crossing configurations.

This report also presents the analysis undertaken to demonstrate that the development meets relevant Council and State Government requirements with regards to stormwater quality management and recommends Stormwater Quality Improvement Devices (SQIDs) to be provided as part of the development.

The following stormwater management plans have previously been completed for the site:

- BMD Consulting (2009), *Storm Water Management Plan for Teviot Downs Estate North of Pub Lane;*
- BMD Consulting (2009), *Watercourse Flood Investigation for Teviot Estate North of Pub Lane; and*
- Hydrology & Water Management Consulting (HWMC) (2012), *Teviot Village Stormwater Management Plan J00110R1V2.*

The primary design strategies and assumptions presented within the above reports have been adopted for this investigation. Reference to these previous reports has been made where applicable.

1.1 DESIGN OBJECTIVES

The objectives of the analyses presented in this report are as follows:

- Demonstrate that the development does not result in adverse impacts to downstream or adjacent properties with respect to peak flows. Determine strategies for peak flow mitigation where required.
- Determine the extents of flooding for the western and eastern drainage corridors;
- Determine appropriate flood immunity levels for development areas adjacent to the drainage corridors and demonstrate no increase in maximum 1% AEP flood levels at the downstream boundaries;
- Determine a stormwater quality management strategy to ensure that the development achieves all Water Quality Objectives (WQOs) required under the *State Planning Policy* (*SPP*, 2016); and
- Address the waterway stability management required under the *SPP* (2016).

1.2 SCOPE OF WORKS

The scope of works undertaken to address the design objectives are:

- Stormwater Quantity
  - Determine the lawful points of discharge for the site under existing and developed conditions;
  - Undertake analysis to determine which discharge points require peak flow mitigation to ensure all modelled storm events (63% to 1% AEP) are non-worsening; and
  - Develop a strategy to achieve the required peak flow mitigation.
- Local Flooding
  - Undertake one-dimensional HEC-RAS analyses to determine the existing flood conditions through the drainage corridors for the 1% AEP storm event;
  - Undertake analyses to determine the post-development flood conditions for the 1% AEP storm event;
  - Undertake sensitivity scenarios with a higher Manning's n value, and culvert blockage scenarios; and
  - Nominate flood immunity levels in accordance with the relevant LCC planning scheme policy.
- Stormwater Quality:
  - Develop a stormwater quality and total water cycle management strategies incorporating SQIDs; and
  - Model the SQIDs using the Model for Urban Stormwater Improvement Conceptualisation (MUSIC) to determine their effectiveness in achieving the identified WQOs.
- Waterway Stability Management
  - Develop strategies to satisfy waterway stability management requirements as required under the *SPP* (2016).

2 SITE CHARACTERISTICS

2.1 LOCATION

The site is located within the Logan City Council (LCC) local government area. **Figure 2-1** provides an aerial view of the site which encompasses an area of approximately 153ha. The real property description is Lot 9968 on SP163061. The site is bound by the Brisbane to Sydney Railway line to the east, the Teviot Downs soccer club to the west and rural residential properties along the remaining boundaries.

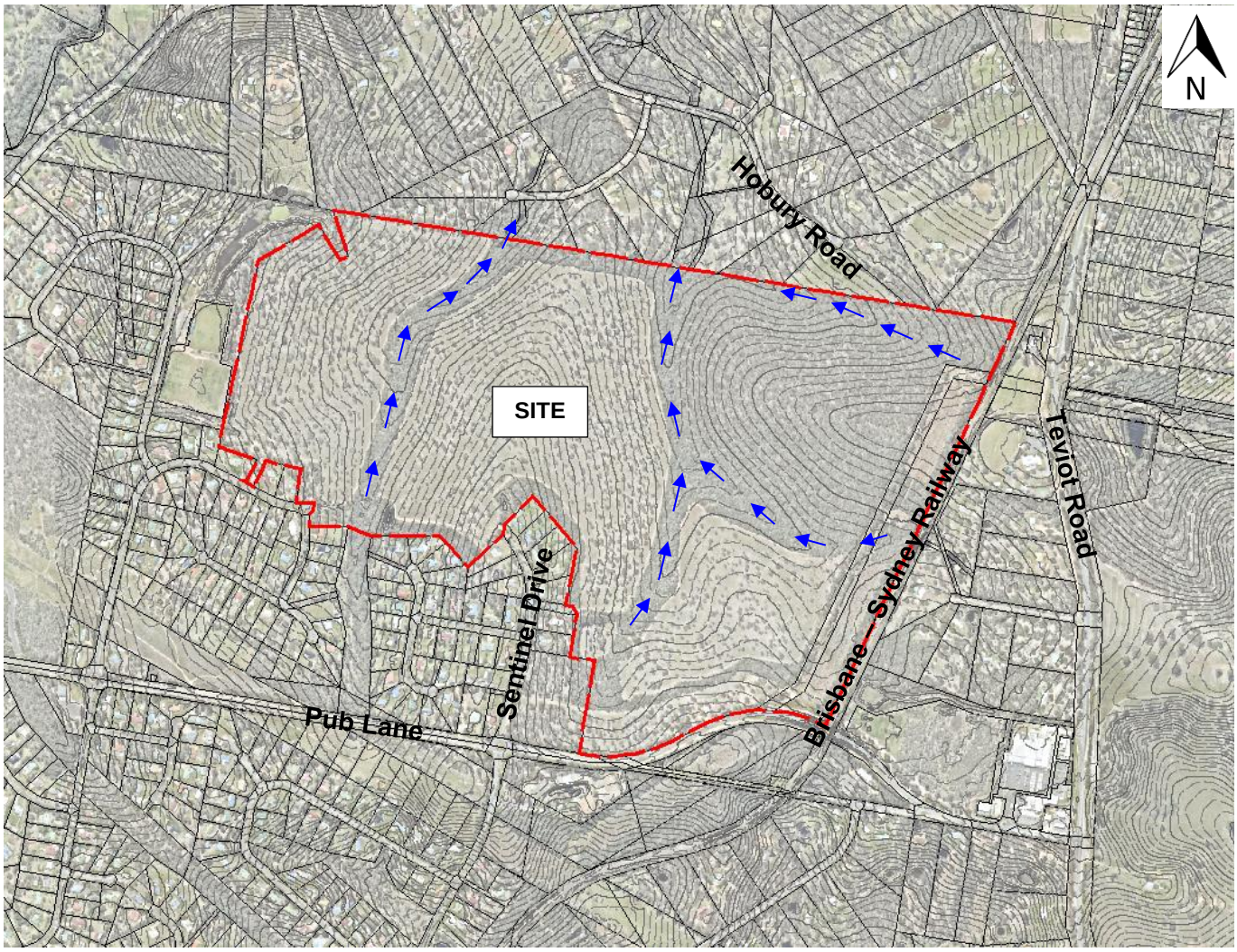


Figure 2-1: Site Location (Source: Nearmap)

2.2 LAND USE

The existing site is undeveloped with multiple drainage corridors and vegetation as illustrated in **Figure 2-1**. Easements containing water, communications and overhead electricity traverse the eastern boundary of the site.

The proposed development will consist of predominately urban residential land use, with open space areas, parks, and sports fields included.

2.3 EXISTING TOPOGRAPHY, DRAINAGE & FLOODING

The existing topography of the site varies from RL 75.5m AHD at Sentinel Drive to the south down to RL48.25m AHD at the northern property boundary. Under existing conditions, two drainage corridors traverse the site from south to north as shown in **Figure 2-1**. There are a number of local gullies within the site that connect to these main drainage paths.

The site ultimately discharges to Oxley Creek downstream of New Beith Road. The overland drainage paths within the site are illustrated within LCC's Flood Hazard Overlay mapping. Oxley Creek flooding is not expected to have any impact on downstream tailwater conditions for the extent of the current investigation area.

There is no municipal drainage infrastructure nor private underground stormwater pipes on the site. The runoff under existing conditions follows the topography and discharge to the north.

3 STORMWATER QUANTITY

A peak flow analysis has been undertaken using hydrological modelling software (XP-RAFTS). This section investigates peak flow discharges at the external perimeter of the site, as well as downstream from the site to ensure that no adverse impacts occur as a result of the proposed Teviot Village development.

Hydrological modelling has been undertaken for the 63%, 39%, 20%, 10%, 5%, 2% and 1% AEP storm events. In order to quantify the magnitude of peak flow increases due to the proposed development, the following scenarios have been analysed:

- **Existing Scenario** represents the hydrology for the catchment under existing conditions. Catchment parameters (i.e. infiltration loss and lag parameter values) were adopted as per HWMC's *Stormwater Management Plan* (Report No. J00110R1V2 dated 5 July 2012).

  Peak flow results determined in this scenario were compared with developed peak flow results to assess the change in peak flows at site discharge locations.

- **Developed Unmitigated Scenario** represents the hydrology for the catchment under proposed development conditions with no mitigation measures. Peak flow discharge to the downstream site boundary and locations along the downstream waterway have been considered in the analysis to quantify changes in site discharge.

- **Developed Mitigated Scenario** represents the hydrology for the catchment under proposed development conditions with mitigation measures. Peak flow discharge to the downstream site boundary and locations along the downstream waterway have been considered in the analysis. Proposed mitigation strategies have been presented to ensure no increase in peak flow discharge at site's northern boundary.

The proposed mitigation strategy presented within HWMC's *Stormwater Management Plan* (Report No. J00110R1V2 dated 5 July 2012) has been adopted. This strategy proposes the use of planned road crossings and flood storage capacity within the natural drainage corridors as mitigation. Hydraulic investigations in **Section 4** of this report provide flood immunity levels for the proposed development.

3.1 XP-RAFTS MODEL PARAMETERS

Hydrological modelling for this investigation has incorporated the previously approved design strategy and assumptions presented within HWMC's *Stormwater Management Plan* (Report No. J00110R1V2 dated 5 July 2012). Although catchment areas between Calibre Consulting's and HWMC's previous analysis differ slightly due to the use of updated survey information, HWMC's assumptions of Manning's roughness, fraction impervious, vectored slope, link lagging and rainfall loss parameters have been adopted.

The 1% AEP peak flow was verified against the Rational Method Calculation in HWMC's *Stormwater Management Plan* (Report No. J00110R1V2 dated 5 July 2012). No further calibration or verification has been undertaken by Calibre Consulting. The existing scenario peak flow results presented in **Section 3.2.4** are similar to results presented within HWMC's report.

General XP-RAFTS parameters adopted in accordance with HWMC's *Stormwater Management Plan* (Report No. J00110R1V2 dated 5 July 2012) are provided in **Table 3-2**.

Table 3-1: XP-RAFTS Calibration Parameter Summary

XP-RAFTS Model Parameter	Value
Storage multiplication co-efficient (Bx)	1.3
Pervious Initial Rainfall Loss (mm)	5
Pervious Continuing Rainfall Loss (mm/hr)	2.5
Impervious Initial Rainfall Loss (mm)	1
Impervious Continuing Rainfall Loss (mm/hr)	0
Pervious Manning's 'n' Roughness Value	0.045
Impervious Manning's 'n' Roughness Value	0.025

3.2 EXISTING SCENARIO

The existing scenario was undertaken to determine peak flows discharging from the site under existing conditions.

3.2.1 CATCHMENT CHARACTERISTICS

Existing scenario catchments were delineated based on survey and aerial information. As previously mentioned, catchment areas differ slightly to those presented in previous reports due to updated survey information.

Catchments were split into pervious and impervious sub-catchments within XP-RAFTS. Site catchment impervious areas were retained as per HWMC's *Stormwater Management Plan* (Report No. J00110R1V2 dated 5 July 2012). Vectored slope values were adopted as per the previous HWMC stormwater management plan for all site catchments. Catchment parameters for additional investigation areas included within this analysis (such as downstream external catchments downstream) were calculated based on client supplied survey.

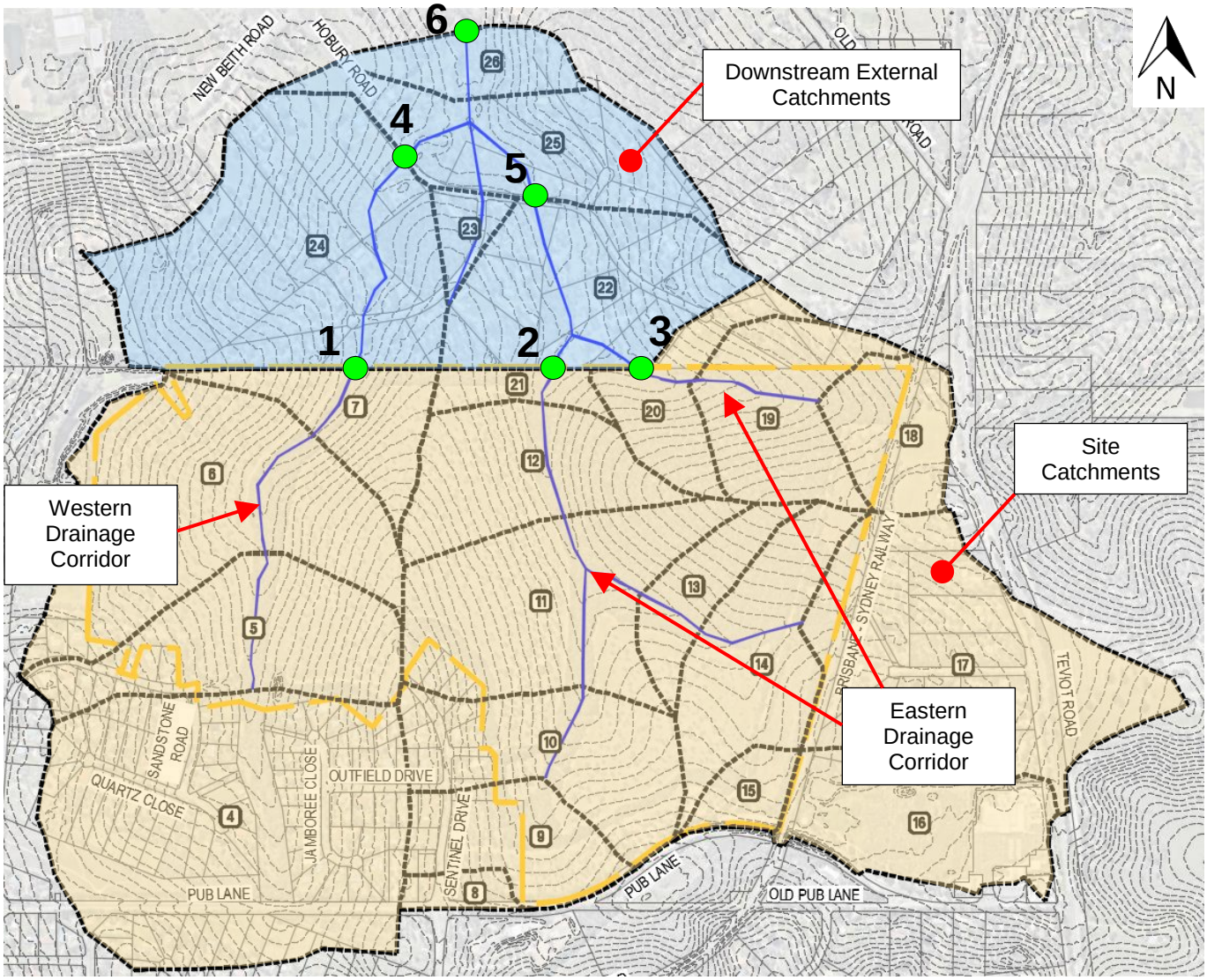


Figure 3-1: Existing Scenario XP-RAFTS Catchment Layout

A summary of the existing catchment details is provided in **Table 3-1**. Refer to Drawing No. **16-002518-SK10** in **Appendix D** for existing catchment layout details.

Table 3-2: Existing Scenario Catchment Details

Catchment	Catchment Area (ha)	Fraction Impervious	Vectored Slope (%)
Site Catchments			
4	46.88	9.74	3.6
5	18.39	5.20	3.6
6	31.19	3.75	3.6
7	8.51	0.00	4.8
8	2.10	27.76	4.5
9	9.90	2.15	5.1
10	16.18	1.94	5.3
11	22.91	0.40	5.25
12	14.43	0.00	5.5
13	6.18	0.00	4
14	14.43	0.00	3.6
15	3.35	0.00	2.5
16	14.87	13.70	1.7
17	32.95	4.81	1.9
18	8.48	1.86	4
19	12.98	1.03	5.2
20	8.03	0.00	5.7
21	3.18	0.00	5.5
Downstream External Catchments			
22	20.20	18.18	2.6
23	2.58	2.33	3.0
24	36.32	32.68	3.2
25	16.48	14.83	2.5
26	6.20	5.89	3.6

3.2.2 CHANNEL ROUTING

Routing of upstream catchments through downstream drainage paths was simulated in XP-RAFTS using 'link lagging'. Site link lag times were adopted from BMD Consulting's *Storm Water Management Plan for Teviot Downs Estate North of Pub Lane* (2009).

Calculation of lag times for external downstream catchments was undertaken using flowpath length of the downstream catchment and assuming an average channel velocity of 1.0m/s.

3.2.3 RAINFALL DATA

Rainfall IFD data provided within *Appendix C* of HWMC's *Stormwater Management Plan* (Report No. J00110R1V2 dated 5 July 2012) was applied in XP-RAFTS using the automatic storm generator. **Table 3-3** summarises the IFD data utilised in this analysis.

Table 3-3: Rainfall IFD Input Data (AR&R)

$^{2}I_{1}$	$^{2}I_{12}$	$^{2}I_{72}$	$^{50}I_{1}$	$^{50}I_{12}$	$^{50}I_{72}$	F2	F50	G
45.66	7.55	2.2	85.96	15.25	4.76	4.39	17.15	0.15

3.2.4 EXISTING PEAK FLOW RESULTS

Modelling was undertaken for the all storm events up to and including the 1% AEP storm event with a storm duration of 60 minutes (this was the critical duration for the investigation area). Peak flow results for the existing scenario have been provided in **Table 3-3** at the site discharge locations, and downstream locations as depicted in **Figure 3-1**.

Table 3-4: Existing Peak Flow Results

AEP (%)	Peak Flow Discharge at Point Location (m^3/s)					
	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6
63	5.33	8.25	2.41	6.85	11.61	19.70
39	7.87	12.05	3.51	10.18	16.95	28.89
20	11.19	16.98	4.94	14.60	23.93	40.72
10	13.31	20.07	5.83	17.38	28.26	48.14
5	16.26	24.32	7.06	21.25	34.26	58.45
2	20.09	29.49	8.49	26.25	41.54	71.33
1	23.34	34.02	9.79	30.48	47.93	82.41

The peak flows at Points 1, 2 and 3 as presented in **Table 3-4** are generally consistent with the existing scenario peak flows determined by HWMC at the same locations. Refer to HWMC's *Stormwater Management Plan* (Report No. J00110R1V2 dated 5 July 2012).

3.3 DEVELOPED UNMITIGATED SCENARIO

The developed unmitigated scenario was modelled to demonstrate variances in peak flow as a result of the proposed development.

3.3.1 CATCHMENT CHARACTERISTICS

Developed scenario catchments were delineated based on preliminary bulk earthworks design and the conceptual site layout provided in **Appendix A**. Refer to Drawing No. **16-002518-SK11** in **Appendix D** for developed scenario catchment delineation.

Fraction impervious assumptions provided in **Table 3-5** were adopted from HWMC's *Stormwater Management Plan* (Report No. J00110R1V2 dated 5 July 2012).

Table 3-5: Developed Scenario Landuse Fraction Impervious (Source: HWMC, 2012)

Landuse	Fraction Impervious Percentage
>2000m^2 Lifestyle Residential Allotments	45%
Proposed 'super lots' (urban residential allotments)	90%
Park (formal)	20%
Remaining development areas of the site (i.e. lots and road reserve)	65%

The vectored slope of undeveloped and external catchment areas remains consistent with the existing scenario. All development areas have adopted a vectored slope of 4% as the preliminary bulk earthworks grading varies from 3% to 5%. A summary of the developed catchment details is provided in **Table 3-6**.

Table 3-6: Developed Scenario Catchment Details

Catchment	Catchment Area (ha)	Fraction Impervious	Vectored Slope (%)
Site Catchments			
4	46.26	10%	3.6
5A	24.06	46%	4.0
5B	2.52	0%	3.6
6A	4.82	15%	3.6
6B	13.77	70%	4.0
6C	1.02	78%	4.0
7A	3.49	0%	4.8
7B	9.31	81%	4.0
8	2.10	15%	4.5
9A	9.76	36%	5.1
9B	5.08	23%	5.1
10	1.94	0%	5.3
11A	5.12	1%	5.25
11B	14.35	59%	4.0
11C	5.23	75%	4.0
11D	11.87	79%	4.0
12A	3.44	11%	5.5
12B	7.70	80%	4.0
12C	12.63	81%	4.0
12D	2.63	0%	5.5
13	1.14	0%	4.0
14A	6.43	0%	3.6
14B	3.31	82%	4.0
14C	5.16	82%	4.0
15	2.38	0%	2.5
16	14.87	20%	1.7
17	32.95	5%	1.9
18	9.23	2%	4.0
19A	6.44	1%	5.2
19B	2.11	84%	4.0
20A	3.83	0%	5.7
Downstream External Catchments			
22	20.20	18.18	2.6
23	2.58	2.33	3.0
24	36.32	32.68	3.2
25	16.48	14.83	2.5
26	6.20	5.89	3.6

3.3.2 INFILTRATION LOSS & LAG PARAMETERS

The same infiltration loss and lag parameter values were adopted as per the existing scenario (refer to **Section 3.1**), which are consistent with HWMC's *Stormwater Management Plan* (Report No. J00110R1V2 dated 5 July 2012).

3.3.3 CHANNEL ROUTING

Channel routing (XP-RAFTS Link Routing) was modelled as per the existing scenario presented in **Section 3.2.2**. Any new flow paths created in the developed scenario were calculated using the methodology presented.

3.3.4 RAINFALL DATA

Rainfall data was generated as per the existing scenario in **Section 3.2.3**.

3.3.5 DEVELOPED UNMITIGATED PEAK FLOW RESULTS

Modelling was undertaken for the all standard storm events up to and including the 1% AEP storm event with a storm duration of 60 minutes (this was the critical duration for the investigation area). Peak flow results for the developed unmitigated scenario have been provided in **Table 3-7** at the site discharge locations, and downstream locations as depicted in **Figure 3-1**.

Table 3-7: Developed Unmitigated Peak Flow Results

AEP (%)	Peak Flow Discharge at Point Location (m^3/s)					
	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6
63	9.20	12.06	1.79	10.77	14.62	26.89
39	12.38	16.31	2.60	14.73	20.11	37.03
20	16.42	21.71	3.62	19.83	27.15	50.06
10	18.90	25.02	4.24	23.00	31.51	58.14
5	22.32	29.57	5.10	27.39	37.53	69.29
2	25.70	34.49	6.10	32.02	44.14	81.50
1	29.24	39.22	7.03	36.67	50.46	93.27

Table 3-8 presents the variance in peak flow compared to the existing scenario.

Table 3-8: Developed Unmitigated Peak Flow Variance

AEP (%)	Peak Flow Variance at Point Location (%)					
	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6
63	73%	46%	-26%	57%	26%	36%
39	57%	35%	-26%	45%	19%	28%
20	47%	28%	-27%	36%	13%	23%
10	42%	25%	-27%	32%	12%	21%
5	37%	22%	-28%	29%	10%	19%
2	28%	17%	-28%	22%	6%	14%
1	25%	15%	-28%	20%	5%	13%

Comparisons provided in **Table 3-8** presents the variance in peak flow compared to the existing scenario.

Table 3-8 shows that peak flow generated from the site is increased following the proposed development. Reductions in peak flow for the 63% to the 1% AEP storm events occur at Point 3 due to a reduction in contributing catchment area.

Due to increases in peak flow at the site boundary, and downstream catchment locations, peak flow mitigation is proposed for the development.

3.4 DEVELOPED MITIGATED SCENARIO

The developed mitigated scenario was undertaken to demonstrate no adverse impacts in peak flow discharge as a result of the development incorporating the proposed mitigation measures. The proposed mitigation strategy utilises waterway crossings as shown on Drawing No. **16-002518-SK12** in **Appendix D**.

3.4.1 PROPOSED MITIGATION MEASURES

The proposed mitigation strategy for the Teviot Village development is to utilise existing flood storage within the drainage corridor and control peak flows through cross drainage. Four crossing locations are proposed for the development which include three vehicular crossings and one pedestrian / bike crossing. The proposed vehicular crossings will be flood immune to the 1% AEP storm event, while the pedestrian crossing will have immunity to the 10% AEP storm event.

The following sections discuss the modelling of mitigation strategies.

3.4.1.1 WESTERN DRAINAGE CORRIDOR CROSSING

Table 3-9 provides details of the detention parameters at the western drainage crossing as modelled in XP-RAFTS. Refer to Drawing No. **16-002518-SK12** in **Appendix D** for the location and conceptual crossing details.

Table 3-9: Western Drainage Corridor Crossing

Detention Parameter	Western Crossing Detention
Detention Volume to Embankment	16,780m^3
Crossing Embankment Level (m AHD)	57.50
Primary Outlet	2 x 300mm RCP at RL 55.20m AHD
Secondary Outlet	9 x 1500mm x 600mm RCBC at RL 56.20m AHD

The stage-storage discharge relationship adopted for the western detention storage was generated from an existing survey topographical model of the site. The adopted stage storage discharge curve is provided in **Table 3-10**.

Table 3-10: Western Drainage Corridor Crossing Stage Storage Discharge Relationship

Stage (m AHD)	Accumulated Storage (m^3)	Discharge (m^3/s)	Detention Arrangement
55.00	0	0.00	
55.10	33	0.00	
55.20	58	0.00	Primary Outlet Pipes
55.30	101	0.02	
55.40	170	0.07	
55.50	281	0.13	
55.60	442	0.20	
55.70	658	0.23	
55.80	942	0.25	
55.90	1283	0.28	
56.00	1681	0.29	
56.10	2154	0.31	
56.20	2697	0.32	Secondary Outlet Pipes
56.30	3314	0.63	
56.40	4004	1.27	
56.50	4769	2.13	
56.60	5614	3.21	
56.70	6550	4.46	
56.80	7572	5.88	
56.90	8674	7.45	
57.00	9850	9.18	
57.10	11101	11.04	

Stage (m AHD)	Accumulated Storage (m^3)	Discharge (m^3/s)	Detention Arrangement
57.20	12420	13.04	
57.30	13803	15.17	
57.40	15253	17.42	
57.50	16781	20.50	Top of Embankment Level (57.50)

The upstream Water Surface Levels (WSLs) for all AEP design storm events are summarised in **Table 3-11**.

Table 3-11: Developed Mitigated Scenario Western Crossing WSLs

AEP (%)	WSL (m AHD)
63	56.61
39	56.73
20	56.87
10	56.95
5	57.05
2	57.17
1	57.27

Results indicate that the crossing is not overtopping in the 1% AEP storm event. This is further demonstrated in the one-dimensional HEC-RAS flood analysis in **Section 4.2**.

3.4.1.2 EASTERN DRAINAGE CORRIDOR CROSSING A

Table 3-12 provides details of the eastern drainage corridor crossing A detention parameters modelled in XP-RAFTS. This crossing is located on tributary 630 of the eastern drainage corridor. Refer to Drawing No. **16-002518-SK12** in **Appendix D** for crossing details.

Table 3-12: Eastern Drainage Corridor Crossing A

Detention Parameter	Eastern Crossing A Detention
Detention Volume to Embankment Level	18,065m^3
Crossing Embankment Level (m AHD)	56.90m
Primary Outlet Pipes	5 x 1800mm x 600mm RCBC at RL 54.60m AHD

The stage-storage discharge relationship adopted for the proposed detention storage was generated from an existing survey topographical model of the site. The adopted stage storage discharge curve is provided in **Table 3-13**.

Table 3-13: Eastern Drainage Corridor A Crossing Stage Storage Discharge Relationship

Stage (m AHD)	Accumulated Storage (m^3)	Discharge (m^3/s)	Detention Arrangement
54.20	0	0.00	
54.30	1	0.00	
54.40	12	0.00	
54.50	51	0.00	
54.60	125	0.00	Primary Outlet Pipes
54.70	241	0.18	
54.80	415	0.55	
54.90	647	1.06	
55.00	932	1.70	
55.10	1272	2.45	
55.20	1673	3.29	
55.30	2141	4.23	
55.40	2675	5.26	
55.50	3275	6.38	

Stage (m AHD)	Accumulated Storage (m^3)	Discharge (m^3/s)	Detention Arrangement
55.60	3941	7.57	
55.70	4683	8.85	
55.80	5490	10.19	
55.90	6359	11.61	
56.00	7286	13.11	
56.10	8271	14.43	
56.30	10410	15.62	
56.40	11567	16.19	
56.50	12778	16.75	
56.60	14042	17.30	
56.70	15348	17.84	
56.80	16690	18.37	
56.90	18064	**18.89**	Top of Embankment Level (56.90)

The upstream WSLs for all AEP design storm events are summarised in **Table 3-14**.

Table 3-14: Developed Mitigated Scenario Eastern Crossing A WSLs

AEP (%)	WSL (m AHD)
63	55.16
39	55.29
20	55.44
10	55.53
5	55.65
2	55.78
1	55.88

Results indicate that the crossing is not overtopped in the 1% AEP storm event, with over 1.0m freeboard.

3.4.1.3 EASTERN DRAINAGE CORRIDOR CROSSING B

Table 3-15 provides details of the eastern drainage corridor crossing B detention parameters modelled in XP-RAFTS. This vehicular crossing is located on tributary 109 of the eastern drainage corridor. Refer to Drawing No. **16-002518-SK12** in **Appendix D** for crossing details.

Table 3-15: Eastern Drainage Corridor Crossing B

Detention Parameter	Eastern Crossing B Detention
Detention Volume to Embankment Level	37,025m^3
Crossing Embankment Level (m AHD)	53.50m
Primary Outlet Pipes	4 x 2400mm x 900mm RCBC at RL 49.40m AHD

The stage-storage discharge relationship adopted for the proposed detention storage was generated from an existing survey topographical model of the site. The adopted stage storage curve is provided in **Table 3-16**

Table 3-16: Eastern Drainage Corridor B Crossing Stage Storage Discharge Relationship

Stage (m AHD)	Accumulated Storage (m^3)	Discharge (m^3/s)	Detention Arrangement
49.40	0	0.00	Primary Outlet Pipes
49.50	0	0.19	
49.60	1	0.59	
49.70	2	1.15	
49.80	4	1.84	
49.90	7	2.65	
50.00	11	3.56	
50.10	15	4.58	
50.20	21	5.69	
50.30	28	6.90	
50.40	38	8.19	
50.50	55	9.57	
50.60	84	11.02	
50.70	133	12.56	
50.80	210	14.17	
50.90	321	15.86	
51.00	472	17.62	
51.10	674	19.45	
51.20	940	21.35	
51.30	1274	23.32	
51.40	1682	26.46	
51.50	2167	27.29	
51.60	2737	28.10	
51.70	3407	28.90	
51.80	4197	29.68	
51.90	5112	30.46	
52.00	6146	31.22	
52.10	7316	31.97	
52.20	8631	32.71	
52.30	10085	33.44	
52.40	11682	34.16	
52.50	13408	34.88	
52.60	15259	35.58	
52.70	17228	36.28	
52.80	19312	36.97	
52.90	21511	37.65	
53.00	23824	38.32	
53.10	26252	38.99	
53.20	28793	39.65	
53.30	31442	40.30	
53.40	34187	40.95	
53.50	37024	41.59	Top of Embankment Level (53.50)

The flood storage WSLs for all AEP design storm events are summarised in **Table 3-17**.

Table 3-17: Developed Mitigated Scenario Eastern Crossing B WSLs

AEP (%)	WSL (m AHD)
63	50.40
39	50.61
20	50.84
10	50.97
5	50.14
2	51.31
1	51.42

Results indicate that there is 1.0m freeboard to the crossing minimum embankment level (53.50m AHD) in the 1% AEP storm event.

3.4.1.4 EASTERN DRAINAGE CORRIDOR CROSSING C

Table 3-18 provides details of the eastern drainage corridor crossing C detention parameters modelled in XP-RAFTS. This crossing is located at the downstream end of the eastern drainage corridor and is proposed for bike / pedestrian use. It has been designed to remain immune for storm events up to and including the 10% AEP storm event. Refer to Drawing No. **16-002518-SK12** in **Appendix D** for crossing details.

Table 3-18: Eastern Drainage Corridor Crossing C

Detention Parameter	Eastern Crossing C Detention
Detention Volume to Embankment Level	18,910m^3
Crossing Embankment Level (m AHD)	51.00m
Primary Outlet Pipes	4 x 900mm RCP at RL 48.70m AHD
Secondary Outlet Pipes	6 x 600mm RCP at RL 50.00m AHD

The stage-storage discharge relationship adopted for the proposed detention storage was generated from an existing survey topographical model of the site. The adopted stage storage discharge curve is provided in **Table 3-19**.

Table 3-19: Eastern Drainage Corridor C Crossing Stage Storage Discharge Relationship

Stage (m AHD)	Accumulated Storage (m^3)	Discharge (m^3/s)	Detention Arrangement
48.70	30	0.00	Primary Outlet Pipes
48.80	69	0.11	
48.90	146	0.35	
49.00	263	0.68	
49.10	446	1.08	
49.20	700	1.55	
49.30	1029	2.09	
49.40	1425	2.69	
49.50	1891	3.35	
49.60	2435	4.05	
49.70	3052	4.81	
49.80	3745	5.79	
49.90	4517	6.12	Secondary Outlet Pipes
50.00	5370	6.43	
50.10	6307	6.86	
50.20	7334	7.41	
50.30	8463	8.04	
50.40	9695	8.76	
50.50	11021	9.54	
50.60	12434	10.38	

Stage (m AHD)	Accumulated Storage (m^3)	Discharge (m^3/s)	Detention Arrangement
50.70	13933	11.27	
50.80	15513	12.03	
50.90	17171	12.55	
51.00	18907	13.05	Top of Embankment Level (51.00)
51.10	20717	21.93	
51.20	22599	37.77	

The flood storage WSLs for all AEP design storm events are summarised in **Table 3-20**.

Table 3-20: Developed Mitigated Scenario Eastern Crossing C WSLs

AEP (%)	WSL (m AHD)
63	50.12
39	50.45
20	50.78
10	50.99
5	51.07
2	51.12
1	51.14

Results indicate the crossing is overtopped by 140mm in the 1% AEP storm event. This is within the maximum recommended overtopping depth specified in the QUDM (2013). Refer to **Section 4.2** for one-dimensional HEC-RAS flood analysis.

3.4.2 DEVELOPED MITIGATED PEAKS FLOW RESULTS

Modelling was undertaken for the all storm events up to and including the 1% AEP storm event with a storm duration of 60 minutes (this was the critical duration for the investigation area). Peak flow results for the developed mitigated scenario are provided in **Table 3-21** at the site discharge locations, and downstream locations as depicted in **Figure 3-1**.

Table 3-21: Developed Mitigated Peak Flow Results

AEP (%)	Peak Flow Discharge at Point Location (m^3/s)					
	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6
63	4.96	7.56	1.79	6.52	10.29	18.03
39	7.05	9.84	2.60	9.48	13.56	24.90
20	10.06	12.68	3.62	13.61	17.82	34.01
10	11.93	13.85	4.24	16.17	20.17	39.46
5	14.49	20.64	5.10	19.68	27.64	49.83
2	17.64	26.79	6.10	24.14	36.04	64.13
1	**20.34**	**31.44**	**7.03**	**27.89**	**42.47**	75.50

Table 3-22: Developed Mitigated Peak Flow Variance

AEP (%)	Peak Flow Variance at Point Location (%)					
	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6
63	-7%	-8%	-26%	-5%	-11%	-8%
39	-10%	-18%	-26%	-7%	-20%	-14%
20	-10%	-25%	-27%	-7%	-26%	-16%
10	-10%	-31%	-27%	-7%	-29%	-18%
5	-11%	-15%	-28%	-7%	-19%	-15%
2	-12%	-9%	-28%	-8%	-13%	-10%
1	-13%	-8%	-28%	-8%	-11%	-8%

Peak flow comparisons provided in **Table 3-22** show that proposed mitigation measures adequately alleviate increases in peak flow runoff generated from the site in all AEP storm events.

Proposed mitigation measures are designed for the ultimate scenario only (complete Teviot Village development). Timing of flood mitigation works will be assessed within each future development application.

The one-dimensional HEC-RAS hydraulic flood investigation presented in **Section 4** used the hydrological results from the existing and developed mitigated scenario. Crossing drainage configurations and flood immunity levels were confirmed during this investigation.

4 FLOOD INVESTIGATION

The objective of this one-dimensional flood investigation is to determine 1% AEP Existing and Developed Scenario peak, flood levels and velocities along the drainage paths through the site. The flood levels determined from this flood analysis have been used to nominate flood immunity levels for the development (refer to **Section** Error! Reference source not found.).

The 1% AEP peak flow values from the hydrological analysis in **Section 3** were applied to nominated cross sections along the drainage corridors. Inflow locations for existing and developed scenarios are indicated on Drawing No. **16-002518-SK12** in **Appendix D**.

HEC-RAS modelling was undertaken for the following scenarios:

- Existing Scenario 1% AEP;
- Developed Scenario 1% AEP; and
- Sensitivity Scenarios
    - High Manning's n (0.15) in 1% AEP;
    - 25% Blockage Scenario of Crossings in 1% AEP storm event; and
    - 100% Blockage Scenario of Crossings in 10% AEP.

4.1 EXISTING SCENARIO

4.1.1 GEOMETRY DATA

Cross sections for the existing scenario were draped against an existing surface Digital Elevation Model (DEM) generated from Lidar survey data.

A Manning's n value of 0.06 was adopted for the main channel of the modelled drainage path. Overbank areas adopted a Manning's n value of 0.1. Refer to Drawing No. **16-002518-SK12** in **Appendix D** for HEC-RAS cross section locations.

4.1.2 PEAK FLOW INPUT

The existing scenario peak flow rates at various points along the drainage corridor were obtained from the XP-RAFTS model. **Table 4-1** presents the existing scenario peak flow rates utilised for HEC-RAS analyses. Refer to Drawing No. **16-002518-SK12** in **Appendix D** for HEC-RAS inflow locations.

Table 4-1: Existing Scenario Peak Flows

Reach	HEC-RAS Cross Section	1% AEP (m^3/s)
81 - (Eastern Corridor – Northern Tributary)	596	2.69
	340	6.93
	189	10.13
630 - (Eastern Corridor – Main Tributary)	1154	5.47
	970	13.09
	798	15.18
21 - (Eastern Corridor – Southern Tributary)	494	4.22
	269	9.21
109 - (Eastern Corridor – Main Tributary)	593	24.40
	536	31.15
	270	35.88
	161	37.20
	494	4.22
	269	9.21
0 - (Western Corridor)	864	9.89
	594	14.70
	413	22.01
	102	24.93

4.1.3 BOUNDARY CONDITIONS

The following boundary conditions were adopted for the HEC-RAS model. Refer to Drawing No. **16-002518-SK12** in **Appendix D** for reach and junction locations.

Western Corridor

Reach 0

- **Upstream**: Inflow applied to represent external upstream catchment and normal depth slope 1%; and
- **Downstream**: Normal depth slope 1%

Eastern Corridor

Reach 630

- **Upstream**: Inflow applied to represent external upstream catchment and normal depth slope 1.65%; and
- **Downstream**: Junction Node

Reach 21

- **Upstream**: Inflow applied to represent external upstream catchment and normal depth slope 1.65%; and
- **Downstream**: Junction Node

Reach 109

- **Upstream**: Junction Node; and
- **Downstream**: Normal depth slope 1.65%

Reach 81

- **Upstream**: Inflow applied to represent external upstream catchment and normal depth slope 1.9%; and
- **Downstream**: Normal depth slope 1.9%

4.1.4 EXISTING FLOOD RESULTS

The 1% AEP flood conditions along the drainage path for the existing scenario are presented in **Table 4-2**. The existing scenario 1% AEP flood extent is shown on Drawing No. **16-002518-SK12** in **Appendix D**.

Table 4-2: Existing Scenario 1% AEP Flood Conditions

River - Reach	HEC-RAS Cross Section	Flood Level (m AHD)	Maximum Flood Depth (m)	Average Velocity (m/s)	Depth-Velocity Product (m^2/s)
West – 0	864	58.49	1.12	0.70	0.78
West – 0	813	58.07	0.98	0.82	0.80
West – 0	752	57.44	0.73	0.76	0.55
West – 0	711	57.02	0.98	0.85	0.83
West – 0	661	56.59	0.53	0.66	0.35
West – 0	594	55.81	0.45	0.97	0.44
West – 0	573	55.48	0.84	0.95	0.80
West – 0	528	54.89	0.58	0.75	0.44
West – 0	488	54.42	0.37	1.08	0.40
West – 0	438	53.75	0.49	0.72	0.35
West – 0	413	53.53	1.16	0.85	0.99
West – 0	352	53.10	1.49	0.76	1.13
West – 0	297	52.60	0.87	1.11	0.97
West – 0	246	52.17	1.78	0.90	1.60
West – 0	219	51.95	1.04	1.01	1.05
West – 0	201	51.80	1.47	0.97	1.43
West – 0	153	51.37	1.17	1.03	1.21
West – 0	102	51.09	1.51	0.81	1.22
West – 0	69	50.93	1.92	0.86	1.65
West – 0	40	50.72	1.04	0.98	1.02
East – 21	494	59.70	0.34	0.67	0.23
East – 21	444	58.52	0.26	0.92	0.24
East – 21	393	57.39	0.28	0.59	0.17
East – 21	342	56.01	0.16	0.96	0.15
East – 21	309	55.40	0.29	0.50	0.15

River - Reach	HEC-RAS Cross Section	Flood Level (m AHD)	Maximum Flood Depth (m)	Average Velocity (m/s)	Depth-Velocity Product (m^2/s)
East – 21	269	54.99	0.47	0.74	0.35
East – 21	219	54.47	0.55	0.76	0.42
East – 21	169	53.91	0.52	0.79	0.41
East – 21	119	53.35	0.80	0.82	0.66
East – 21	69	52.71	0.47	0.83	0.39
East – 21	45	52.39	0.43	0.77	0.33
East – 21	28	52.17	0.47	0.84	0.39
East – 21	21	52.10	0.49	0.82	0.40
East – 630	1154	57.77	0.31	0.64	0.20
East – 630	1104	57.09	0.35	0.68	0.24
East – 630	1054	56.14	0.30	0.83	0.25
East – 630	1004	55.41	0.33	0.56	0.18
East – 630	970	55.10	0.70	0.63	0.44
East – 630	933	54.79	0.37	0.69	0.26
East – 630	873	54.23	0.42	0.59	0.25
East – 630	850	54.08	0.54	0.57	0.31
East – 630	798	53.67	0.64	0.79	0.51
East – 630	748	53.21	0.60	0.85	0.51
East – 630	698	52.77	0.63	0.76	0.48
East – 630	657	51.94	0.99	1.68	1.66
East – 109	593	51.99	0.95	0.70	0.67
East – 109	585	51.96	0.94	0.69	0.65
East – 109	536	51.62	1.02	1.10	1.12
East – 109	510	51.38	2.00	0.99	1.98
East – 109	438	51.05	1.83	0.86	1.57
East – 109	417	50.90	1.75	0.95	1.66
East – 109	367	50.54	1.01	1.01	1.02
East – 109	326	50.25	1.04	0.97	1.01
East – 109	270	49.78	0.90	1.07	0.96
East – 109	238	49.44	0.78	0.99	0.77
East – 109	191	49.07	1.53	0.98	1.50
East – 109	161	48.82	1.34	0.98	1.31
East – 109	109	48.44	1.07	1.20	1.28
East – 81	594	58.24	0.21	0.58	0.12
East – 81	544	56.85	0.17	0.86	0.15
East – 81	494	55.78	0.26	0.51	0.13
East – 81	444	54.52	0.23	1.06	0.24
East – 81	391	53.69	0.30	0.43	0.13
East – 81	338	52.79	0.33	1.03	0.34
East – 81	290	51.84	0.37	0.74	0.27
East – 81	239	50.88	0.48	0.92	0.44
East – 81	187	50.19	0.57	0.79	0.45
East – 81	131	49.45	0.47	0.97	0.46

4.2 DEVELOPED SCENARIO

4.2.1 GEOMETRY DATA

Cross sections for the developed scenario were draped against a superimposed Triangulated Irregular Network (TIN) surface model generated of the preliminary bulk earthworks design topography and Lidar survey data.

Manning's n roughness values were unchanged from the existing scenario modelling. HEC-RAS cross section locations did not differ between existing and developed scenario modelling. Refer to Drawing No. **16-002518-SK12** in **Appendix D** for HEC-RAS cross section locations.

There are four main crossings proposed through the drainage paths. These crossings have been conceptually sized during hydrological analyses presented in **Section 3** of this report. **Table 4-3** summarises the crossing configurations modelled in HEC-RAS. Ineffective flow areas upstream and downstream of the culvert crossings assume a contraction angle of 1:1 and expansion angle of 1:1.5 in accordance with *Chapter 6* of the *HEC-RAS Hydraulic Reference Manual v4.1* (2010).

Table 4-3: Developed Scenario HEC-RAS Crossing Configurations

Crossing Location[A]	Western Crossing	Eastern Crossing A	Eastern Crossing B	Eastern Crossing C
Primary Culvert Configuration	2 x 300mm RCP	5 x 1800mm x 600mm RCBC	4 x 2400mm x 900mm RCBC	4 x 900mm RCP
Invert Levels (m AHD)	US = 55.20 DS = 55.12	US = 54.60 DS = 54.52	US = 49.40 DS = 49.32	US = 48.70 DS = 48.65
Secondary Culvert Configuration	9 x 1500mm x 600mm RCBC	N/A	N/A	6 x 600mm RCP
Invert Levels (m AHD)	US = 56.20 DS = 56.12	N/A	N/A	US = 50.00 DS = 49.95
Culvert Length (m)	16	16	16	10
Deck Level (High Chord) (m AHD)	57.5	56.9	53.5	51.0
Distance to Upstream XS (m)	15.1	25.2	17.2	9.5

[A] Refer to Drawing No. **16-002518-SK12** in **Appendix D** for crossing locations.

All culvert crossings presented in **Table 4-3** adopted the following general parameters:

- **Solution Criteria**: Highest U.S. Energy Gradient;
- **Entrance Loss Coefficient**: 0.5;
- **Exit Loss Coefficient**: 1;
- **Manning's n (Top & Bottom):** 0.013; and
- **Headwall Configuration**: Flared Wingwalls – 30 to 75 degrees.

Saunders Havill Group's '*Pedestrian Linkage Plan'* provided in **Appendix A** illustrates additional paths across the riparian corridors. At this stage the crossings shown on this drawing (which have not been included within this flood investigation) are proposed to be provided 'on-grade' in that they will be constructed at existing surface levels and will not incorporate a raised embankment or elevated platform / walkway. As such, these paths will not impact on the major flow (1% AEP) event through the riparian corridors. The paths will only incorporate low lying culvert crossings to traverse the invert of the riparian corridor and allow for the conveyance of frequent flows and minor storm events (i.e. up to the 63% AEP storm event) underneath. Appropriate flood warning signage can be incorporated along the paths traversing the riparian corridors to warn users of the potential for flooding and deter use during inclement weather.

Modelling to determine the configuration of these crossings and confirm flood levels will be undertaken as part of detailed design.

4.2.2 PEAK FLOW INPUT

The developed scenario peak flow rates at various points along the drainage corridor was obtained from the XP-RAFTS model. **Table 4-4** presents the developed mitigated scenario peak flow rates utilised for HEC-RAS analyses. Refer to Drawing No. **16-002518-SK12** in **Appendix D** for HEC-RAS inflow locations.

Table 4-4: Developed Scenario Peak Flows

Reach	HEC-RAS Cross Section	1% AEP (m^3/s)
81 - (Eastern Corridor – Northern Tributary)	594	2.88
	544	3.44
	338	5.69
	239	5.69
	187	7.03
630 - (Eastern Corridor – Main Tributary)	1154	5.47
	1104	8.80
	970	12.50
	873	11.48
	748	11.58
	698	15.68
21 - (Eastern Corridor – Southern Tributary)	494	6.66
	269	7.48
109 - (Eastern Corridor – Main Tributary)	593	23.16
	510	27.40

Reach	HEC-RAS Cross Section	1% AEP (m³/s)
	438	26.03
	367	28.31
	238	29.27
	191	29.17
	161	31.44
0 - (Western Corridor)	864	9.84
	573	15.93
	528	14.68
	219	18.07
	102	20.34

4.2.3 BOUNDARY CONDITIONS

Boundary conditions adopted for the existing scenario as presented in **Section 4.1.3** remain unchanged for the developed scenario.

4.2.4 DEVELOPED FLOOD RESULTS

The 1% AEP flood conditions along the drainage path for the Developed Scenario are presented in **Table 4-5**.

Table 4-5: Developed Scenario 1% AEP Flood Conditions

River - Reach	HEC-RAS Cross Section	Flood Level (m AHD)	Maximum Flood Depth (m)	Average Velocity (m/s)	Depth-Velocity Product (m²/s)
West – 0	864	58.48	1.08	0.71	0.77
West – 0	813	58.07	0.94	0.83	0.78
West – 0	752	57.40	0.68	0.85	0.58
West – 0	711	57.27[A]	1.06	0.58	0.61
West – 0	661	57.27[A]	1.07	0.22	0.24
West – 0	594	57.27[A]	1.77	0.09	0.16
West – 0	573	57.27[A]	2.47	0.14	0.35
Western Culvert Crossing					
West – 0	528	54.88	0.56	0.79	0.44
West – 0	488	54.46	0.40	0.93	0.37
West – 0	438	53.71	0.45	0.83	0.37
West – 0	413	53.42	0.90	0.79	0.71
West – 0	352	53.00	1.23	0.65	0.80
West – 0	297	52.45	0.72	1.13	0.81
West – 0	246	52.08	1.61	0.71	1.14
West – 0	219	51.88	0.97	0.97	0.94
West – 0	201	51.73	1.33	0.92	1.22
West – 0	153	51.30	1.09	0.99	1.08
West – 0	102	51.03	1.44	0.77	1.11
West – 0	69	50.88	1.77	0.82	1.45

River - Reach	HEC-RAS Cross Section	Flood Level (m AHD)	Maximum Flood Depth (m)	Average Velocity (m/s)	Depth-Velocity Product (m^2/s)
West – 0	40	50.67	0.96	0.95	0.91
East – 21	494	59.83	0.12	0.00	0.00
East – 21	444	58.64	0.35	0.96	0.34
East – 21	393	57.41	0.30	0.79	0.24
East – 21	342	56.09	0.24	0.87	0.21
East – 21	309	55.43	0.32	0.67	0.21
East – 21	269	54.95	0.42	0.70	0.29
East – 21	219	54.43	0.50	0.71	0.36
East – 21	169	53.87	0.47	0.76	0.36
East – 21	119	53.31	0.74	0.76	0.56
East – 21	69	52.67	0.42	0.81	0.34
East – 21	45	52.37	0.41	0.68	0.28
East – 21	28	52.28	0.59	0.49	0.29
East – 21	21	52.27	0.66	0.42	0.28
East – 630	1154	57.76	0.30	0.68	0.20
East – 630	1104	57.20	0.45	0.67	0.30
East – 630	1054	56.14	0.30	1.34	0.40
East – 630	1004	55.88[A]	0.66	0.29	0.19
East – 630	970	55.88[A]	1.32	0.28	0.37
East – 630	933	55.88[A]	1.29	0.20	0.26
Eastern Culvert Crossing A					
East – 630	873	54.31	0.50	0.69	0.35
East – 630	850	54.11	0.57	0.78	0.44
East – 630	798	53.60	0.56	0.78	0.44
East – 630	748	53.19	0.58	0.72	0.42
East – 630	698	52.79	0.65	0.78	0.51
East – 630	657	51.96	0.97	1.68	1.63
East – 109	593	52.24	1.19	0.45	0.54
East – 109	585	52.23	1.20	0.44	0.53
East – 109	536	52.20	1.59	0.36	0.57
East – 109	510	52.18	2.76	0.42	1.16
Eastern Culvert Crossing B					
East – 109	438	51.29	2.07	0.55	1.14
East – 109	417	51.25	2.07	0.51	1.06
East – 109	367	51.21	1.68	0.39	0.66
East – 109	326	51.20	1.99	0.29	0.58
East – 109	270	51.20	2.31	0.19	0.44
East – 109	238	51.19	2.52	0.24	0.60
Eastern Culvert Crossing C					
East – 109	191	49.05	1.48	0.90	1.33
East – 109	161	48.80	1.32	0.96	1.27
East – 109	109	48.43	1.05	1.09	1.14
East – 81	594	58.25	0.22	0.59	0.13

River - Reach	HEC-RAS Cross Section	Flood Level (m AHD)	Maximum Flood Depth (m)	Average Velocity (m/s)	Depth-Velocity Product (m^2/s)
East – 81	544	56.87	0.18	0.87	0.16
East – 81	494	55.80	0.28	0.56	0.16
East – 81	444	54.55	0.25	1.03	0.26
East – 81	391	53.70	0.32	0.52	0.17
East – 81	338	52.76	0.30	1.01	0.30
East – 81	290	51.82	0.35	0.69	0.24
East – 81	239	50.85	0.45	0.91	0.41
East – 81	187	50.12	0.50	0.71	0.36
East – 81	131	49.39	0.41	0.88	0.36
East – 81	81	49.05	1.48	0.90	1.33

[A] Note: WSLs from the XP-RAFTS detention analysis presented in **Section 3.4** are higher and are presented within this table. Refer to **Section 4.2.5** for further discussion.

Although the flood levels along the drainage path increase through the site as a result of the peak flow increases and the proposed fill, this will not create adverse impacts because:

- Increases are contained within the site;
- Appropriate flood immunity will be provided for the development;
- The 1% AEP flood levels at the downstream boundaries are lower in the developed scenario; and
- Upstream catchment connections are proposed where required. Refer to Drawing No. **16-002518-SK12** for concept.

Table 4-6 presents the flooding at crossing locations.

Table 4-6: Developed Scenario HEC-RAS 1% AEP Crossing Results

Crossing Location	Culvert #	Through Culvert Peak Flow (m^3/s)	Upstream Flood Level (m AHD)	Downstream Flood Level (m AHD)	Culvert Upstream Velocity (m/s)	Culvert Downstream Velocity (m/s)
Western Crossing RL 57.5	Primary #1	0.45	57.23[A]	54.88	3.18	3.18
	Secondary #2	15.48			1.91	2.24
Eastern Crossing A RL 56.9	Primary #1	12.50	55.89 [A]	54.31	2.31	2.39
Eastern Crossing B RL 53.5	Primary #1	27.40	52.49 [A]	51.29	3.17	3.17
Eastern Crossing C RL 51.0	Primary #1	10.79	51.19	49.05	4.24	4.24
	Secondary #2	4.27			2.52	2.67
	Weir Flow	14.21			N/A	N/A

[A] Note: WSLs from the XP-RAFTS detention analysis presented in **Section 3.4** are higher and are presented within this table. Refer to **Section 4.2.5** for further discussion.

It is recommended that the culvert crossing design is confirmed during subsequent detailed design phases.

4.2.5 DETENTION STORAGE WATER SURFACE LEVELS

The HEC-RAS modelling undertaken along the drainage corridors is one-dimensional steady state water surface calculation based on the one-dimensional energy equation. This does not take into account the stage-storage-discharge characteristics of detention basins and the dynamic rainfall patterns.

As a result, WSLs over storage areas within the one-dimensional steady state HEC-RAS model vary to those calculated by XP-RAFTS in **Section 3.4**. Consequently, the XP-RAFTS WSLs have been adopted at locations noted in **Table 4-5**.

4.2.6 SENSITIVITY SCENARIOS

4.2.6.1 HIGH MANNING'S

A sensitivity scenario with a higher Manning's n value of 0.15 has been modelled for confirming the freeboard to the habitable floors. All other HEC-RAS parameters, including peak flow rates and boundary conditions were retained as per the Developed Scenario. The 1% AEP flood levels along the drainage path for the sensitivity scenario are presented in **Table 4-7**. All vehicular crossings remain immune to overtopping during this scenario.

Table 4-7: Sensitivity Scenario – High Manning's 1% AEP Local Flood Levels

River - Reach	HEC-RAS Cross Section	Flood Level (m AHD)
West – 0	864	58.77
West – 0	813	58.31
West – 0	752	57.70
West – 0	711	57.30
West – 0	661	57.27[A]
West – 0	594	57.27[A]
West – 0	573	57.27[A]
Western Culvert Crossing		
West – 0	528	55.11
West – 0	488	54.67
West – 0	438	53.94
West – 0	413	53.70
West – 0	352	53.28
West – 0	297	52.83
West – 0	246	52.47
West – 0	219	52.28
West – 0	201	52.13
West – 0	153	51.76
West – 0	102	51.45
West – 0	69	51.24
West – 0	40	51.00
East – 21	494	59.91
East – 21	444	58.80
East – 21	393	57.56
East – 21	342	56.21
East – 21	309	55.6

River - Reach	HEC-RAS Cross Section	Flood Level (m AHD)
East – 21	269	55.17
East – 21	219	54.65
East – 21	169	54.08
East – 21	119	53.65
East – 21	69	52.57
East – 21	45	52.71
East – 21	28	52.66
East – 21	21	52.65
East – 630	1154	57.94
East – 630	1104	57.41
East – 630	1054	56.26
East – 630	1004	55.85
East – 630	970	55.88[A]
East – 630	933	55.88[A]
Eastern Culvert Crossing A		
East – 630	873	54.56
East – 630	850	54.36
East – 630	798	53.88
East – 630	748	53.48
East – 630	698	53.09
East – 630	657	51.96
East – 109	593	52.61
East – 109	585	52.59
East – 109	536	52.52
East – 109	510	52.48
Eastern Culvert Crossing B		

River - Reach	HEC-RAS Cross Section	Flood Level (m AHD)
East – 109	438	51.58
East – 109	417	51.49
East – 109	367	51.33
East – 109	326	51.25
East – 109	270	51.22
East – 109	238	51.19
Eastern Culvert Crossing C		
East – 109	191	49.39
East – 109	161	49.1
East – 109	109	48.72

River - Reach	HEC-RAS Cross Section	Flood Level (m AHD)
East – 81	594	58.33
East – 81	544	57.01
East – 81	494	55.9
East – 81	444	54.71
East – 81	391	53.84
East – 81	338	52.95
East – 81	290	51.96
East – 81	239	51.03
East – 81	187	50.34
East – 81	131	49.57

4.2.6.2 25% CULVERT BLOCKAGE

A sensitivity scenario incorporating a 25% sedimentation culvert blockage has been modelled for confirming the flood immunity levels for the habitable floors. All other HEC-RAS parameters, including peak flow rates and boundary conditions were retained as per the developed scenario. The 1% AEP flood levels along the drainage path for the sensitivity scenario are presented in **Table 4-8**. All vehicular crossings remain immune to overtopping during this scenario.

Table 4-8: Sensitivity Scenario – 25% Blockage 1% AEP Local Flood Levels

River - Reach	HEC-RAS Cross Section	Flood Level (m AHD)
West – 0	864	58.50
West – 0	813	58.00
West – 0	752	57.53
West – 0	711	57.49
West – 0	661	57.48
West – 0	594	57.48
West – 0	573	57.48
Western Culvert Crossing		
West – 0	528	54.88
West – 0	488	54.46
West – 0	438	53.71
West – 0	413	53.42
West – 0	352	53.00
West – 0	297	52.45
West – 0	246	52.08
West – 0	219	51.88
West – 0	201	51.73
West – 0	153	51.30
West – 0	102	51.03
West – 0	69	50.88
West – 0	40	50.67

River - Reach	HEC-RAS Cross Section	Flood Level (m AHD)
East – 21	494	59.84
East – 21	444	58.64
East – 21	393	57.42
East – 21	342	56.08
East – 21	309	55.43
East – 21	269	54.94
East – 21	219	54.45
East – 21	169	53.84
East – 21	119	53.36
East – 21	69	52.57
East – 21	45	53.00
East – 21	28	53.00
East – 21	21	53.00
East – 630	1154	57.77
East – 630	1104	57.19
East – 630	1054	56.15
East – 630	1004	56.19
East – 630	970	56.19
East – 630	933	56.19
Eastern Culvert Crossing A		
East – 630	873	54.31

River - Reach	HEC-RAS Cross Section	Flood Level (m AHD)
East – 630	850	54.11
East – 630	798	53.60
East – 630	748	53.19
East – 630	698	52.79
East – 630	657	51.96
East – 109	593	52.99
East – 109	585	52.99
East – 109	536	52.99
East – 109	510	52.98
Eastern Culvert Crossing B		
East – 109	438	51.31
East – 109	417	51.27
East – 109	367	51.24
East – 109	326	51.23
East – 109	270	51.22

River - Reach	HEC-RAS Cross Section	Flood Level (m AHD)
East – 109	238	51.22
Eastern Culvert Crossing C		
East – 109	191	49.05
East – 109	161	48.80
East – 109	109	48.43
East – 81	594	58.25
East – 81	544	56.87
East – 81	494	55.80
East – 81	444	54.55
East – 81	391	53.70
East – 81	338	52.76
East – 81	290	51.82
East – 81	239	50.85
East – 81	187	50.12
East – 81	131	49.39

4.2.6.3 100% CULVERT BLOCKAGE

A sensitivity scenario incorporating 100% culvert blockage has been modelled for confirming the flood immunity levels for the habitable floors. The 10% AEP was modelled. All other HEC-RAS parameters, including peak flow rates and boundary conditions were retained as per the developed scenario. The 10% AEP flood levels along the drainage path for the sensitivity scenario are presented in **Table** 4-9.

Table 4-9: Sensitivity Scenario – 100% Blockage 10% AEP Local Flood Levels

River - Reach	HEC-RAS Cross Section	Flood Level (m AHD)
West – 0	864	58.37
West – 0	813	57.78
West – 0	752	57.65
West – 0	711	57.64
West – 0	661	57.64
West – 0	594	57.64
West – 0	573	57.64
Western Culvert Crossing		
West – 0	528	54.77
West – 0	488	54.37
West – 0	438	53.63
West – 0	413	53.29
West – 0	352	52.87
West – 0	297	52.30
West – 0	246	51.87
West – 0	219	51.69
West – 0	201	51.55

River - Reach	HEC-RAS Cross Section	Flood Level (m AHD)
West – 0	153	51.08
West – 0	102	50.82
West – 0	69	50.70
West – 0	40	50.51
East – 21	494	59.81
East – 21	444	58.57
East – 21	393	57.37
East – 21	342	56.03
East – 21	309	55.38
East – 21	269	54.86
East – 21	219	54.36
East – 21	169	53.75
East – 21	119	53.26
East – 21	69	52.51
East – 21	45	53.74
East – 21	28	53.74
East – 21	21	53.73

River - Reach	HEC-RAS Cross Section	Flood Level (m AHD)
East – 630	1154	57.77
East – 630	1104	56.99
East – 630	1054	57.03
East – 630	1004	57.03
East – 630	970	57.03
East – 630	933	57.03
Eastern Culvert Crossing A		
East – 630	873	54.20
East – 630	850	54.00
East – 630	798	53.48
East – 630	748	53.08
East – 630	698	52.68
East – 630	657	51.78
East – 109	593	53.73
East – 109	585	53.73
East – 109	536	53.73
East – 109	510	53.73
Eastern Culvert Crossing B		
East – 109	438	51.27
East – 109	417	51.26
East – 109	367	51.24
East – 109	326	51.24
East – 109	270	51.24
East – 109	238	51.23
Eastern Culvert Crossing C		
East – 109	191	48.82
East – 109	161	48.58
East – 109	109	48.25
East – 81	594	58.20
East – 81	544	56.83
East – 81	494	55.76
East – 81	444	54.49
East – 81	391	53.63
East – 81	338	52.69
East – 81	290	51.75
East – 81	239	50.78
East – 81	187	50.03
East – 81	131	49.31

In this sensitivity scenario, all four crossings are overtopped due to 100% blockage of the culverts. Maximum flow depths across the Western and Eastern A crossings remain below 200mm in accordance with the requirements QUDM (2013) for roadway flood depth during a minor storm. Additionally, depth-velocity products for all four crossings are well below 0.3m^2/s in accordance with QUDM (2013). However, the remaining crossings (Eastern Crossings B & C) will be non-trafficable during this event. Nonetheless, emergency evacuation routes remain available for all areas of the development.

Flood immunity for habitable floor levels adjacent to each drainage corridor have been assigned based on EDQ standards. Refer to **Section 4.3** for further details on flood immunity levels adopted for the development.

4.3 FLOOD IMMUNITY

4.3.1 FLOOD IMMUNITY STANDARDS

Table 4-10 provides details of flood immunity levels for the development. The habitable floor flood immunity is in accordance with LCC guidelines as required under *Table 1* of the *PDA Guideline No. 15 Protection from Flood and Storm Tide Inundation* (2015). The park flood immunity standards are in accordance with *Table 5* of the *PDA Guideline No. 12 Park Planning and Design* (2015).

Table 4-10: Flood Immunity Standards

Floor Type	Flood Immunity Standard
Habitable Floor	Greater of: • 1% AEP + 500mm or • Sensitivity Scenario

4.3.2 FLOOD IMMUNITY LEVELS

The minimum flood immunity level along the drainage corridors are presented in **Table 4-11**. These are based on the minimum flood immunity standards presented in **Table 4-10**.

Table 4-11: Minimum Flood Immunity Levels

River - Reach	HEC-RAS Cross Section	Minimum Habitable Floor Levels (m AHD)
West – 0	864	58.98
West – 0	813	58.57
West – 0	752	57.90
West – 0	711	57.65
West – 0	661	57.64
West – 0	594	57.64
West – 0	573	57.64
Western Culvert Crossing		
West – 0	528	55.38
West – 0	488	54.96
West – 0	438	54.21
West – 0	413	53.92
West – 0	352	53.50
West – 0	297	52.95
West – 0	246	52.58
West – 0	219	52.38
West – 0	201	52.23
West – 0	153	51.80
West – 0	102	51.53
West – 0	69	51.38
West – 0	40	51.17
East – 21	494	60.33
East – 21	444	59.14
East – 21	393	57.91
East – 21	342	56.59
East – 21	309	55.93
East – 21	269	55.45
East – 21	219	54.93
East – 21	169	54.37
East – 21	119	53.81
East – 21	69	53.17
East – 21	45	53.74
East – 21	28	53.74
East – 21	21	53.73
East – 630	1154	58.26

River - Reach	HEC-RAS Cross Section	Minimum Habitable Floor Levels (m AHD)
East – 630	1104	57.70
East – 630	1054	57.03
East – 630	1004	57.03
East – 630	970	57.03
East – 630	933	57.03
Eastern Culvert Crossing A		
East – 630	873	54.81
East – 630	850	54.61
East – 630	798	54.10
East – 630	748	53.69
East – 630	698	53.29
East – 630	657	52.46
East – 109	593	53.74
East – 109	585	53.74
East – 109	536	53.73
East – 109	510	53.73
Eastern Culvert Crossing B		
East – 109	438	51.79
East – 109	417	51.75
East – 109	367	51.71
East – 109	326	51.70
East – 109	270	51.70
East – 109	238	51.69
Eastern Culvert Crossing C		
East – 109	191	49.55
East – 109	161	49.30
East – 109	109	48.93
East – 81	594	58.75
East – 81	544	57.37
East – 81	494	56.30
East – 81	444	55.05
East – 81	391	54.20
East – 81	338	53.26
East – 81	290	52.32
East – 81	239	51.35

River - Reach	HEC-RAS Cross Section	Minimum Habitable Floor Levels (m AHD)
East – 81	187	50.62
East – 81	131	49.89

River - Reach	HEC-RAS Cross Section	Minimum Habitable Floor Levels (m AHD)
East – 81	191	49.55

Note: Minimum habitable floor level immunity levels have been rounded up to nearest 5mm.

Table 4-12 provides the minimum road crossing levels. These are based on the 1% AEP flood/detention levels for vehicular crossings and the 10% AEP flood/detention level for the pathway/bike.

Table 4-12: Minimum Road Crossing Levels

Crossing	RL (m AHD)
Western	57.50
Eastern A	56.90
Eastern B	53.50
Eastern C	51.00

5 STORMWATER QUALITY

To improve the quality of the runoff leaving the site, a treatment train incorporating Stormwater Quality Improvement Devices (SQIDs) is proposed. SQIDs will intercept and capture pollutants so that any potential stormwater quality impacts from the site will be mitigated and the required WQOs will be achieved.

This section of the report discusses:

- The identification of key stormwater pollutants associated with the proposed development;
- The WQOs applicable for the site;
- Proposed SQIDs for stormwater quality management; and
- Modelling of the proposed SQIDs to assess if they achieve the required WQOs.

5.1 POLLUTANTS OF CONCERN

Typical key pollutants expected to be generated during the operational (post-construction) phase of an urban development are listed as follows, with those presented in capitals being the key pollutants to be targeted for treatment:

- LITTER
- SEDIMENT
- Oxygen demanding substances (possibly present)
- NUTRIENTS (Nitrogen & Phosphorus)
- Pathogens / Faecal coliforms
- Hydrocarbons
- HEAVY METALS (associated with fine sediments)
- Surfactants
- Organochlorines & organophosphates
- Thermal pollution
- pH altering substances

Only the key pollutants will be further addressed in this report; however, the treatment train developed will adequately mitigate the other pollutant loads. As heavy metals will predominately be associated with fine sediment, controls proposed to reduce total suspended solids will also adequately reduce loads of heavy metals.

5.2 WATER QUALITY OBJECTIVES

The load reduction WQOs presented in **Table 5-1** have been adopted from *Appendix 3* of the *SPP* (2016).

Table 5-1: Water Quality Objectives

Pollutant	Total Suspended Solids	Total Phosphorus	Total Nitrogen	Gross Pollutants
Load Reduction Target	80%	60%	45%	90%

5.3 STORMWATER QUALITY MANAGEMENT STRATEGY

To mitigate the potential increase in pollutant loads generated by the development area, a stormwater quality management strategy comprising of various bioretention treatment systems is proposed. The following SQIDs are proposed:

- Bioretention basins located along the perimeter of each drainage corridor; and
- At-source bioretention pod systems integrated within road reserves.

Refer to Drawing No. **15-002518-SK13** in **Appendix D** for the stormwater quality catchment delineation and proposed treatment locations.

Due to the multiple site discharge locations, assessment of stormwater quality has been undertaken for runoff discharging from the western drainage corridor and runoff discharging from the eastern drainage corridors.

Bioretention systems utilise sandy loam soil based media to filter runoff. Sediment particles and suspended solids are trapped within vegetation and on the surface of the filter media while micro-organisms and vegetation remove dissolved nutrients (nitrogen and phosphorus) through biological uptake processes. Subsoil drainage provided below the filter media allows for the treated water to discharge from the bioretention systems. Details regarding the maintenance of the bioretention systems are presented in **Section 6.**

5.4 MUSIC MODELLING METHODOLOGY

Water quality modelling has been undertaken using MUSIC Version 6.2, developed by the Cooperative Research Centre for Catchment Hydrology (CRCCH). MUSIC enables the user to conceptualise the transfer of pollutants through a stormwater drainage system and provides an aid in quantifying the effectiveness of the proposed stormwater quality treatment train. MUSIC only provides quantitative modelling for Total Suspended Solids (TSS), Total Phosphorous (TP), Total Nitrogen (TN) and Gross Pollutants (GP).

The MUSIC model was setup in accordance with Water by Design *MUSIC Modelling Guidelines* (2010).

5.4.1 METEOROLOGICAL DATA

Six-minute pluviographic data was sourced from the eWater website for Greenbank Thompson Road (Station No. 040659).

In accordance with *Table 3.1* from *Music Modelling Guidelines* (2010), the 10-year period from 1 January 1980 to 31 December 1989 has been adopted for the rainfall duration. The mean annual rainfall for this period based on 6-minute pluviograph data is 745mm.

5.4.2 SOURCE NODES

Source nodes represent catchments areas for MUSIC modelling purposes. The split catchment approach has been used in accordance with the *MUSIC Modelling Guidelines* (2010), which divides each catchment into three types of surfaces: Roof, Road and Ground. Refer to Calibre Consulting Drawing No. **16-002518-SK13** in **Appendix D** for MUSIC modelling catchment delineation.

Rainfall runoff and pollutant export parameters were assigned for the different land use areas in accordance with *Table 3.7* and *Table 3.8* of the *MUSIC Modelling Guidelines* (2010).

The following fraction impervious assumptions have been adopted in accordance with *Table 3.6* of the *MUSIC Modelling Guidelines* (2010). These values generally align with HWMC's *Stormwater Management Plan* (Report No. J00110R1V2 dated 5 July 2012).

Table 5-2: Land Use Fraction Impervious Values (Source: HWMC, 2012)

Land Use	Fraction Impervious
Roof	100%
Road Reserve	70%
Ground (includes park areas)	25%

The source node parameters presented in **Table 5-2** were implemented in MUSIC modelling. Refer to **Appendix C** for MUSIC model data.

It is noted that only the development footprint areas (including parks and sports fields) have been included in the MUSIC analyses. Undeveloped areas, particularly those within the drainage corridors and upstream external catchments have been excluded from the MUSIC analysis. Refer to Drawing No. **15-002518-SK13** in **Appendix D** for the MUSIC catchment delineation. The catchment naming convention has been adopted to align with the stormwater quantity catchments identified in Section 3 of this report for consistency.

The MUSIC modelling is to be updated during subsequent ROL application phases as necessary to reflect any updates to the site layout and stormwater drainage strategies.

Table 5-3: MUSIC Source Nodes

Catchment	Total Area (ha)	Road (ha)	Roof (ha)	Ground (ha)
6c	0.824	12	0.258	0.168
6b	9.177	128	2.752	1.351
5a	11.693	117	2.516	1.269
5b	7.971	104	2.236	0.970
7b3	1.782	28	0.602	0.319
7b1	4.801	75	1.613	0.732
7b2	3.574	60	1.290	0.567
12b1	0.645	9	0.194	0.123
12b2	1.682	26	0.559	0.277
12b3	3.472	60	1.290	0.543
12b4	2.216	27	0.581	0.368
11b	12.296	143	3.075	1.688
9a	5.449	63	1.355	0.690
11d1	3.936	61	1.312	0.739
11d2	4.786	72	1.548	0.863
11d3	3.250	43	0.925	0.484
14c	5.498	100	2.150	0.715
12c1	2.144	30	0.645	0.407
12c2	4.458	68	1.462	0.577
20b1	2.627	45	0.968	0.391
20b2	5.771	94	2.021	0.886
11c	5.557	71	1.527	0.986
14b	3.151	62	1.333	0.434

5.4.3 DRAINAGE LINKS

Default drainage link settings have been adopted for the model. As stated in *Section 4.17* of *MUSIC Modelling Guidelines* (2010), MUSIC's default settings apply a conservative approach in assessing treatment performance, assuming all flows and pollutants from the catchment arrive at the treatment node at the same time. Flow routing has not been incorporated in accordance with *Section 4.17* of *MUSIC Modelling Guidelines* (2010).

5.4.4 TREATMENT NODES

5.4.4.1 BIORETENTION TREATMENT

Bioretention treatment was modelled with the filter areas presented in **Table 5-3**. During detailed design, pre-treatment in accordance with *Table 13* of the *Bioretention Technical Design Guidelines* (2014) will be provided in addition to the filter areas specified.

Bioretention filter areas presented below are to be proportionally split into multiple basins within the catchments. This will be investigated further during subsequent ROL applications.

Table 5-4: Bioretention Filter Areas

MUSIC Catchment	Total Bioretention Pod Filter Area (m²)	'End-of-line' Bioretention Basin Filter Area
5a	326	250
5b	374	250
6b	687	250
6c	0	
7b1	294	280
7b2	334	
7b3	90	
11b	588	600
12b1	75	
12b2	149	
12b3	298	
12b4	75	
14c	322	800
11d1	251	
11d2	161	
11d3	143	400
9a	278	
12c1	80	400
12c2	355	
20b1	128	
20b2	366	
11c	333	100
14b	74	
Total	**5,780**	**3,330**

Bioretention pod filter areas have been combined within each catchment.

The following parameters were applied consistently across all bioretention pod nodes:

- 500mm filter media depth;
- 100mm ponding extended detention depth;
- 50mg/kg filter media Orthophosphate content;
- 400mg/kg filter media TN content; and
- 200mm/hr filter media saturated hydraulic conductivity.

The following parameters were applied consistently across all bioretention basin nodes:

- 500mm filter media depth;
- 300mm ponding extended detention depth;
- Overflow weirs were modelled as 10% of the filter area;
- 50mg/kg filter media Orthophosphate content;
- 400mg/kg filter media TN content; and
- 200mm/hr filter media saturated hydraulic conductivity.

The Orthophosphate and TN content in the filter media were adopted from Healthy Waterways *http://healthywaterways.org/initiatives/waterbydesign/stormwater*

5.5 MUSIC MODELLING RESULTS

Results for the proposed stormwater quality management strategies are presented in **Table 5-5** and **Table 5-6**

Table 5-5: MUSIC Model Results for Western Drainage Corridor

Description	TSS	TP	TN	GP
WQO (%)	80	60	45	90
Source Loads (kg/yr)	24,100	51.9	328	4,480
Residual Loads (kg/yr)	3,310	20.8	162	0
Load Reduction Achieved (%)	86	60	51	100
Load Reduction Achieved > WQO?	Yes	Yes	Yes	Yes

Table 5-6: MUSIC Model Results for Eastern Drainage Corridor

Description	TSS	TP	TN	GP
WQO (%)	80	60	45	90
Source Loads (kg/yr)	41,600	90.4	577	7,790
Residual Loads (kg/yr)	5,270	35.8	273	0
Load Reduction Achieved (%)	87	60	53	100
Load Reduction Achieved > WQO?	Yes	Yes	Yes	Yes

The above results demonstrate that the proposed stormwater quality management strategy achieves the WQOs required under the *SPP* (2014).

6 CONSTRUCTION & OPERATIONAL MANAGEMENT OF SQIDS

The following sections provide detail of the procedures to be adopted for the construction and operational management of the bioretention pods. No testing or monitoring of water quality is proposed. The level of operation management and maintenance proposed from herein is considered best practice and if followed will ensure these treatment devices will operate to their design intent.

6.1 CONSTRUCTION & ESTABLISHMENT

For bioretention systems to perform as designed there is a need to protect filter media and vegetation during construction. A staged construction and establishment methodology is therefore proposed generally in accordance with Option 1 of *Table 3.6* and *Section 3.8.1* of the Water by Design *Construction and Establishment Guidelines* (2010). A summary of this methodology is presented below:

1. Civil Works (Functional Installation) – Earthworks and shaping to create the layout and functional elements of the bioretention systems will be undertaken as part of the civil works phase. The installation of these functional elements (e.g. inlets, outlets structures, subsoil drainage, transition layers and filter media) shall be undertaken as per the methodology detailed in *Section 3.9.1* in the Water by Design *Construction and Establishment Guidelines* (2010). Prior to the commencement of the following phase, sediment fences will be erected around the perimeter of the systems to avoid the entry of sediment. Laying a temporary filter cloth (or 25mm thick layer of course sand, 25mm of topsoil and followed by a layer of turf) over the pod shall protect the bioretention systems during the construction and building phases.
2. Building Phase Protection (Building Construction) – During this phase the sediment fences shall remain around the perimeter of the systems to restrict sediment inflow. Clear indications of the restriction of traffic to the bioretention systems shall also be displayed.
3. Landscape Establishment (Operational Establishment) – Remove the temporary protective measures and remove any accumulation of sediment when the Building Phase is 80-90% complete. The systems shall be planted with vegetation and landscaping as proposed. Sufficient watering and removal of weeds shall be undertaken. This phase shall be performed in accordance with *Section 3.9.3* of the Water by Design *Construction and Establishment Guidelines* (2010).

6.2 OPERATIONAL PHASE MANAGEMENT & MAINTENANCE

Once the bioretention systems are installed, they must be inspected and maintained at recommended intervals to ensure they are functioning properly and satisfy the design intent. The following sections provide a summary of the maintenance requirements.

6.2.1 INSPECTION REQUIREMENTS

Checklists have been developed for maintenance inspection of bioretention systems. The condition and maintenance carried out will be recorded on the checklist at the time the inspection and/or maintenance is undertaken. A copy of the checklist is presented in **Appendix C**.

Maintenance personnel are to be encouraged to report and document changes in vegetation type within bioretention systems. Photographic documentation and mapping of vegetation types are to be recorded annually to determine changes in vegetation over time. Photographs of each device are to be taken at the same location annually. Through these procedures a reliable maintenance database can be developed and used to determine if the maintenance undertaken is ensuring that the bioretention systems are functioning as intended.

It should be noted that except for periods of extended wet weather, mosquitoes are unlikely to be an issue as surface water within the bioretention systems is not expected to remain for more than one day.

6.2.2 WEED REMOVAL

Maintenance personnel will need to identify species of both terrestrial and semi-aquatic weeds common to the area. As the bioretention systems are “dry” SQIDs, aquatic weed infestation is unlikely. When weeds have been identified they are to be removed by hand immediately or eradication methods scheduled before the infestation becomes larger and more difficult to control. It should be noted that herbicides should not be used in the removal of invasive weeds as this has negative impacts on downstream water quality.

6.2.3 REPLANTING

Replanting of vegetation is to be carried out to replace dead or damaged vegetation, vegetation that has been removed by scour or erosion, or vegetation that is being re-planted following tilling or the replacement of filter media. Removed vegetation should be replaced by plants of similar size and species, or as indicated on the appropriate Landscaping Plans.

6.2.4 FILTER INSPECTION AND REPLACEMENT

Fine sediment and silt may accumulate within the filter media of the bioretention systems over time. Removal of sediment and silt trapped within the filter media is expected to be the most costly maintenance requirement for these SQIDs.

It is recommended that visual inspection of the infiltration properties be undertaken at least three times per year with more frequent inspections no greater than three months apart between October and May. This is to determine whether built-up fine sediment and silt has reached a point where the filter media has become clogged.

The infiltration properties of the filter media of each bioretention system needs to be checked after a period of significant rainfall event, which is defined as a 24 hour period with rainfall greater than 200mm, or a shorter period with an average rainfall intensity greater than 20mm/hr. This is an ideal period to assess the infiltration properties as water should not pond for an extended period. Therefore inspections should occur within 24 hours after a suitable rainfall event.

In the event that isolated boggy patches occur within a pod, or a pod remains saturated for an extended period, then the subsoil drainage pipes may be blocked. If this is not the case and no other blockages have been observed then surface of the media is to be tilled (raked and aerated) to a depth of 150mm. This will require temporarily removing and storing the surface vegetation and topsoil (if present) prior to tilling the filter media surface. Should the infiltration properties be improved then the removed topsoil layer can once again be established and vegetation replanted.

Should tilling prove unsuccessful or if an infiltration check indicates filter media may be clogged, then the top portion of the filter media is to be replaced as follows:

1. Removal of topsoil, surface vegetation and store for re-establishment;
2. Remove the top 150mm of filter media and dispose of in an approved manner;
3. Till the remaining filter media to a further depth of 300mm;
4. Place a new layer of appropriate filter media as per relevant specifications, free from organic matter, clay and silt; and
5. Replace the topsoil and replant the removed vegetation.

If blockages occur frequently, a filter media with a higher saturated hydraulic conductivity should be considered. Reassessing the species and planting density of vegetation is also an option.

Unless changes to the filter media specification are made through a review of the SQID performance, the filter media to be used for the bioretention pod is to be a Sandy Loam as per the FAWB *Guidelines for Filter Media in Biofiltration Systems* (Version 3.01, 2009) as included in **Appendix C.**

6.2.5 SUBSOIL DRAINAGE INSPECTION & CLEANOUT

The build-up of fine sediment and silt within the subsoil drainage pipes is unlikely as it will be trapped by the filter media. However the subsoil drainage is to be checked annually for blockages that may be caused by foreign matter entering through cleanout inspection openings or by small fauna. This can be done by either:

- Observing the condition of the subsoil drain through the cleanout and inspection openings located towards the downstream end of a subsoil drainage pipe;
- Observing the amount of sediment and silt flushed into the downstream field inlet when water is pumped into the upstream end of the subsoil drainage line (through a cleanout and inspection opening).

If a considerable amount of sediment and silt is observed or carried into the downstream inlet, then each subsoil drainage line must be flushed out with high pressure water. Water is to be pumped into each subsoil drainage pipe through the upstream cleanout inspection opening until all sediment has been ejected from the pipe. To collect the water and ejected sediment within the downstream pit a temporary barrier is to be placed over the downstream pipe opening (such as sand bags) and a pump used to draw the water, sediment and silt out of the pit and irrigated onto areas of open space away from each pod. This will ensure the sediment and silt does not enter the downstream waterway.

6.3 GENERAL REQUIREMENTS

6.3.1 YEARLY REVIEW OF MAINTENANCE MANAGEMENT PLAN

Each year a review is to be carried out to determine if the programmed inspection and maintenance (including checklists) is ensuring each SQID is functioning as intended. The review should include an assessment of the maintenance database to determine whether the programmed inspections and maintenance is effective. Information on the database should be assessed to determine whether any noticeable changes are evident in vegetation, presence of fauna and operational efficiency of any structures or features of the device. This will further provide indicators as to whether sufficient information is being recorded for management purposes.

6.3.2 MAINTENANCE PERSONNEL SAFETY (OH&S)

The *Workplace Health and Safety ACT 1995* requires that all reasonably practicable steps be taken to protect an employee's health in a workplace. Organisations involved in the inspection and maintenance of the SQIDs should therefore:

- Have a documented occupational health and safety policy in place;
- Ensure all staff and maintenance personnel are aware of and abide by the policy; and
- The policy provides a mechanism for review and improvement.

As part of the policy personnel involved in the maintenance of the SQIDs are to have sufficient resources (such as personnel protective equipment, training etc.) to carry out the task in a safe manner.

6.3.3 GENERAL PUBLIC SAFETY

The safety of the general public in the area of the SQID being maintained also needs to be ensured. Given that inspection and maintenance tasks will to some degree encroach on resident's lot access sufficient notice and safety precautions are warranted and must be followed. This includes, but is not limited to:

- Issuing letter notices to residents 3-4 days prior to inspection and maintenance
- Placing safety barriers around maintenance site (including the road, if required)
- Placing warning signage appropriately at key locations around the maintenance sites (these are not to be removed until all works have finished).

7 WATERWAY STABILITY MANAGEMENT

This section discusses the waterway stability management required under the *SPP* (2016). This waterway stability management strategy will demonstrate that the receiving drainage corridors on site and Oxley Creek downstream will not be adversely impacted in the 63% AEP storm event.

Hydrological analyses presented within **Section 3** of this report demonstrate negligible increases in 63% AEP peak flow discharge from the site. Additionally, reductions in peak flow are evident for all design storm events (including the 63% AEP) at the downstream extent of the investigation area (downstream of Hobury Road; upstream of Oxley Creek). Therefore, it is expected that a negligible change in flood condition will be experienced at Oxley Creek.

Although the 63% AEP peak flows increase along the drainage corridors within the site, modelling indicates flow velocities will predominately decrease. Refer to **Table 7-1**. There are a few concentrated locations where the 63% AEP velocity has increased. Locations of increased velocities are associated to inflow locations as shown on Drawing No. **16-002518-SK12** in **Appendix D**. In reality, peak flow concentrations are not expected to occur. Irrespective of the increases in velocity, the maximum velocity in the waterways for developed conditions is still below 1.5m/s, which is not expected to have the potential to cause scour or erosion.

Appropriate scour protection such as rock armouring can be provided at any locations of further concern.

Table 7-1: Waterway Stability Management 63% AEP Developed Flood Conditions

River - Reach	HEC-RAS Cross Section	Existing Average Velocity (m/s)	Developed Average Velocity (m/s)	Variance (%)
West – 0	864	0.46	0.44	-4%
West – 0	813	0.65	0.76	17%
West – 0	752	0.53	0.46	-13%
West – 0	711	0.63	1.09	73%
West – 0	661	0.39	0.15	-62%
West – 0	594	0.63	0.03	-95%
West – 0	573	0.74	0.06	-92%
Western Culvert Crossing				
West – 0	528	0.44	0.47	7%
West – 0	488	0.74	0.66	-11%
West – 0	438	0.42	0.46	10%
West – 0	413	0.72	0.71	-1%
West – 0	352	0.42	0.38	-10%
West – 0	297	1.20	1.19	-1%
West – 0	246	0.61	0.51	-16%
West – 0	219	0.77	0.75	-3%
West – 0	201	0.73	0.70	-4%
West – 0	153	0.99	0.94	-5%
West – 0	102	0.47	0.47	0%
West – 0	69	0.47	0.46	-2%
West – 0	40	0.66	0.65	-2%
East – 21	494	0.50	0.00	-100%
East – 21	444	0.50	0.63	26%

River - Reach	HEC-RAS Cross Section	Existing Average Velocity (m/s)	Developed Average Velocity (m/s)	Variance (%)
East – 21	393	0.43	0.54	26%
East – 21	342	0.46	0.55	20%
East – 21	309	0.37	0.46	24%
East – 21	269	0.51	0.50	-2%
East – 21	219	0.50	0.49	-2%
East – 21	169	0.55	0.55	0%
East – 21	119	0.60	0.60	0%
East – 21	69	0.51	0.49	-4%
East – 21	45	0.51	0.50	-2%
East – 21	28	0.50	0.49	-2%
East – 21	21	1.00	0.97	-3%
East – 630	1154	0.34	0.25	-26%
East – 630	1104	0.50	0.80	60%
East – 630	1054	0.43	0.42	-2%
East – 630	1004	0.44	0.76	73%
East – 630	970	0.40	0.36	-10%
East – 630	933	0.43	0.15	-65%
Eastern Culvert Crossing A				
East – 630	873	0.41	0.46	12%
East – 630	850	0.37	0.46	24%
East – 630	798	0.64	0.77	20%
East – 630	748	0.43	0.34	-21%
East – 630	698	1.14	1.27	11%
East – 630	657	0.32	0.40	25%
East – 109	593	0.48	0.56	17%
East – 109	585	0.46	0.56	22%
East – 109	536	0.94	0.84	-11%
East – 109	510	0.89	1.28	44%
Eastern Culvert Crossing B				
East – 109	438	0.52	0.45	-13%
East – 109	417	0.61	0.44	-28%
East – 109	367	0.74	0.30	-59%
East – 109	326	0.61	0.19	-69%
East – 109	270	0.67	0.10	-85%
East – 109	238	0.63	0.12	-81%
Eastern Culvert Crossing C				
East – 109	191	0.64	0.65	2%
East – 109	161	0.64	0.71	11%

River - Reach	HEC-RAS Cross Section	Existing Average Velocity (m/s)	Developed Average Velocity (m/s)	Variance (%)
East – 109	109	0.89	1.23	38%
East – 81	594	0.69	0.67	-3%
East – 81	544	0.57	0.35	-39%
East – 81	494	0.33	0.79	139%
East – 81	444	0.80	0.85	6%
East – 81	391	0.24	0.32	33%
East – 81	338	0.86	0.81	-6%
East – 81	290	0.43	0.41	-5%
East – 81	239	0.80	0.76	-5%
East – 81	187	0.51	0.47	-8%
East – 81	131	0.65	0.60	-8%

Furthermore, increase in inundation extent throughout the drainage corridor during the 63% AEP storm event is negligible, except for upstream of the culvert crossings where detention is proposed. Refer to **Figure 7-1** for 63% AEP flood extent changes.

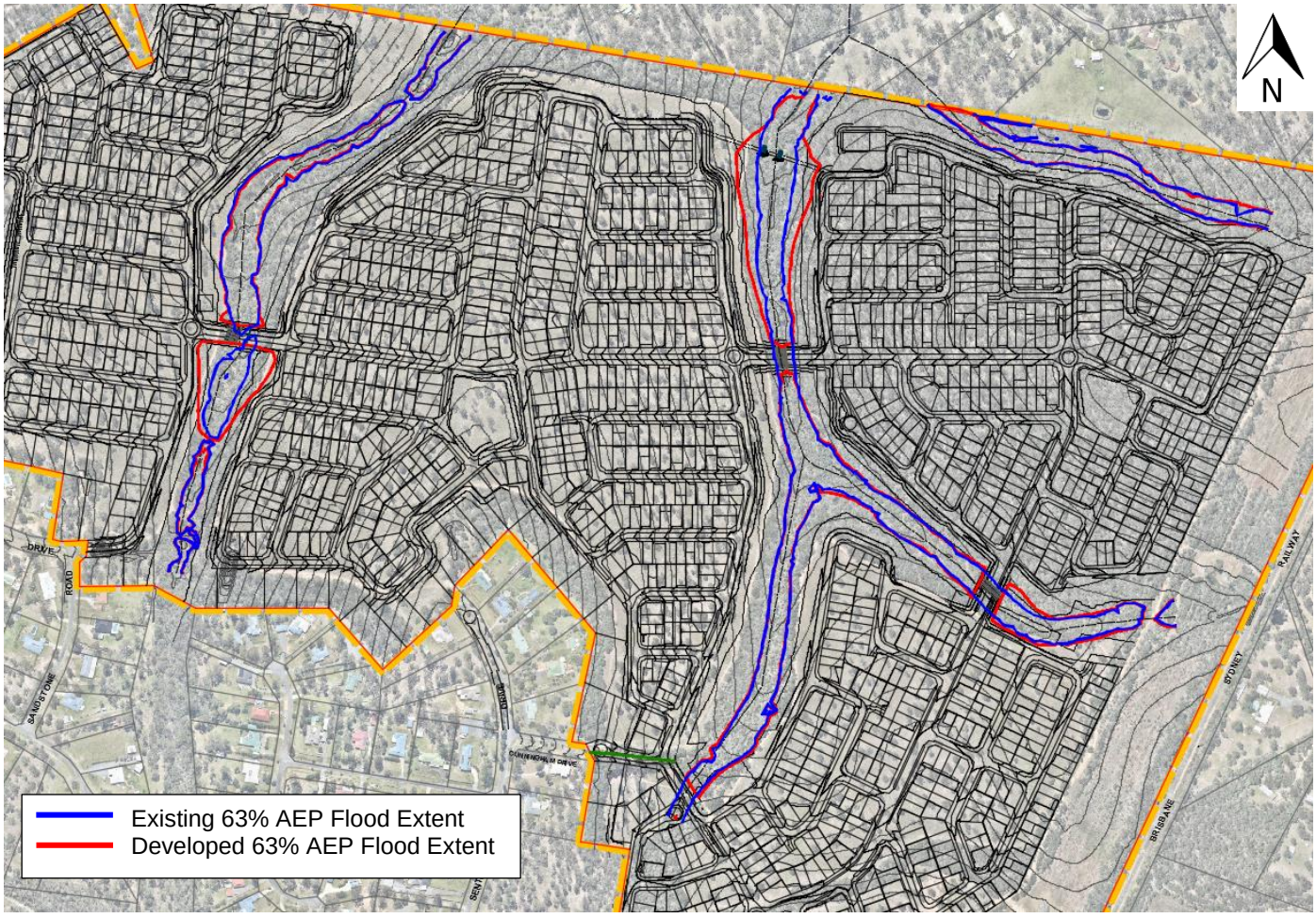


Figure 7-1: 63% AEP Flood Extent

The time of inundation within the detention basins for the 63% AEP have been assessed to demonstrate that vegetation will not be adversely inundated. **Figure 7-2** shows a graph of the detention characteristics over a 9 hour period at the upstream end of the western crossing. As can be seen, ponding depth of greater than 300mm occurs for a period of approximately 7 hours.

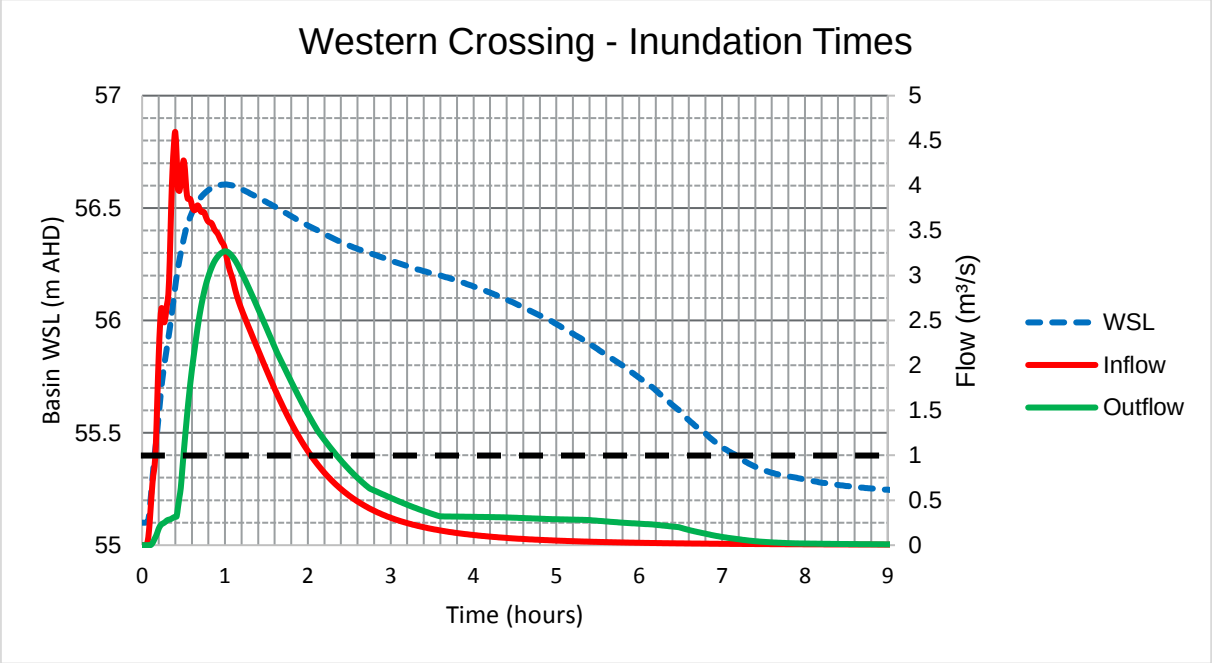


Figure 7-2: Western Crossing 63% AEP Inundation

Figure 7-3 shows a graph of the detention characteristics over a 5 hour period at the upstream of Eastern Crossing A. As can be seen, ponding depth of greater than 300mm occurs for a period of approximately 3 hours.

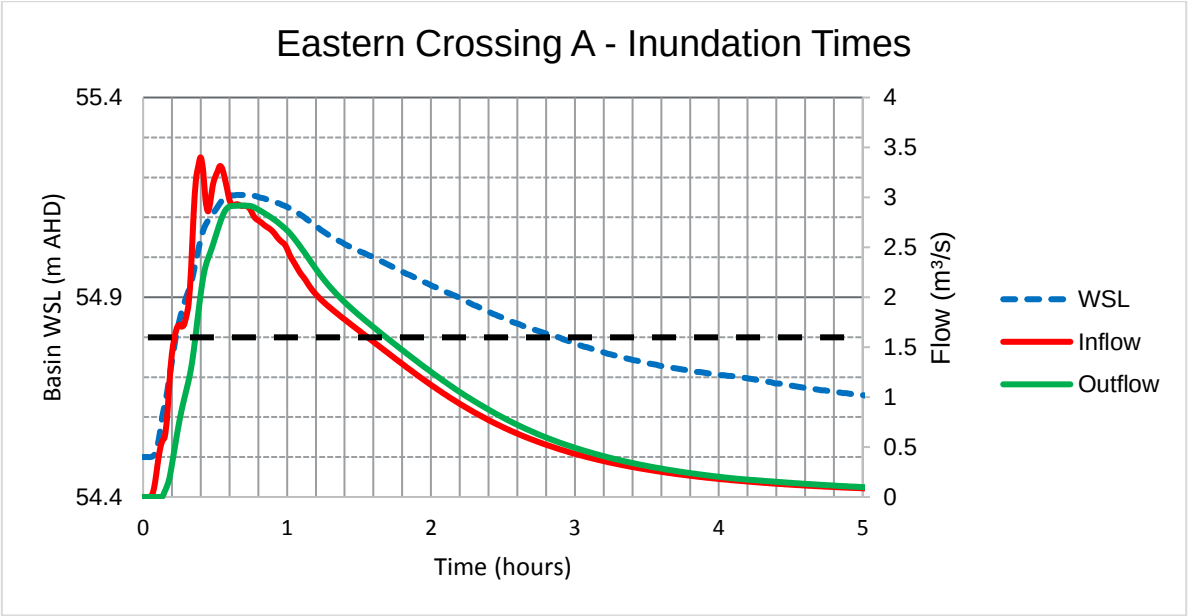


Figure 7-3: Eastern Crossing A 63% AEP Inundation

Similarly, **Figure 7-4** and **Figure 7-5** show graphs of the detention characteristics over a 9 hour period at the upstream of Eastern Crossing A and B, respectively. Eastern Crossing B retains a ponding depth of greater than 300mm for a period of approximately 2.5 hours. While Eastern Crossing C retains a ponding depth of greater than 300mm for approximately 3 hours.

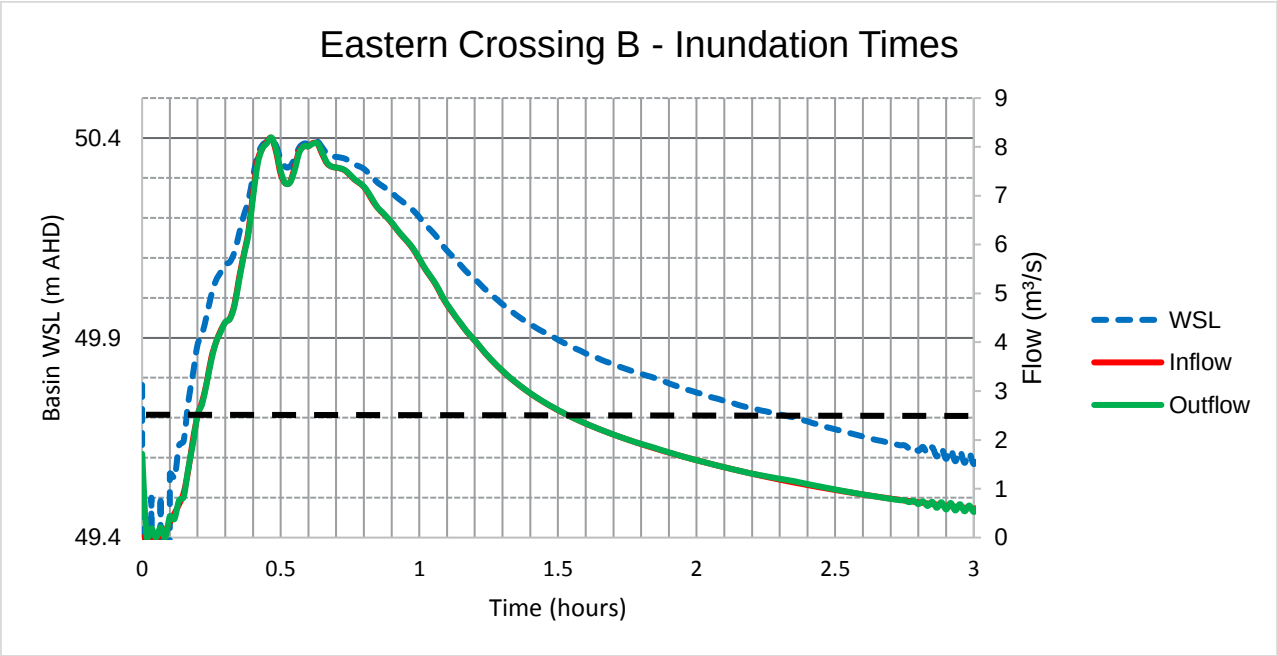


Figure 7-4: Eastern Crossing B 63% AEP Inundation

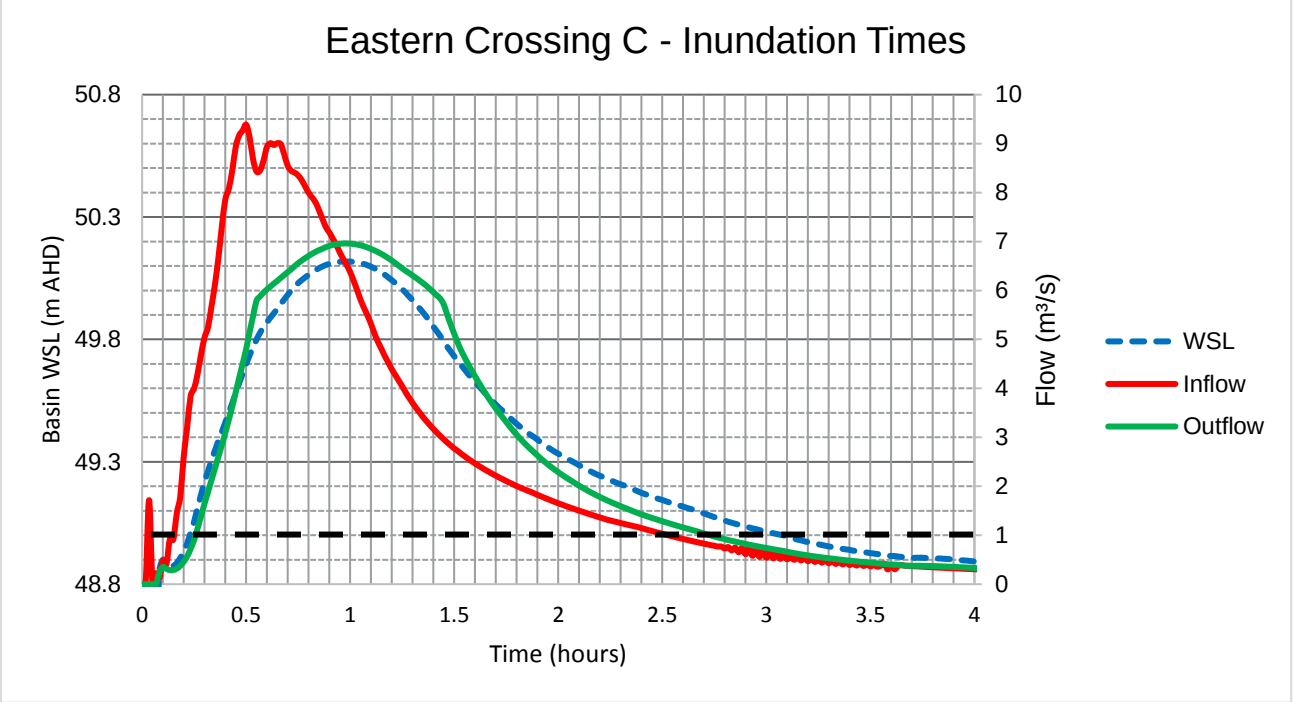


Figure 7-5: Eastern Crossing C 63% AEP Inundation

The inundation times during the 63% AEP at the detention systems are not expected to cause adverse impacts to the vegetation within the drainage corridors.

As such, an appropriate performance based outcome established on modelled velocity and time of inundation has been provided for waterway stability management.

8 CONCLUSION

Calibre Consulting (Qld) Pty Ltd has prepared this *Concept Stormwater Management Plan and Flood Investigation* for the proposed Teviot Village Development within the Greater Flagstone PDA. This report has addressed stormwater quality, stormwater quantity, waterway stability and flood management for the site.

The outcomes of the analyses are:

- Stormwater Quantity:
  - XP-RAFTS hydrological modelling undertaken for existing and developed scenarios demonstrated that the mitigation measures incorporating online detention storage can generally mitigate peak flow increases at the downstream site boundary. As such, no adverse impacts or actionable nuisances will occur to downstream properties;
  - The following crossing configurations were designed to provide online detention:
    - Western Crossing:
      - 2 x 300mm RCP primary culverts and 9 x 1500mm x 600mm RCBC secondary culverts;
      - Minimum embankment level = 57.5m AHD; and
      - Detention Volume = 16,780m^3
    - Eastern Crossing A:
      - 5 x 1800mm x 600mm RCBC primary culverts;
      - Minimum embankment level = 56.9m AHD; and
      - Detention Volume = 18,065m^3
    - Eastern Crossing B:
      - 4 x 2400mm x 900mm RCBC primary culverts;
      - Minimum embankment level = 53.5m AHD; and
      - Detention Volume = 37,025m^3
    - Eastern Crossing C:
      - 4 x 900mm RCP primary culverts and 6 x 600mm RCP secondary culverts;
      - Minimum embankment level = 51.0m AHD; and
      - Detention Volume = 18,910m^3
  - Timing for the construction of the detention systems are subject to further analyses during subsequent staging of the development.
- Flooding:
  - HEC-RAS steady state (one-dimensional) hydraulic analyses determined the existing and developed scenario flood characteristics for the 1% AEP storm event. 1% AEP flood levels increases are generally maintained within the site and the new development areas will be designed accordingly;
  - Appropriately sized drainage connections are required to be provided for upstream external catchments, subject to detailed design;
  - Flood immunity levels for habitable floor levels have been nominated and confirmed via sensitivity scenarios.

- Stormwater Quality:
    - Stormwater quality management strategy comprises at source bioretention pods and 'end-of-line' bioretention basins within the waterway corridors;
    - MUSIC modelling determined the adequacy of the proposed bioretention systems in meeting the WQOs required under the *SPP* (2016); and
    - The construction and operational management strategy presented will ensure the bioretention systems continue to operate to their design intent.
- Waterway Stability Management:
    - Waterway stability management analyses has determined the following:
        - Hydrological modelling of the 63% AEP storm event indicates negligible increases in peak flow at the downstream site boundary and peak flow reductions further downstream prior to conveyance to Oxley Creek;
        - Reductions in average velocities throughout the drainage reserves within the site, with maximum developed velocities less than 1.5m/s, which are not expected to cause scour or erosion; and
        - Inundation times at the online detention basins during the 63% AEP storm event are not expected to adversely affect the vegetation.
    - The above outcomes address the waterway stability management requirement specified in the *SPP* (2016).

The above outcomes demonstrate there are solutions for managing stormwater and flooding associated with the development. During subsequent phases, further analyses will be required for all the strategies presented.

9 RECOMMENDATION

It is recommended that this *Concept Stormwater Management Plan and Flood Investigation* be approved and the management strategies presented within this report be incorporated into future design development. Timing for the construction of the stormwater infrastructure are to be confirmed during subsequent staging of the development. Future design may result in changes to the concepts, however the design objectives are to be maintained.

10 REFERENCES

- Department of Energy and Water Supply (31 October 2013), *Queensland Urban Drainage Manual (Vol. 1 3rd Ed.)*.
- Department of State Development, Infrastructure and Planning (2016), *State Planning Policy*.
- EDQ (May 2015) *Guideline 15 Protection from Flood and Storm*.
- *Greater Flagstone Urban Development Area Development Scheme* dated October 2011.
- Healthy Waterways (2010), *MUSIC Modelling Guidelines Version 1.0*.
- Healthy Waterways (2010), *Water Sensitive Urban Design Technical Design Guidelines*.
- Institution of Engineers, Australia (1987), *Australian Rainfall and Runoff*.
- US Army Corps of Engineers (2010*), HEC-RAS River Analysis System – Hydraulic Reference Manual v4.1*.

11 DISCLAIMER

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Our investigation and analysis has been specifically catered for the particular requirements of Villa Green Ltd and may not be applicable beyond this scope. For this reason, any other third parties are not authorised to utilise this report without further input and advice from Calibre Consulting (QLD) Pty Ltd.

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The investigation and analysis has relied on information provided by others. We accept no responsibility for accuracy of material supplied by others. The accuracy of the investigation, analysis and report is dependent upon the accuracy of this information.

APPENDICES

APPENDIX A : SITE LAYOUT
APPENDIX B : HEC-RAS SUMMARY
APPENDIX C : MUSIC SUMMARY
APPENDIX D : CONCEPT DRAWINGS

APPENDIX A : SITE LAYOUT

DRAFT
For Discussion Only

STAGE 16
STAGE 15
STAGE 14
STAGE 12
STAGE 13
STAGE 10
STAGE 27
STAGE 9
STAGE 8
STAGE 11
STAGE 7
STAGE 6
STAGE 5
STAGE 4
STAGE 26
STAGE 25
STAGE 24
STAGE 23
STAGE 21
STAGE 20
STAGE 22
STAGE 19
STAGE 18
STAGE 17
STAGE 2
STAGE 3
STAGE 1
2.826 ha
7915 m²
3000 m²
5180 m²
BPS
SPS
SENTINEL DRIVE
ROAD
CUNNINGHAM DRIVE
RAILWAY
SYDNEY
BRISBANE
PUB
Emt J
Emt E
Emt I
Emt C
Emt F

Legend

General
- Site Boundary
- Stage Boundary
- Indicative External Footpath
- Management Lot Area

Constraints
- 10m Retained Vegetation Buffer in Allotment
- Retained Remnant Endangered Regional Ecosystem
- 33m Buffer to Remnant Endangered Regional Ecosystem
- 33m Bushfire Setback
- Drainage Centerline
- BMD Q100
- 50m Buffer to Sewer Pump Station
- Proposed Balance Area Allotment

Open Space
- District Sports Park
- Linear Open Space (Active)
- Linear Open Space (Conservation)
- Neighbourhood Recreation Park
- Pedestrian Linkage / Landscape Treatment
- Existing Easement

Super Allotments
- Services Allotment
- Sales Office Allotment

Lifestyle Residential
- Lifestyle Allotment
- Premium Lifestyle Allotment

28m Residential
- Villa Allotment
- Premium Villa Allotment
- Courtyard Allotment
- Premium Courtyard Allotment

30m Residential
- Villa Allotment
- Premium Villa Allotment
- Courtyard Allotment
- Premium Courtyard Allotment
- Traditional Allotment

32m Residential
- Villa Allotment
- Premium Villa Allotment
- Courtyard Allotment
- Traditional Allotment
- Premium Traditional Allotment

Allotment Breakdown - Overall

	10.5m	12.5m	14m	16m	20m	22m	Lifestyle (>800m²)	Lifestyle (>2000m²)	Overall	Overall %
32m deep product	13	40	62	—	1	5	7	25	153	10.2%
30m deep product	51	338	290	85	3	—	—	—	767	51.1%
28m deep product	53	258	208	63	—	—	—	—	582	38.7%
Overall	117	636	560	148	4	5	7	25	1502	100.0%
Achieved %	7.8%	42.3%	37.3%	9.9%	0.3%	0.3%	0.5%	1.7%	100.0%	—

Scale 1 : 2500 @ A1
0 20 40 60 80 100 120 140

REVISION
A: 24/08/16 Amend Layout and Road Widths
B: 14/09/16 Amend Lot Mix
C: 14/09/16 Amendments to Stage 1
D: 28/10/16 Amend Overall Layout
E: 14/11/16 Amend Overall Layout & Add Staging
F: 29/11/16 Amend Stage 1, 2 & Road Widths
G: 02/12/16 Amend Layou & Stage Boundaries

Note:
All dimensions and areas are approximate only, and are subject to survey and Council approval.

Dimensions have been rounded to the nearest 0.1 metres.

Areas have been rounded down to the nearest 5m².

The boundaries shown on this plan should not be used for final detailed engineers design.

Source Information:
Site boundaries: Land Partners.
Adjoining information: DCDB.
Contours: Land Partners.
Flood: BMD

CLIENT
VILLAWORLD

PROJECT
TEVIOT VILLAGE

PROPOSED OVERALL ALLOTMENT LAYOUT

Date.	02 DECEMBER 2016
Comp By.	BDC / WNW / MD / SE
Checked By.	PHE
DWG Name.	132965-03
Job Ref.	132965
Local Authority.	ECONOMIC DEVELOPMENT QUEENSLAND
Locality.	TEVIOT DOWNS
Scale	1 : 2500
Sheet	A1
Plan Ref	132965 – 03
Rev	G

RPS Australia East Pty Ltd
ACN 140 292 762
ABN 44 140 292 762

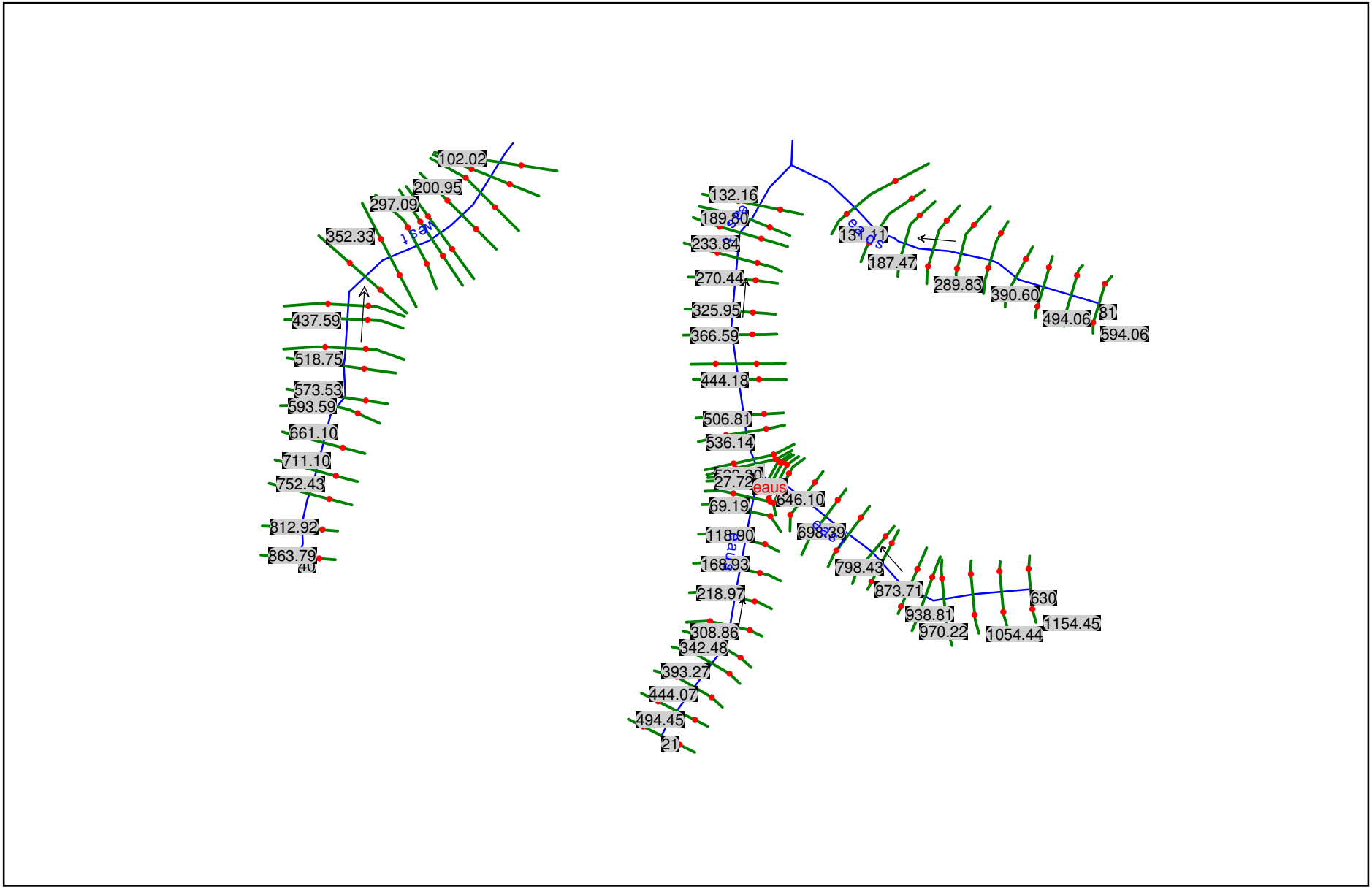
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Brisbane Design Studio
455 Brunswick Street
Fortitude Valley QLD 4006

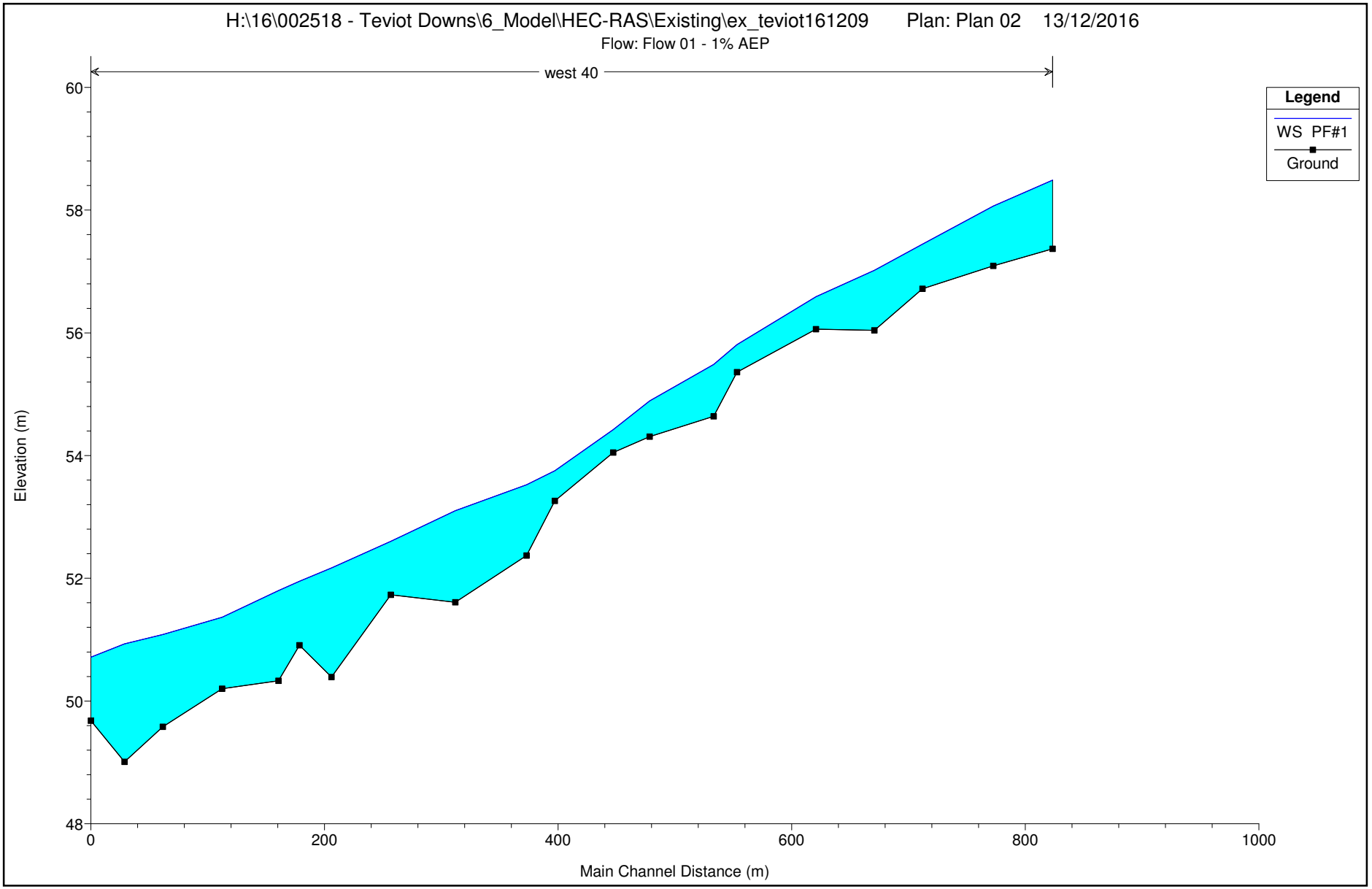
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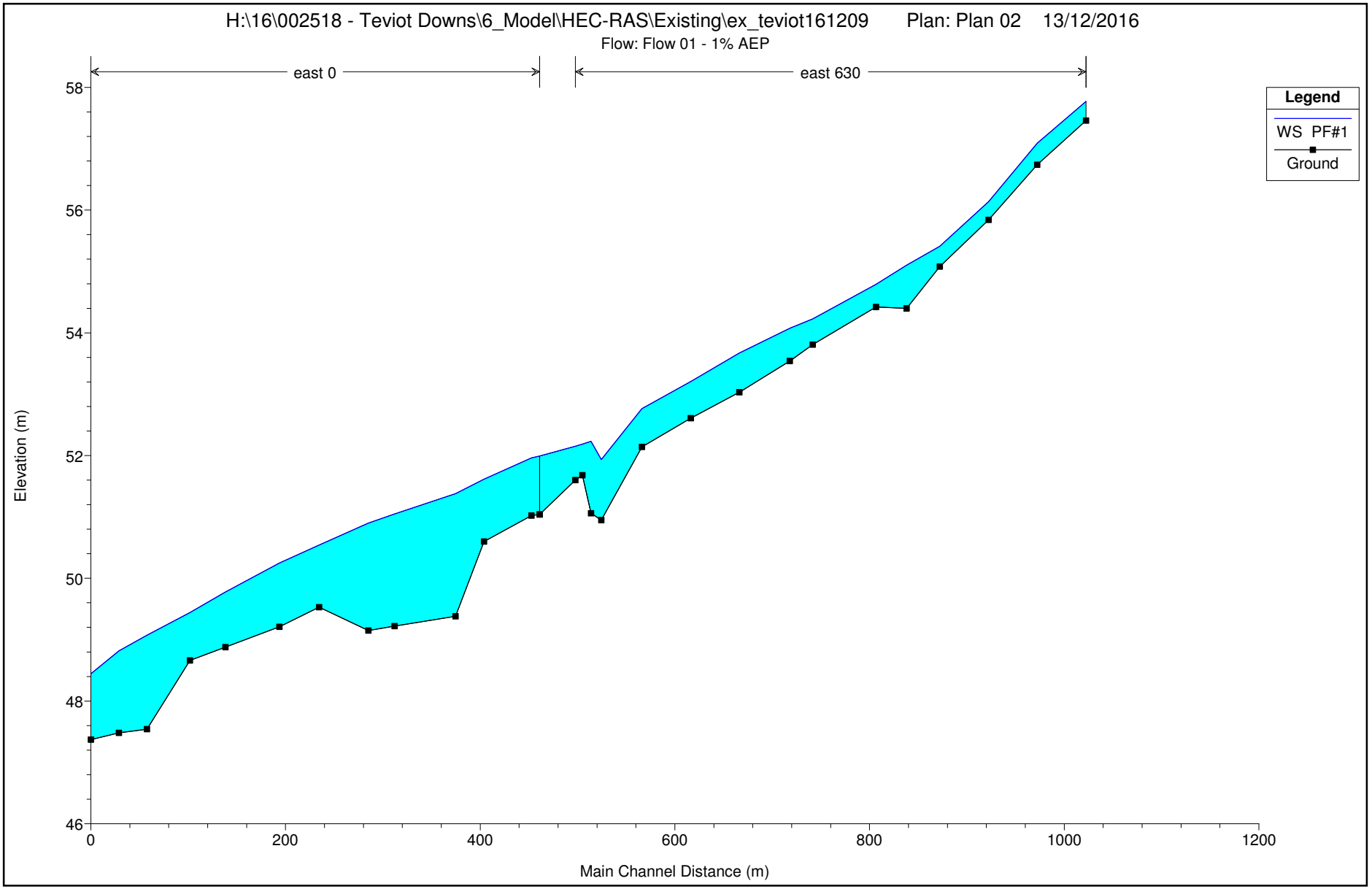
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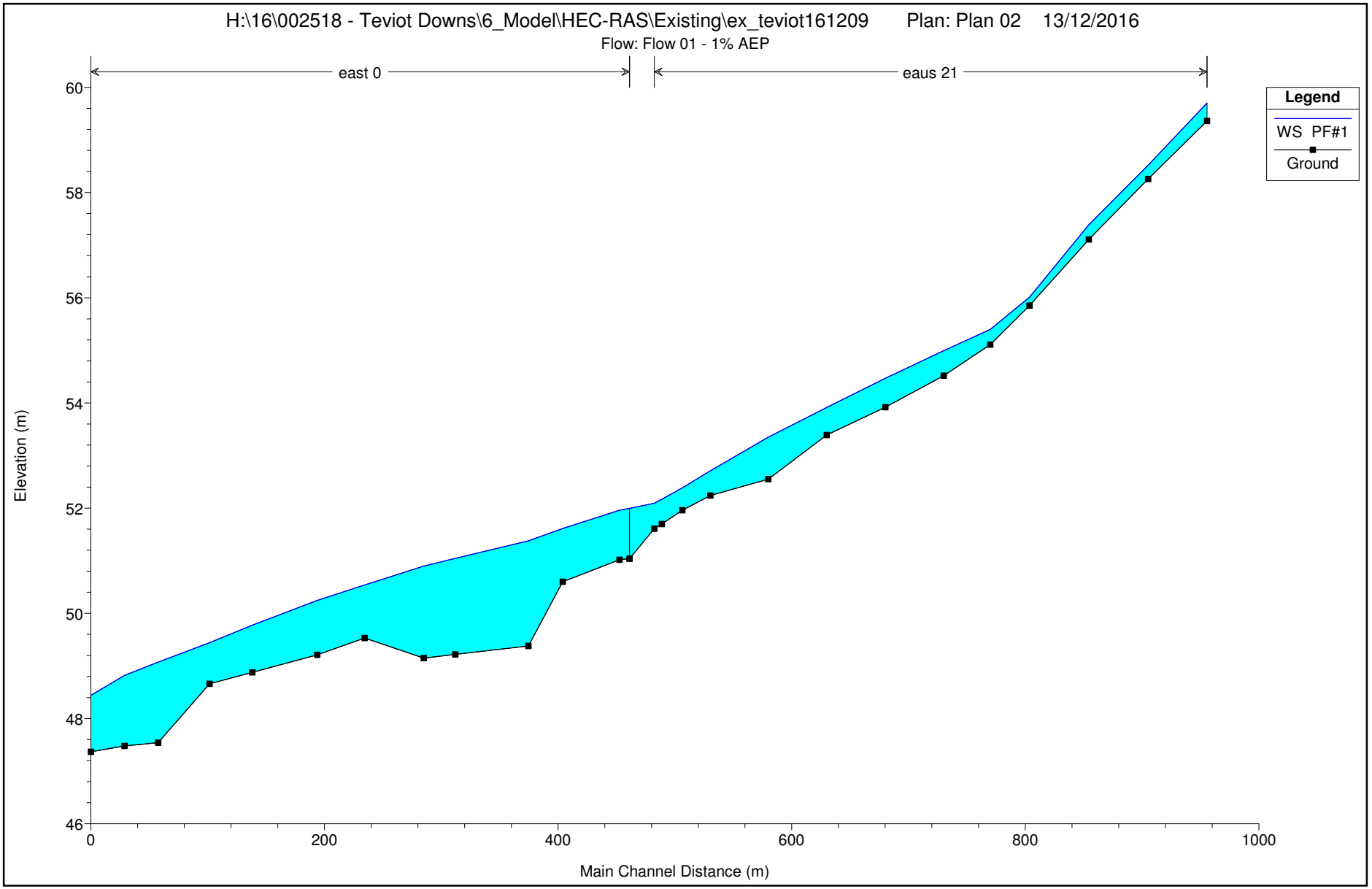
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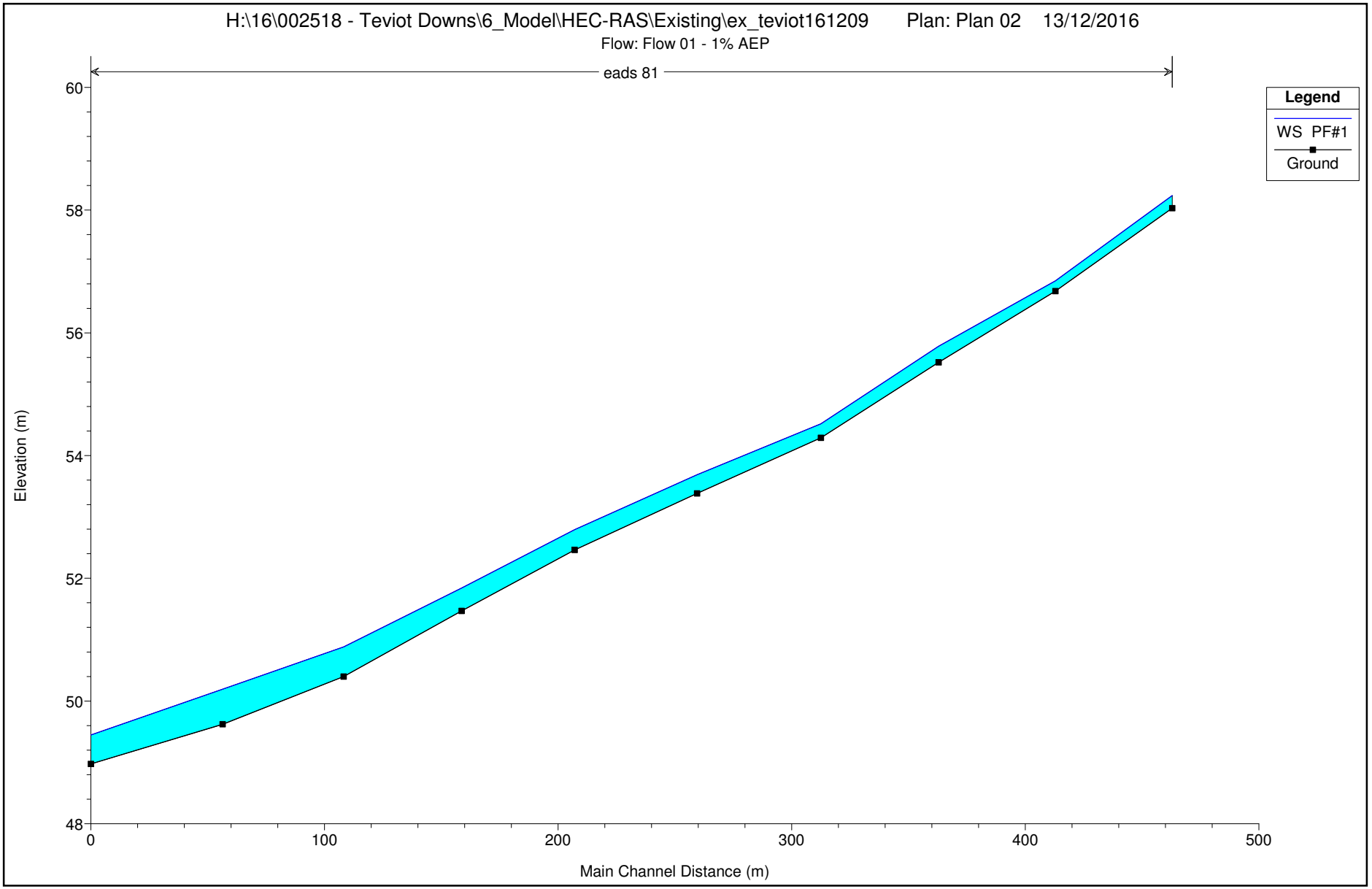
APPENDIX B : HEC-RAS SUMMARY

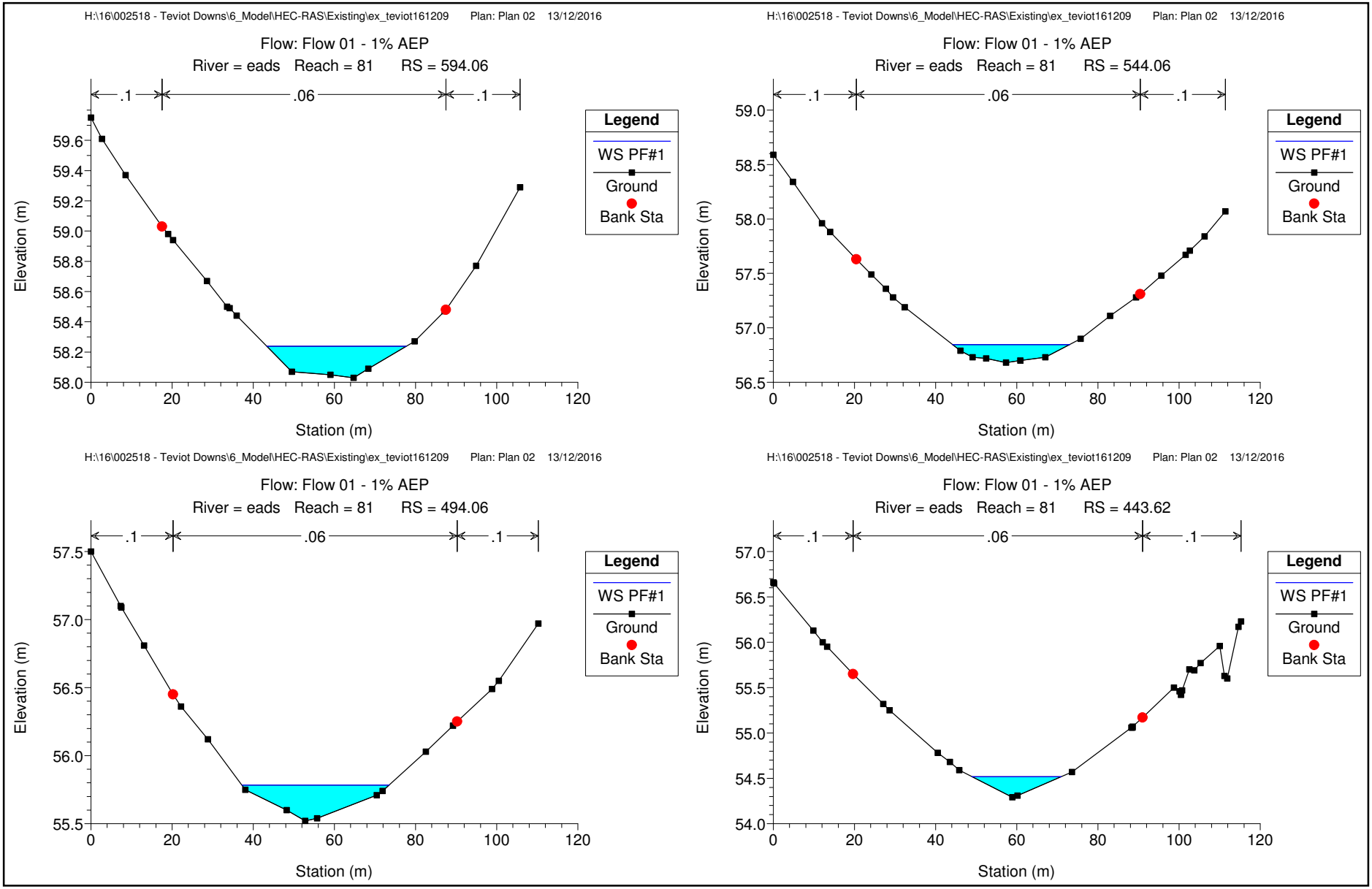

102.02
200.95
297.09
352.33
437.59
518.75
573.53
593.59
661.10
711.10
752.43
812.92
863.79
132.16
189.80
233.84
270.44
325.95
366.59
444.18
506.81
536.14
27.72
69.19
118.90
168.93
218.97
308.86
342.48
393.27
444.07
494.45
646.10
798.43
873.71
938.81
970.22
1054.44
630
1154.45
187.47
289.83
390.60
494.06
594.06


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Flow: Flow 01 - 1% AEP
west 40
Legend
WS PF#1
Ground
Elevation (m)
60
58
56
54
52
50
48
0
200
400
600
800
1000
Main Channel Distance (m)


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Flow: Flow 01 - 1% AEP
east 0
east 630
Legend
WS PF#1
Ground
Elevation (m)
58
56
54
52
50
48
46
0
200
400
600
800
1000
1200
Main Channel Distance (m)


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Flow: Flow 01 - 1% AEP
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eaus 21
Legend
WS PF#1
Ground
Elevation (m)
60
58
56
54
52
50
48
46
0
200
400
600
800
1000
Main Channel Distance (m)

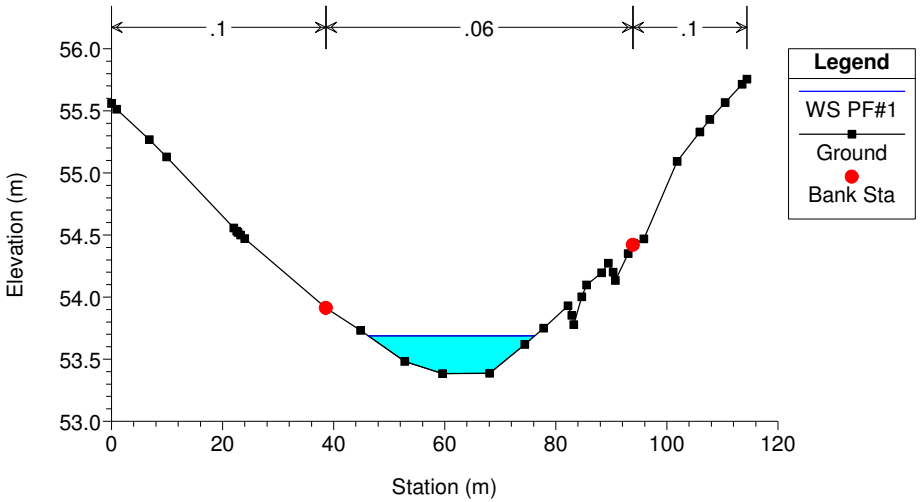

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eads 81
Legend
WS PF#1
Ground
Elevation (m)
60
58
56
54
52
50
48
0
100
200
300
400
500
Main Channel Distance (m)


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.1
.06
.1
Legend
WS PF#1
Ground
Bank Sta
Elevation (m)
Station (m)
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.06
.1
Legend
WS PF#1
Ground
Bank Sta
Elevation (m)
Station (m)
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.06
.1
Legend
WS PF#1
Ground
Bank Sta
Elevation (m)
Station (m)
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.06
.1
Legend
WS PF#1
Ground
Bank Sta
Elevation (m)
Station (m)

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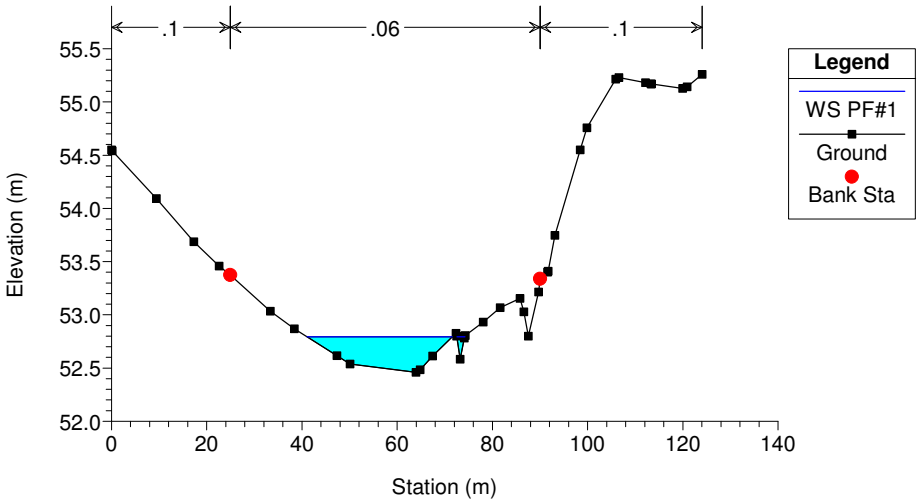
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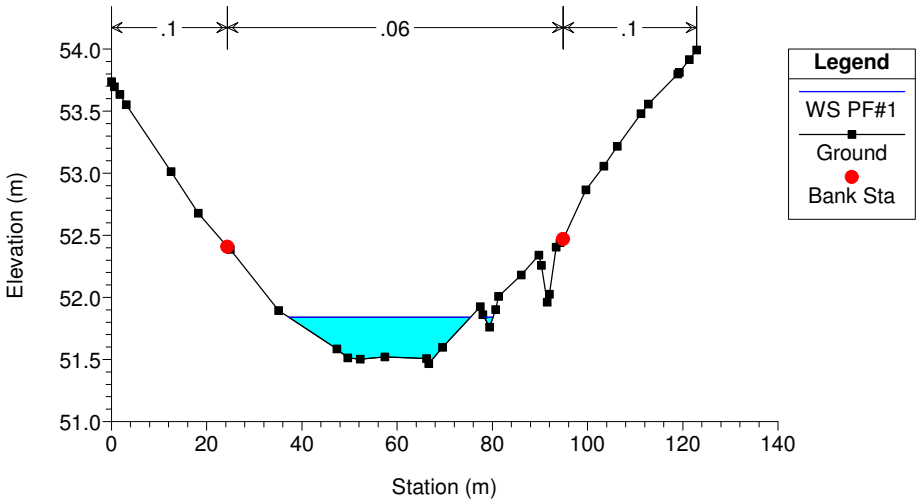
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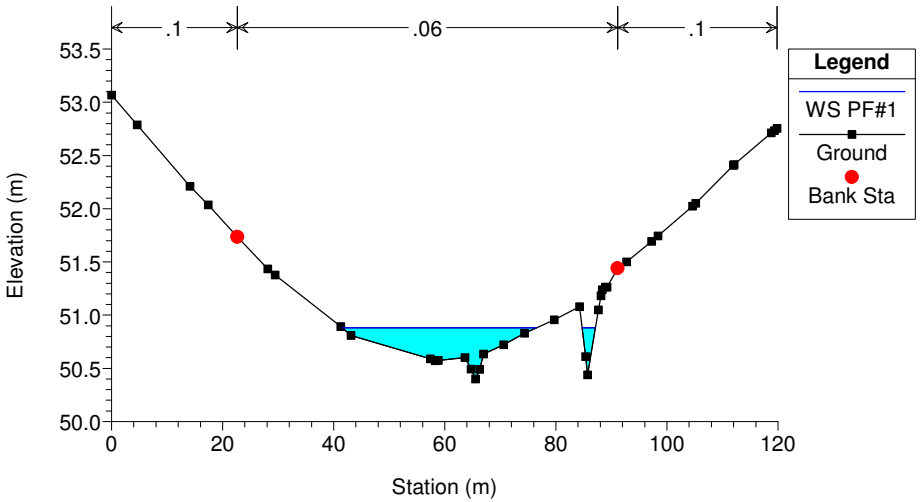
River = eads Reach = 81 RS = 289.83



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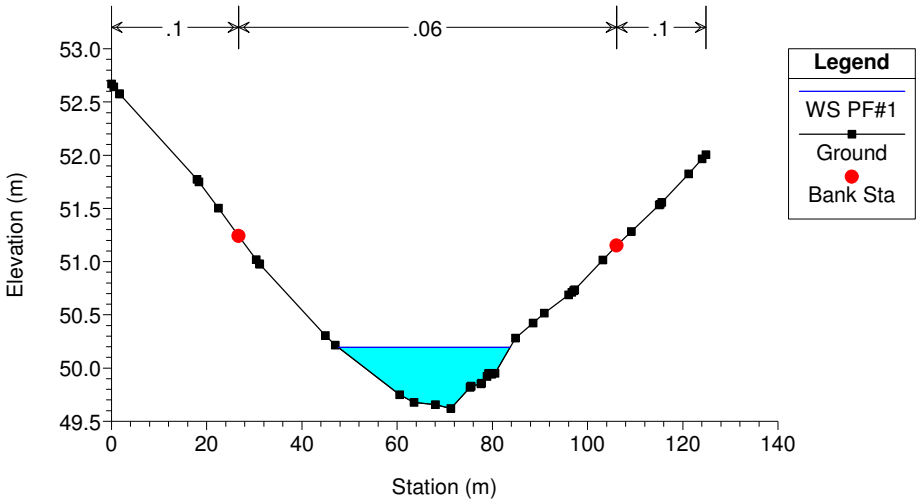
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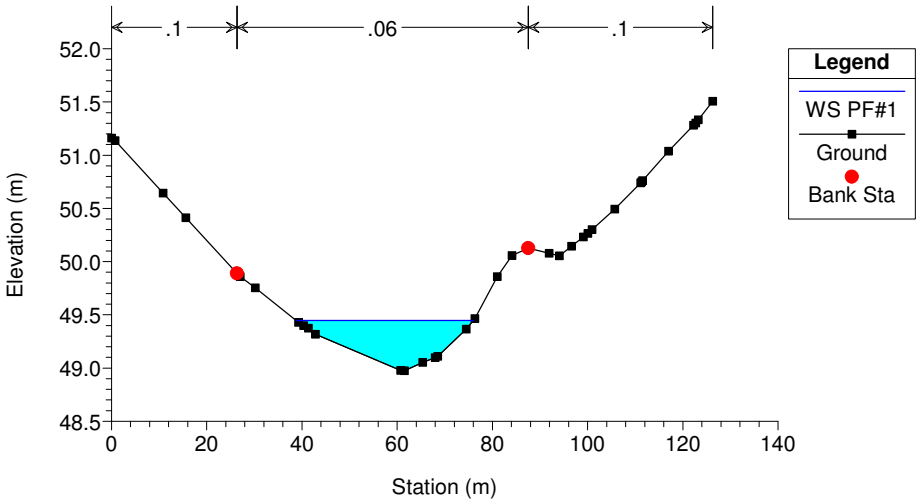
River = eads Reach = 81 RS = 187.47



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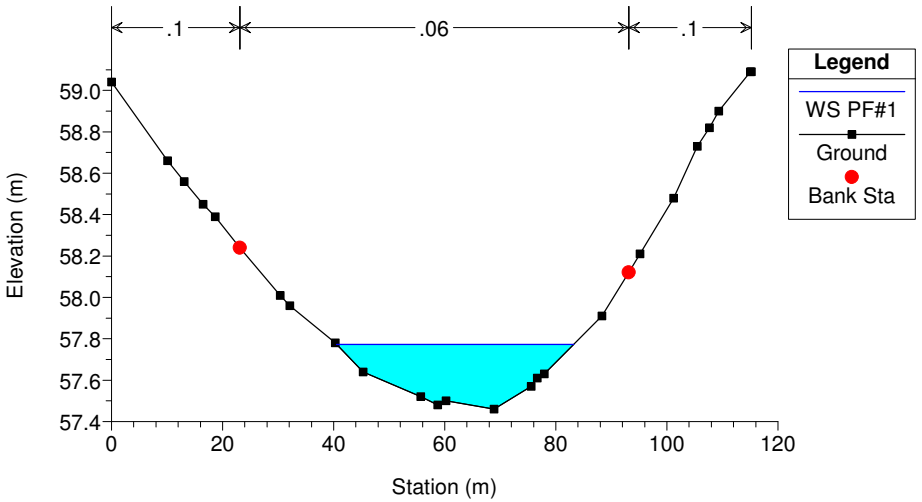
River = eads Reach = 81 RS = 131.11



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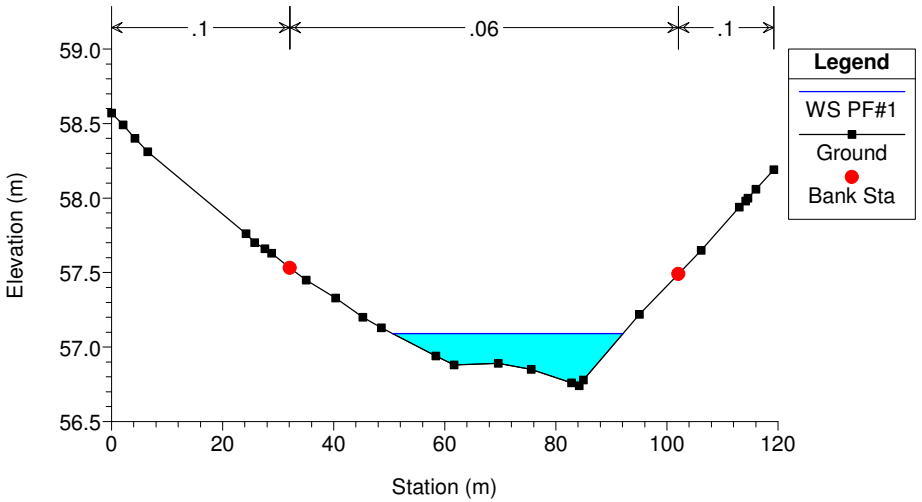
River = east Reach = 630 RS = 1154.45



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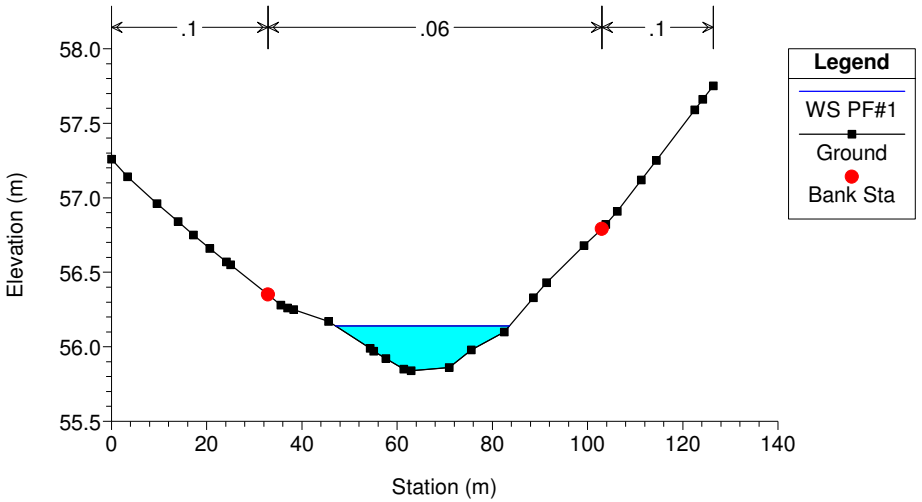
River = east Reach = 630 RS = 1104.45



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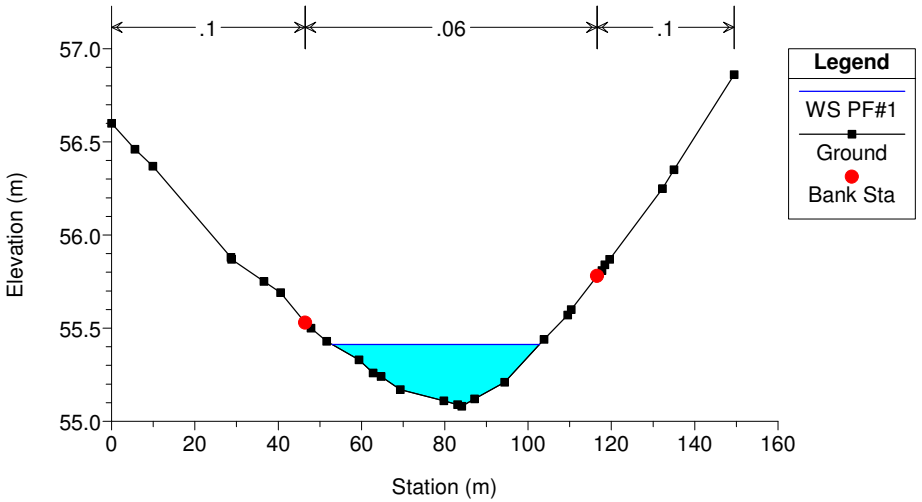
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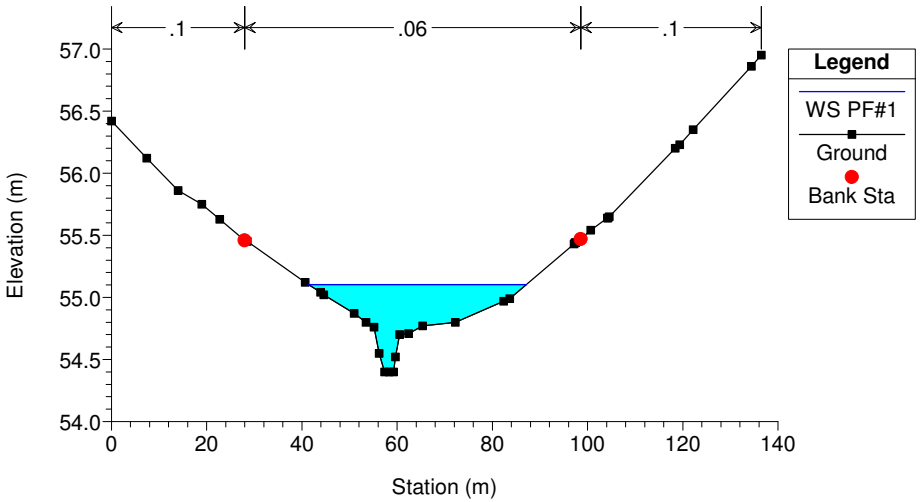
River = east Reach = 630 RS = 1004.33



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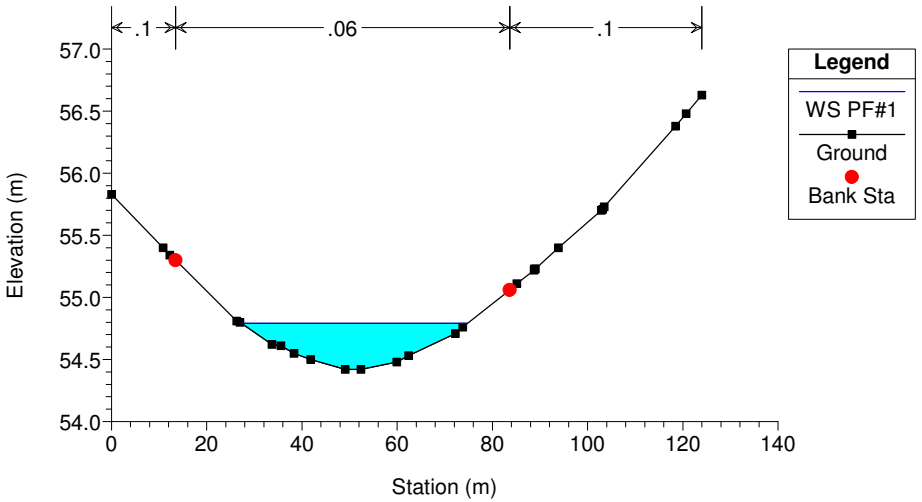
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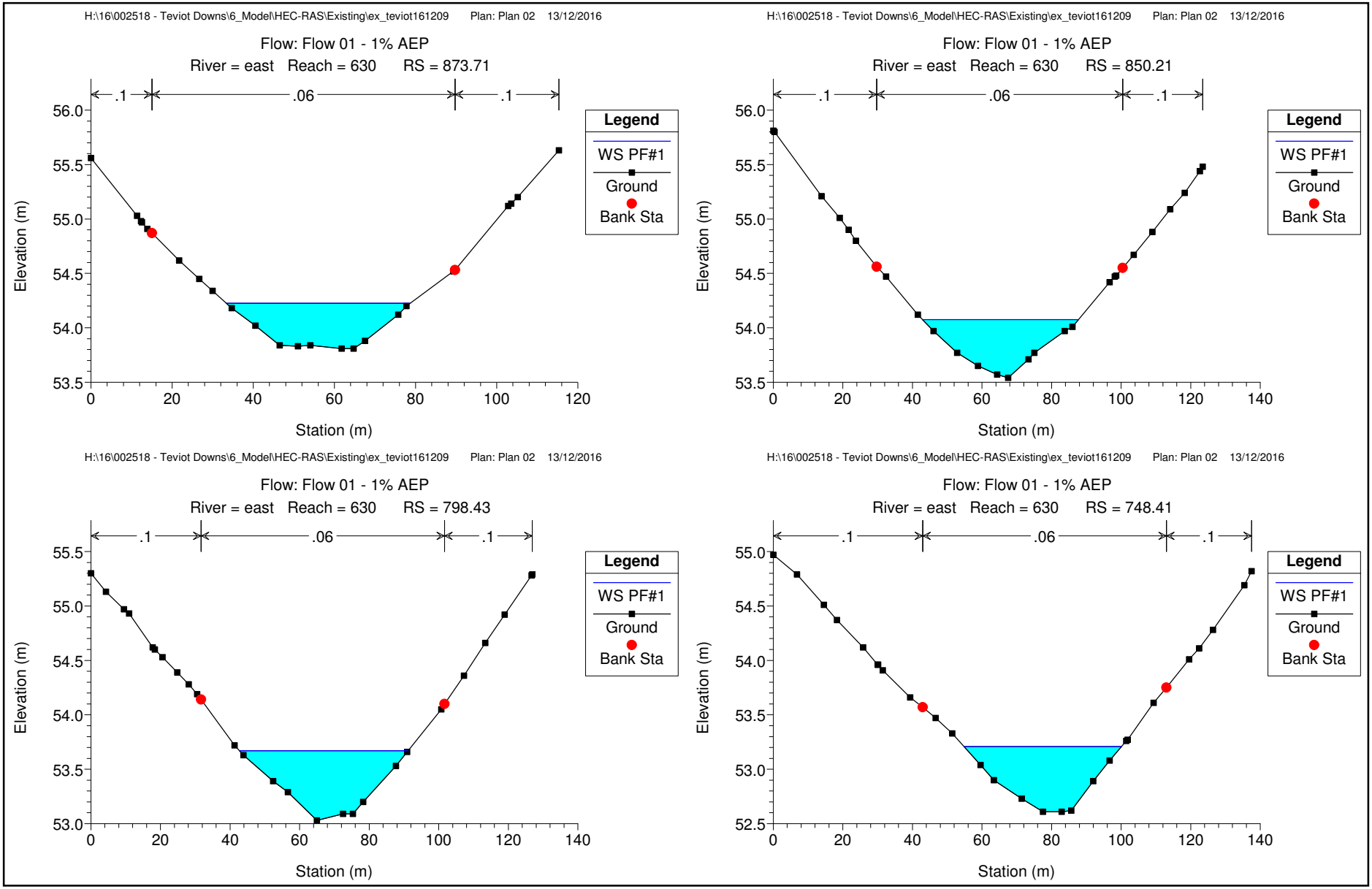


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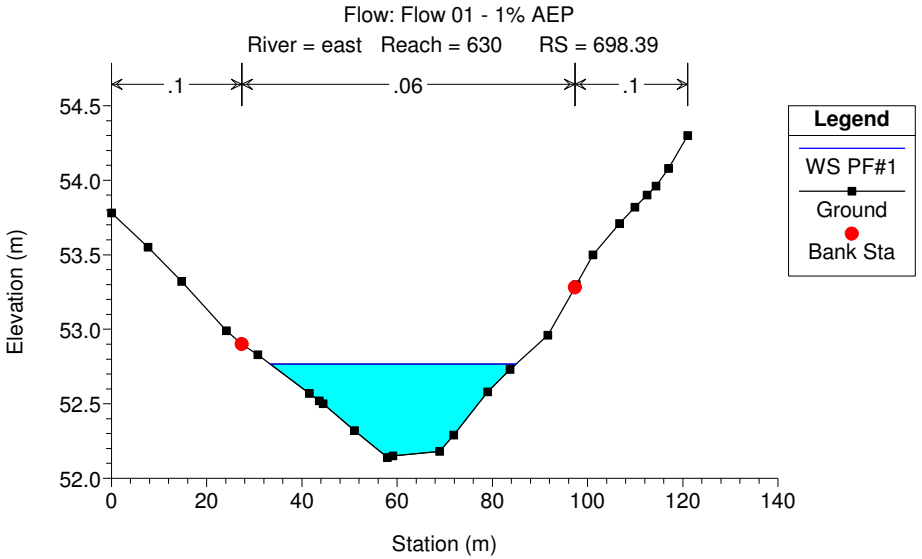
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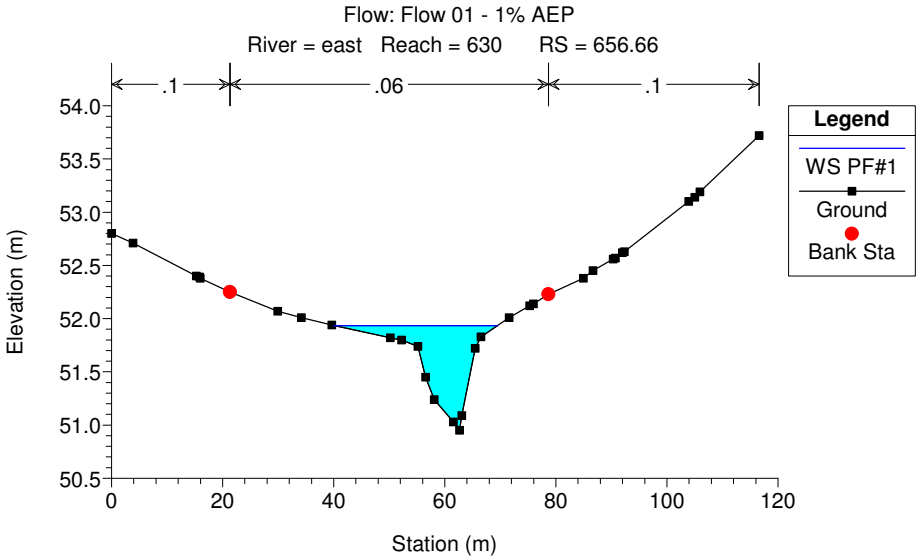



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River = east Reach = 630 RS = 873.71
.1
.06
.1
Legend
WS PF#1
Ground
Bank Sta
Elevation (m)
Station (m)
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Ground
Bank Sta
Elevation (m)
Station (m)
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Flow: Flow 01 - 1% AEP
River = east Reach = 630 RS = 798.43
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WS PF#1
Ground
Bank Sta
Elevation (m)
Station (m)
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Flow: Flow 01 - 1% AEP
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WS PF#1
Ground
Bank Sta
Elevation (m)
Station (m)

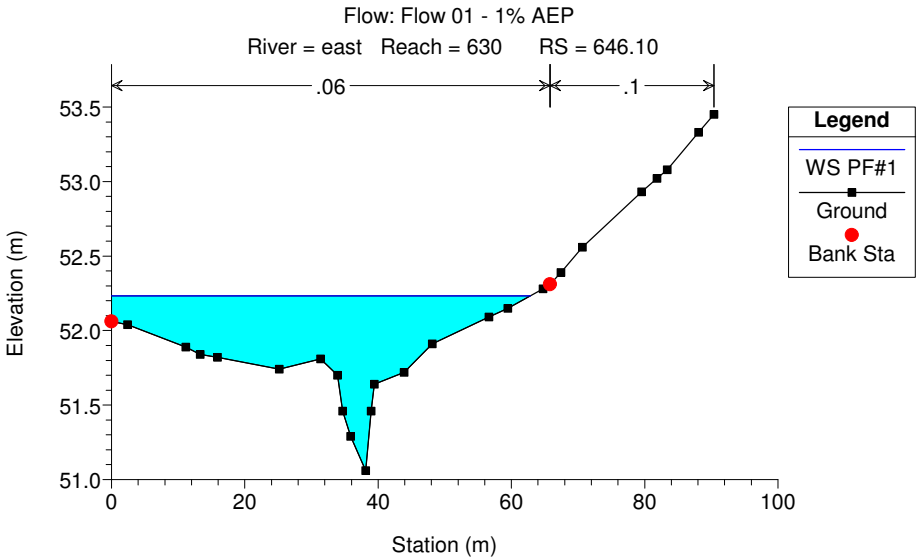
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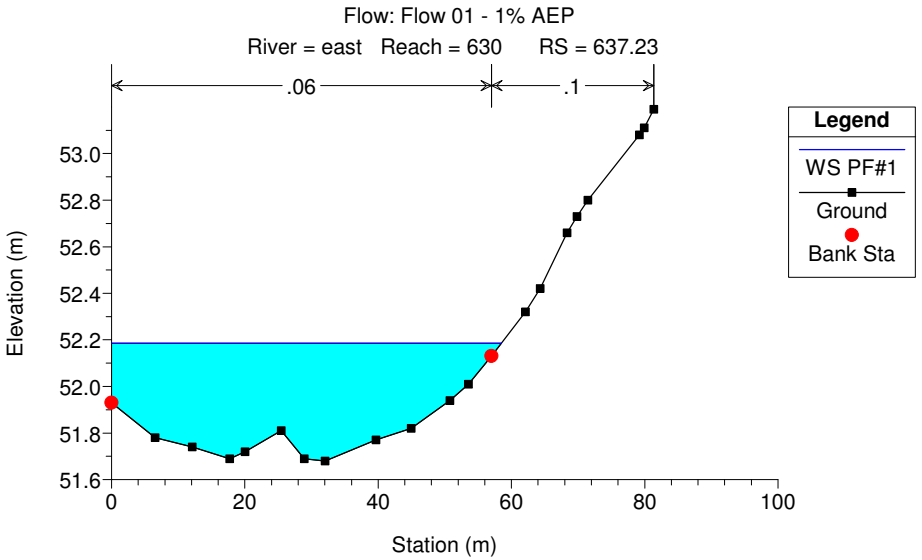
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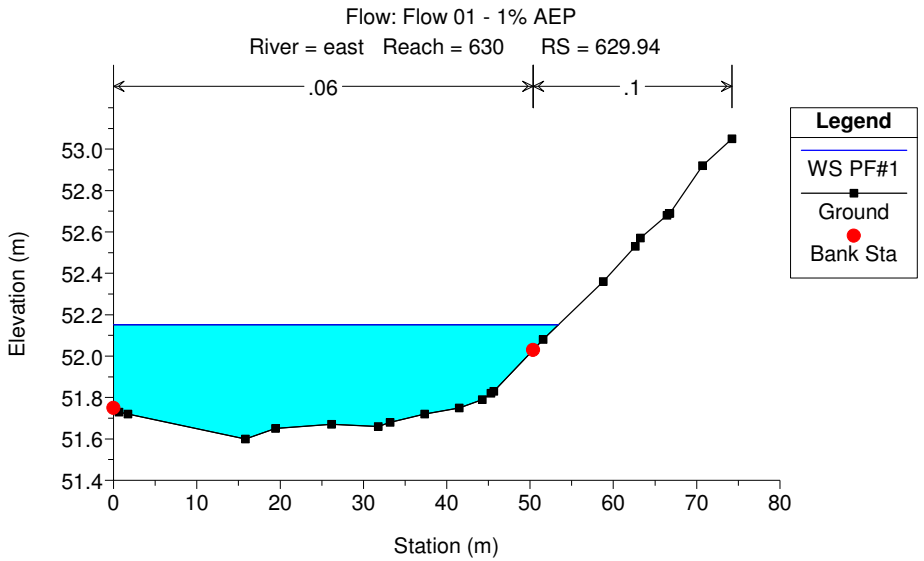
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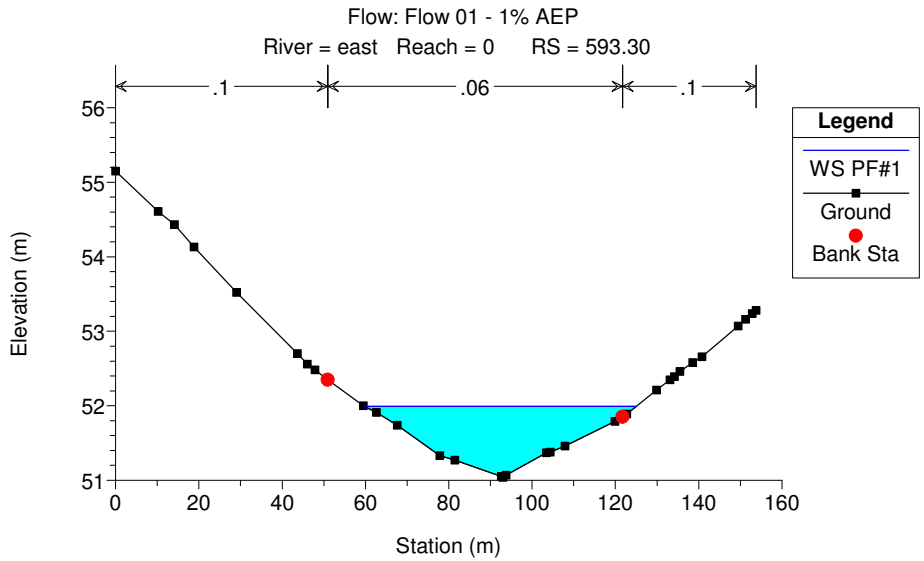
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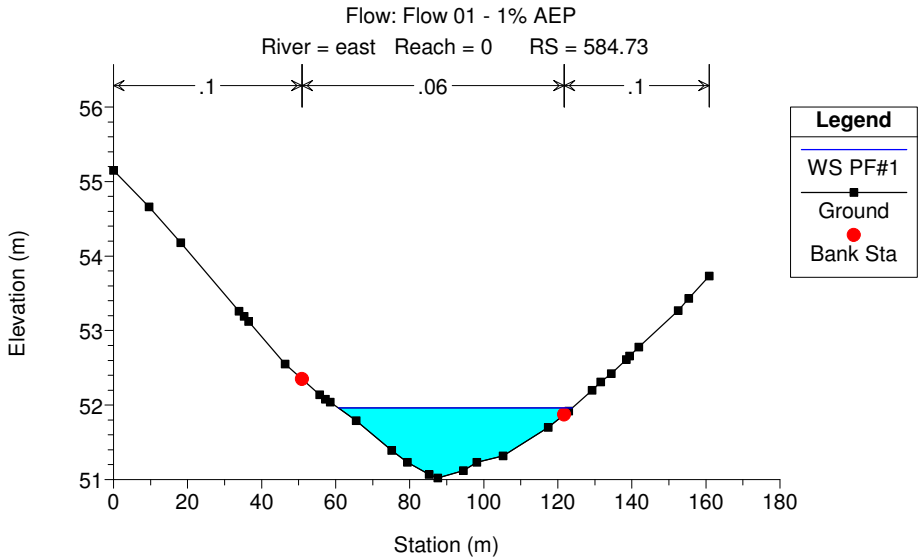
H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Existing\ex_teviot161209 Plan: Plan 02 13/12/2016



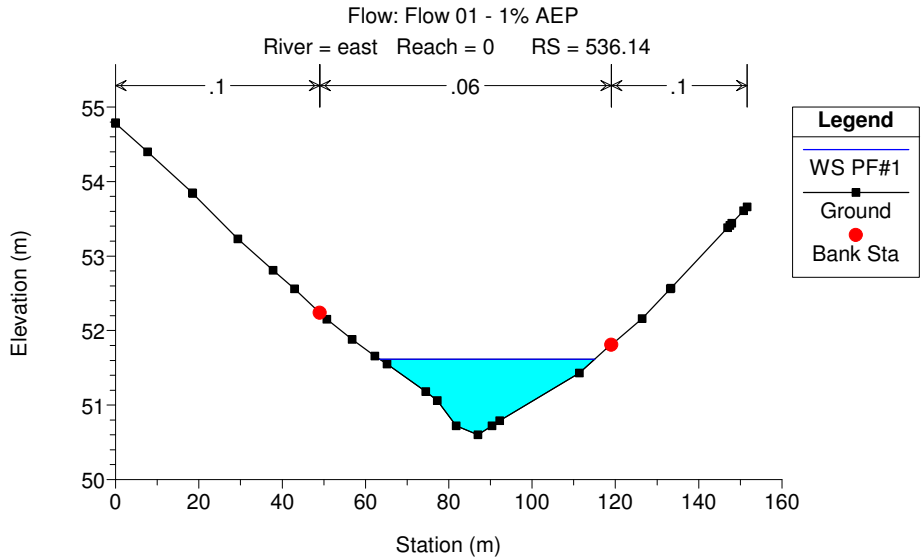
H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Existing\ex_teviot161209 Plan: Plan 02 13/12/2016



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Existing\ex_teviot161209 Plan: Plan 02 13/12/2016



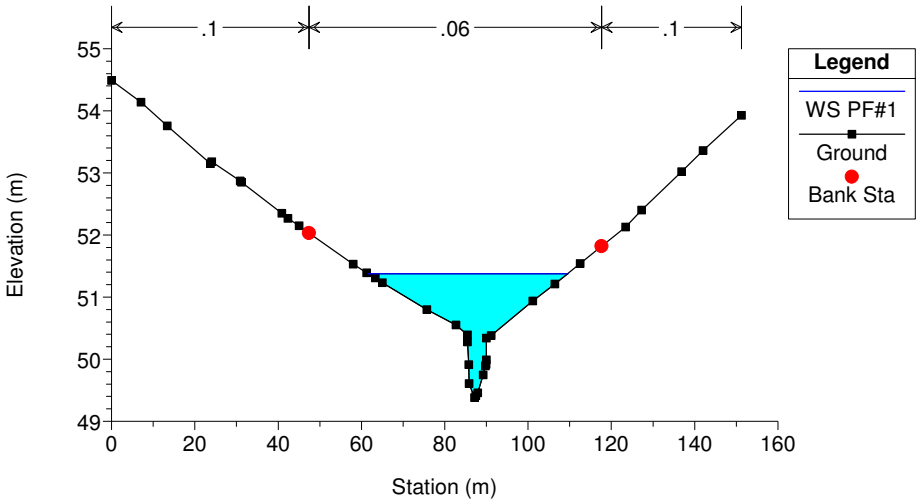
H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Existing\ex_teviot161209 Plan: Plan 02 13/12/2016



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Existing\ex_teviot161209 Plan: Plan 02 13/12/2016

Flow: Flow 01 - 1% AEP

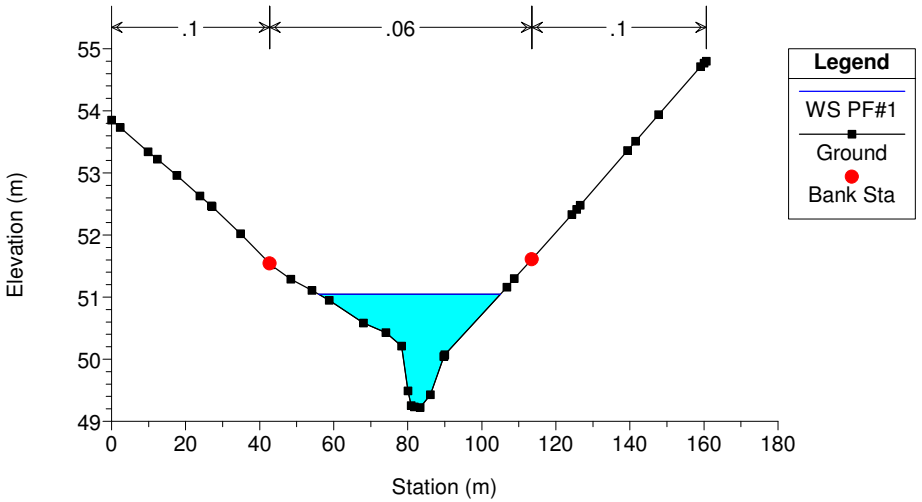
River = east Reach = 0 RS = 506.81



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Existing\ex_teviot161209 Plan: Plan 02 13/12/2016

Flow: Flow 01 - 1% AEP

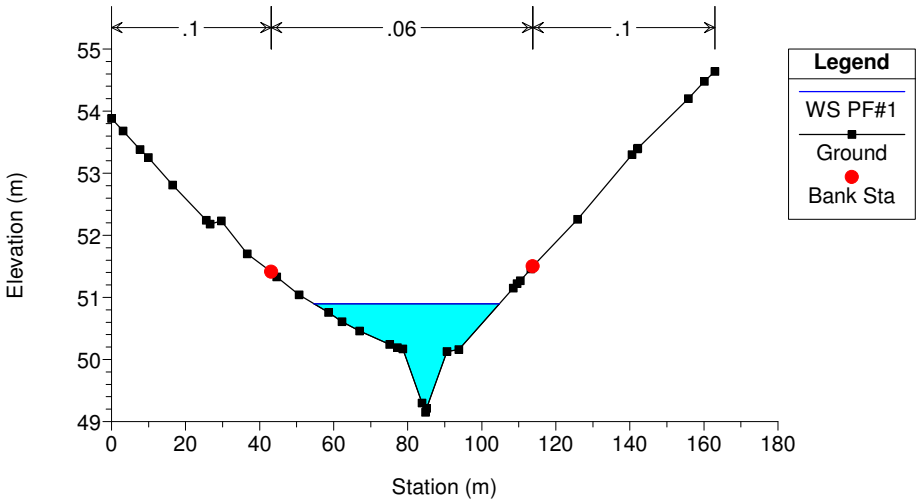
River = east Reach = 0 RS = 444.18



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Existing\ex_teviot161209 Plan: Plan 02 13/12/2016

Flow: Flow 01 - 1% AEP

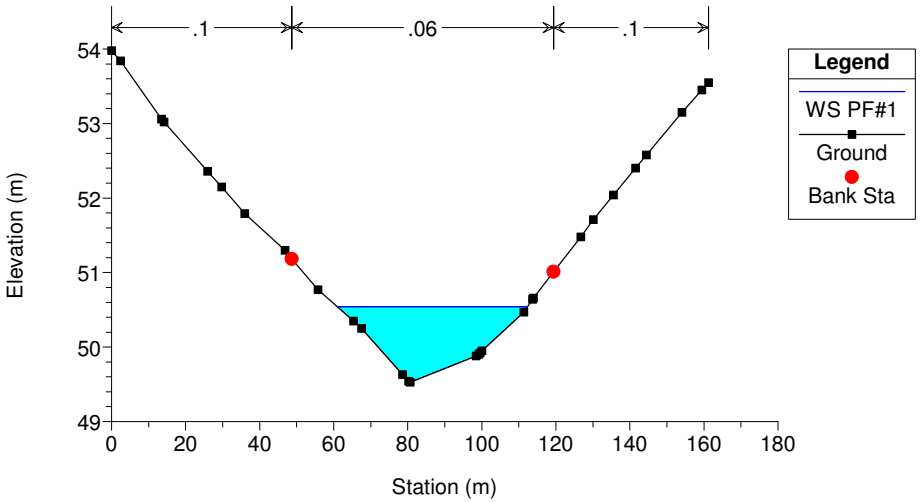
River = east Reach = 0 RS = 417.24

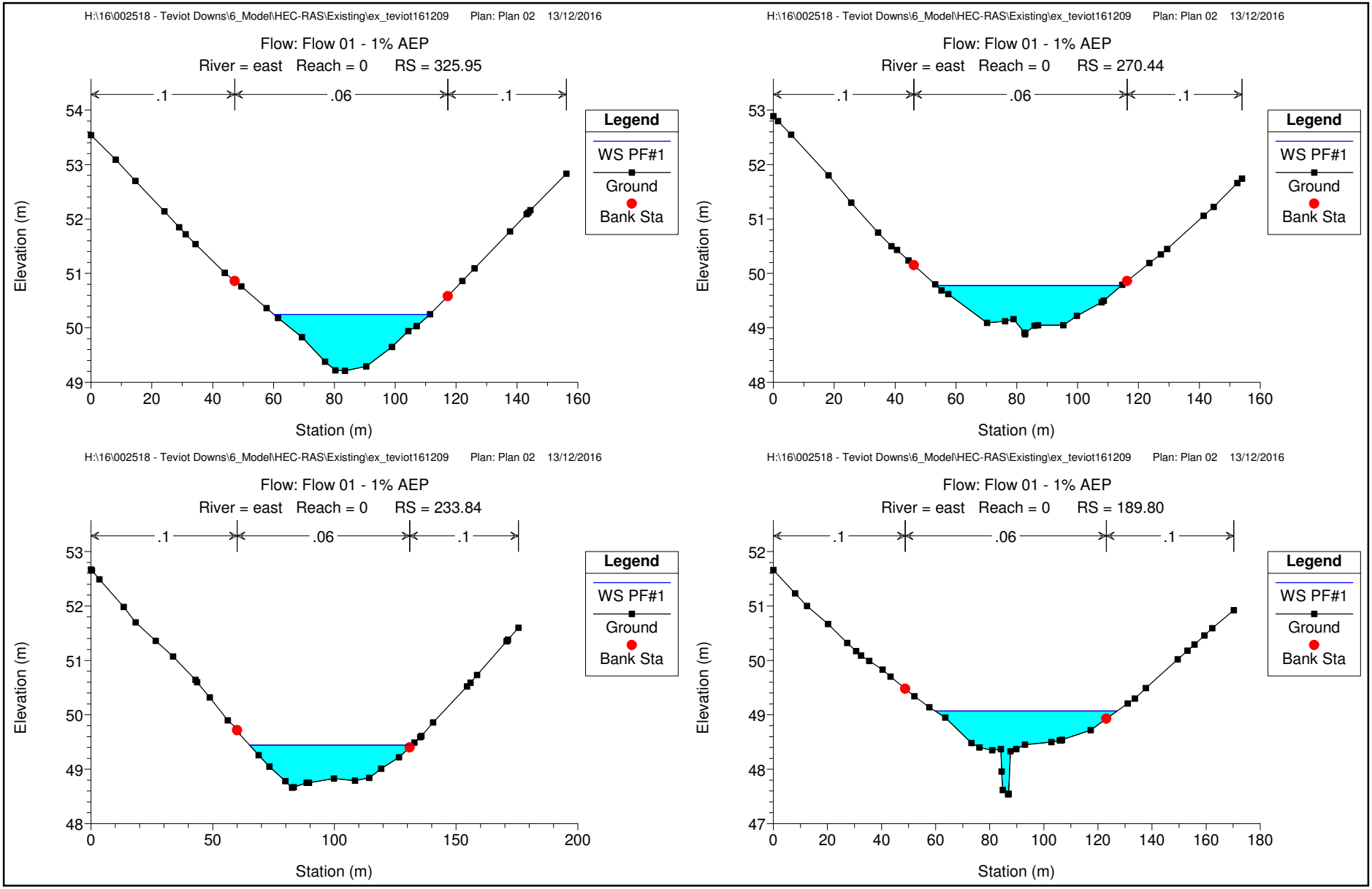


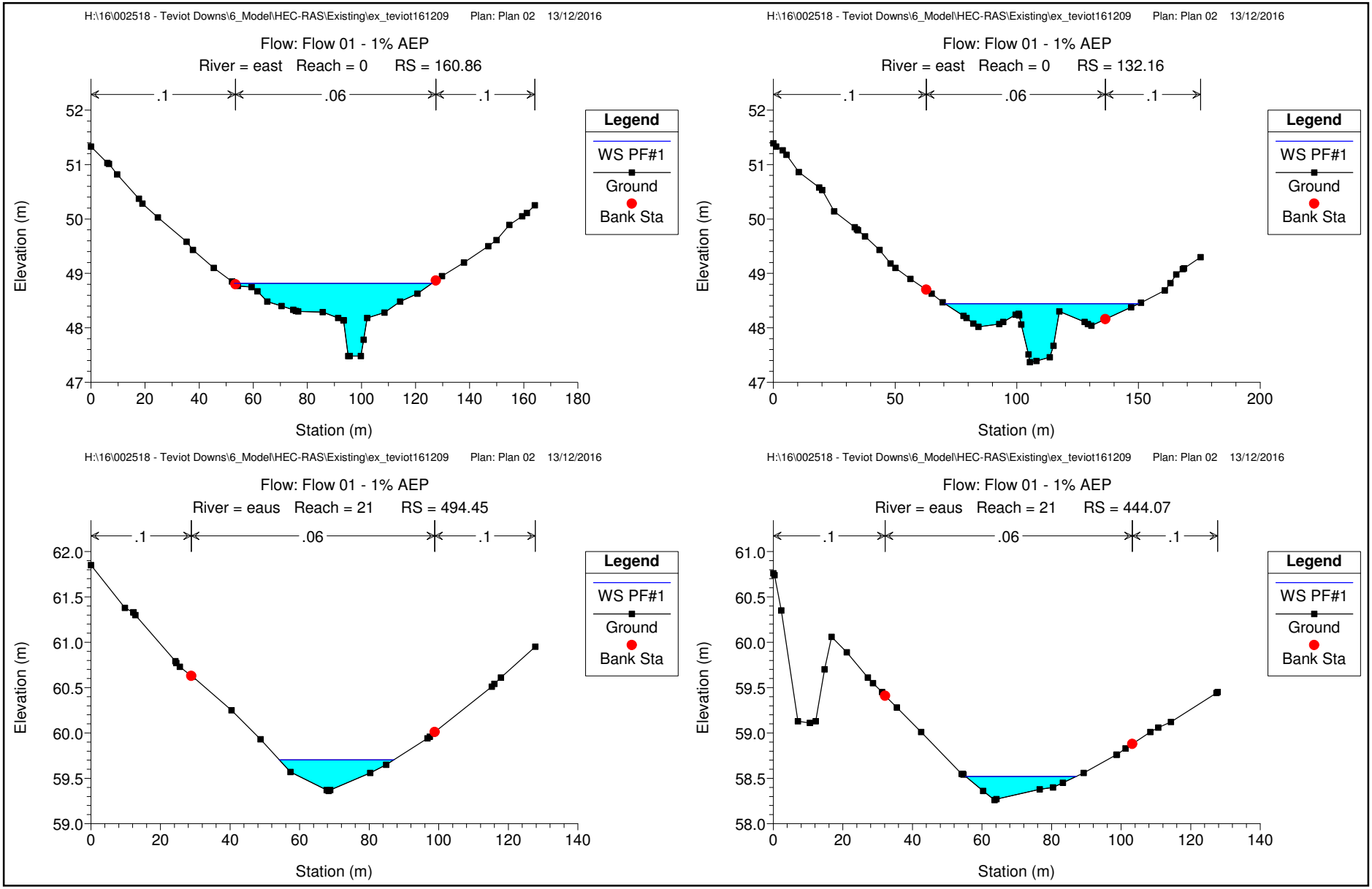
H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Existing\ex_teviot161209 Plan: Plan 02 13/12/2016

Flow: Flow 01 - 1% AEP

River = east Reach = 0 RS = 366.59



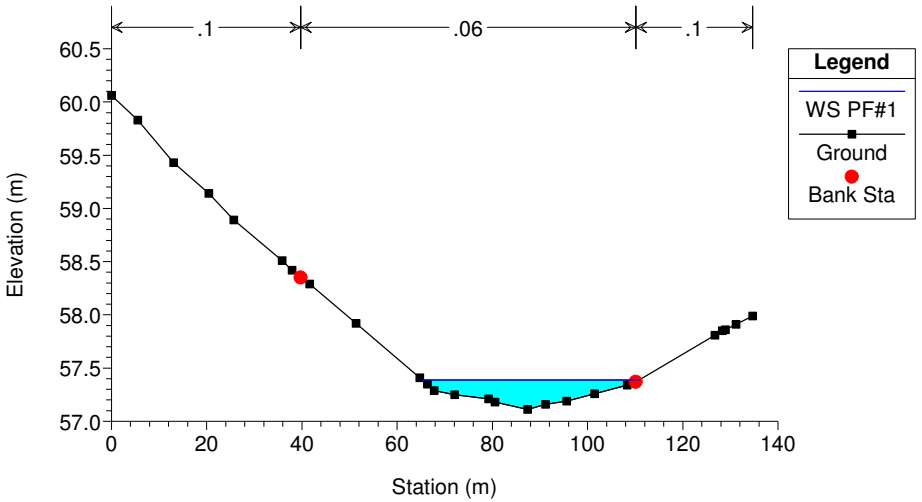

H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Existing\ex_teviot161209 Plan: Plan 02 13/12/2016
Flow: Flow 01 - 1% AEP
River = east Reach = 0 RS = 325.95
.1
.06
.1
Legend
WS PF#1
Ground
Bank Sta
Elevation (m)
Station (m)
H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Existing\ex_teviot161209 Plan: Plan 02 13/12/2016
Flow: Flow 01 - 1% AEP
River = east Reach = 0 RS = 270.44
.1
.06
.1
Legend
WS PF#1
Ground
Bank Sta
Elevation (m)
Station (m)
H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Existing\ex_teviot161209 Plan: Plan 02 13/12/2016
Flow: Flow 01 - 1% AEP
River = east Reach = 0 RS = 233.84
.1
.06
.1
Legend
WS PF#1
Ground
Bank Sta
Elevation (m)
Station (m)
H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Existing\ex_teviot161209 Plan: Plan 02 13/12/2016
Flow: Flow 01 - 1% AEP
River = east Reach = 0 RS = 189.80
.1
.06
.1
Legend
WS PF#1
Ground
Bank Sta
Elevation (m)
Station (m)


H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Existing\ex_teviot161209 Plan: Plan 02 13/12/2016
Flow: Flow 01 - 1% AEP
River = east Reach = 0 RS = 160.86
.1
.06
.1
Legend
WS PF#1
Ground
Bank Sta
Elevation (m)
Station (m)
H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Existing\ex_teviot161209 Plan: Plan 02 13/12/2016
Flow: Flow 01 - 1% AEP
River = east Reach = 0 RS = 132.16
.1
.06
.1
Legend
WS PF#1
Ground
Bank Sta
Elevation (m)
Station (m)
H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Existing\ex_teviot161209 Plan: Plan 02 13/12/2016
Flow: Flow 01 - 1% AEP
River = eaus Reach = 21 RS = 494.45
.1
.06
.1
Legend
WS PF#1
Ground
Bank Sta
Elevation (m)
Station (m)
H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Existing\ex_teviot161209 Plan: Plan 02 13/12/2016
Flow: Flow 01 - 1% AEP
River = eaus Reach = 21 RS = 444.07
.1
.06
.1
Legend
WS PF#1
Ground
Bank Sta
Elevation (m)
Station (m)

H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Existing\ex_teviot161209 Plan: Plan 02 13/12/2016

Flow: Flow 01 - 1% AEP

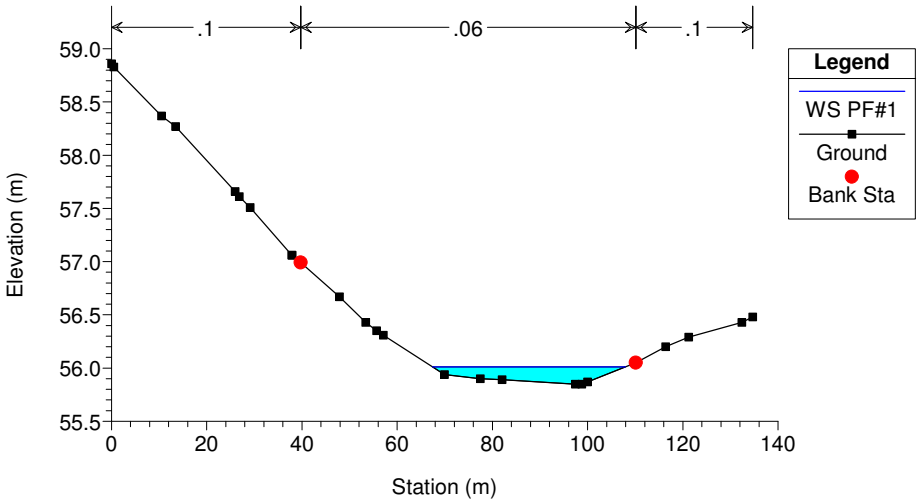
River = eaus Reach = 21 RS = 393.27



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Existing\ex_teviot161209 Plan: Plan 02 13/12/2016

Flow: Flow 01 - 1% AEP

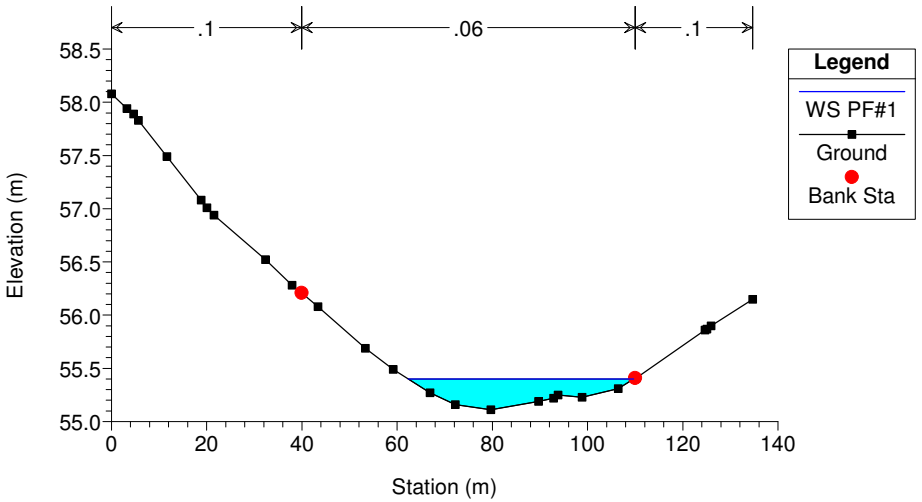
River = eaus Reach = 21 RS = 342.48



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Existing\ex_teviot161209 Plan: Plan 02 13/12/2016

Flow: Flow 01 - 1% AEP

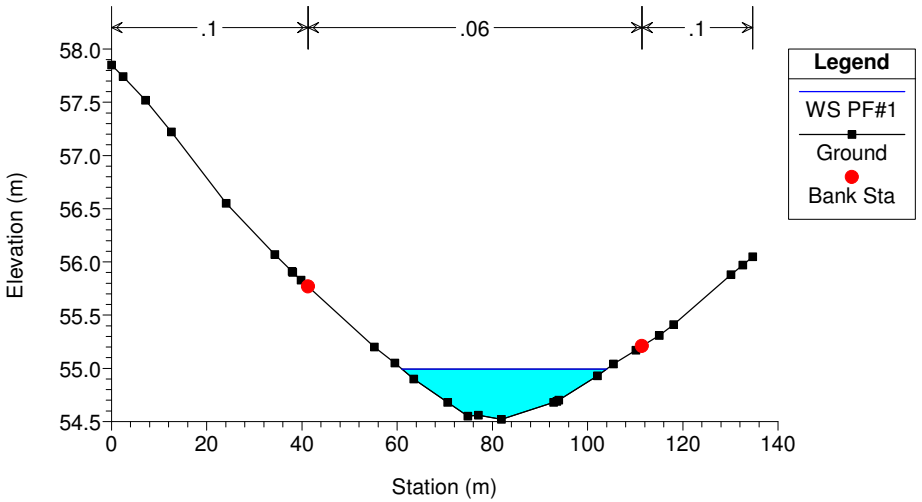
River = eaus Reach = 21 RS = 308.86

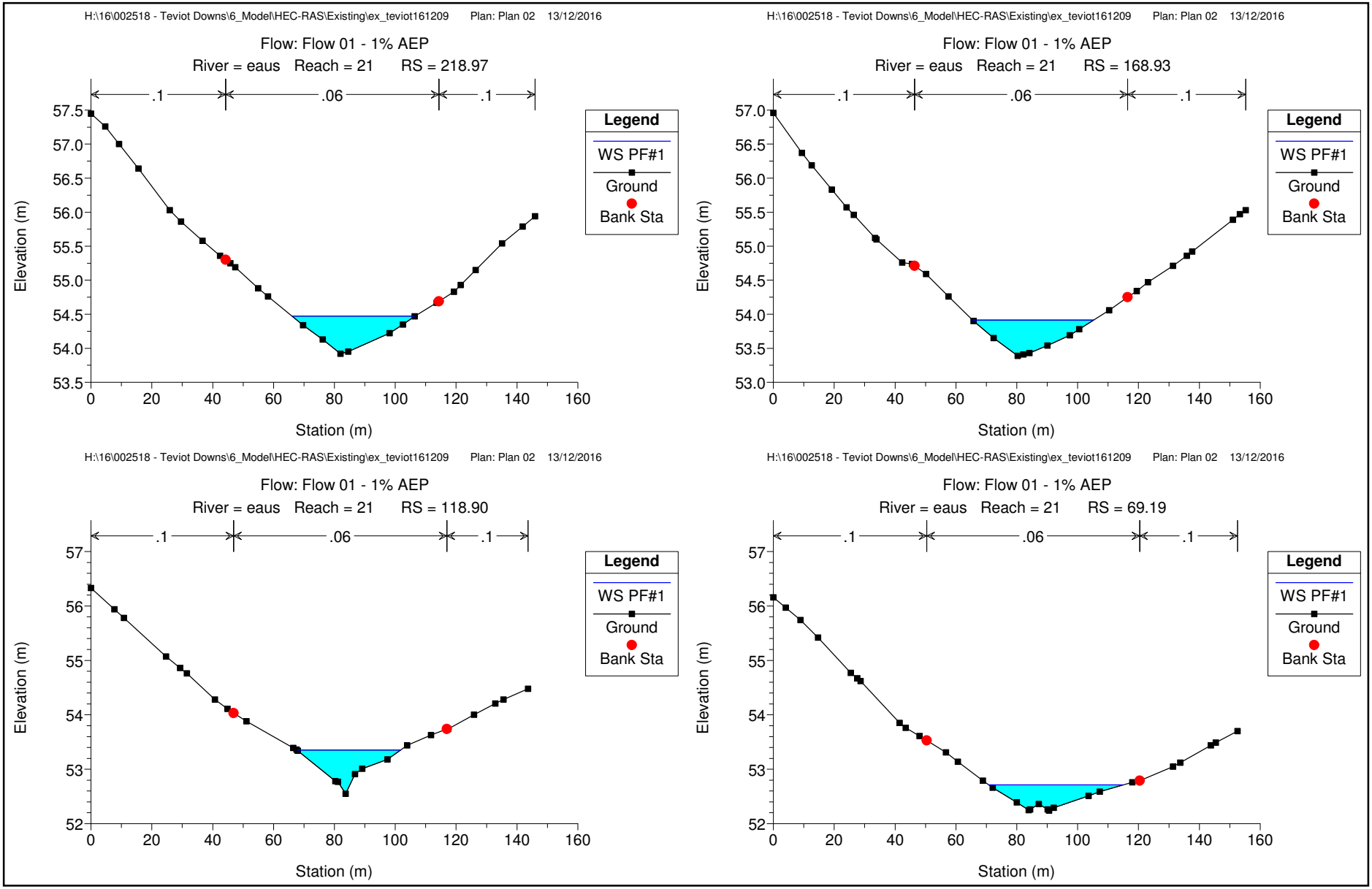


H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Existing\ex_teviot161209 Plan: Plan 02 13/12/2016

Flow: Flow 01 - 1% AEP

River = eaus Reach = 21 RS = 269.04

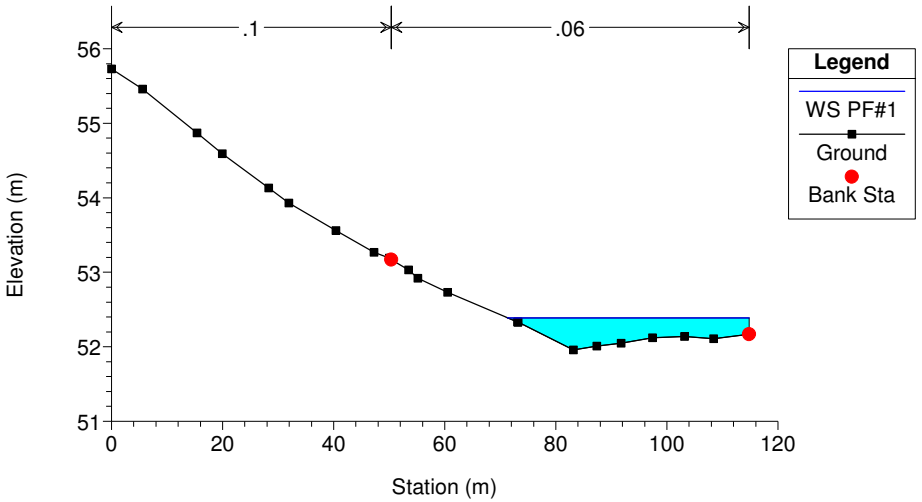



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Existing\ex_teviot161209 Plan: Plan 02 13/12/2016
Flow: Flow 01 - 1% AEP
River = eaus Reach = 21 RS = 218.97
.1
.06
.1
Legend
WS PF#1
Ground
Bank Sta
Elevation (m)
Station (m)
H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Existing\ex_teviot161209 Plan: Plan 02 13/12/2016
Flow: Flow 01 - 1% AEP
River = eaus Reach = 21 RS = 168.93
.1
.06
.1
Legend
WS PF#1
Ground
Bank Sta
Elevation (m)
Station (m)
H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Existing\ex_teviot161209 Plan: Plan 02 13/12/2016
Flow: Flow 01 - 1% AEP
River = eaus Reach = 21 RS = 118.90
.1
.06
.1
Legend
WS PF#1
Ground
Bank Sta
Elevation (m)
Station (m)
H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Existing\ex_teviot161209 Plan: Plan 02 13/12/2016
Flow: Flow 01 - 1% AEP
River = eaus Reach = 21 RS = 69.19
.1
.06
.1
Legend
WS PF#1
Ground
Bank Sta
Elevation (m)
Station (m)

H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Existing\ex_teviot161209 Plan: Plan 02 13/12/2016

Flow: Flow 01 - 1% AEP

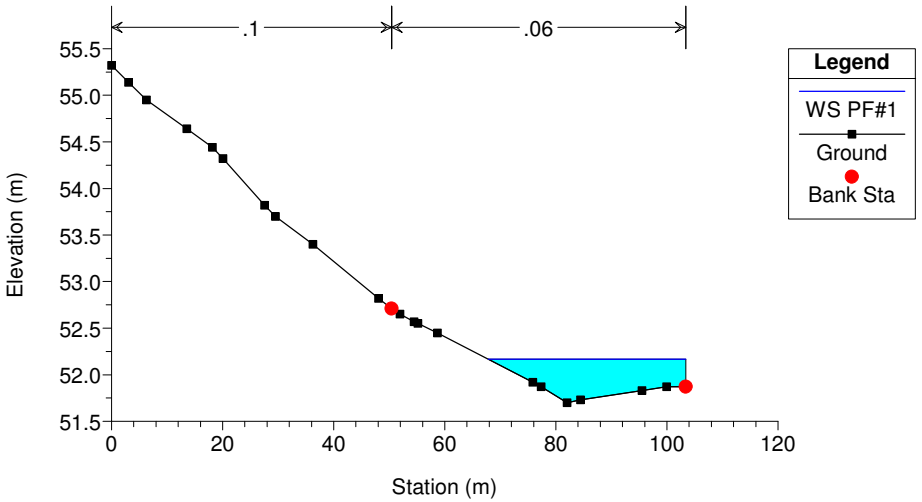
River = eaus Reach = 21 RS = 45.34



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Existing\ex_teviot161209 Plan: Plan 02 13/12/2016

Flow: Flow 01 - 1% AEP

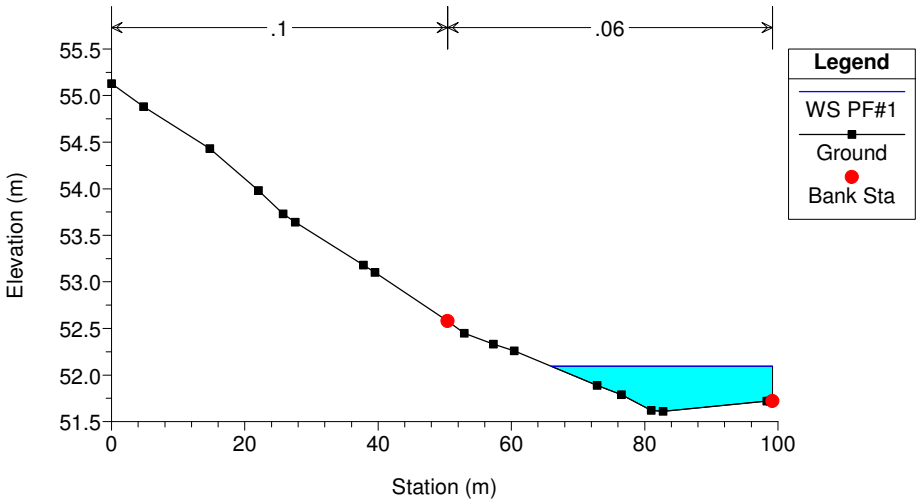
River = eaus Reach = 21 RS = 27.72



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Existing\ex_teviot161209 Plan: Plan 02 13/12/2016

Flow: Flow 01 - 1% AEP

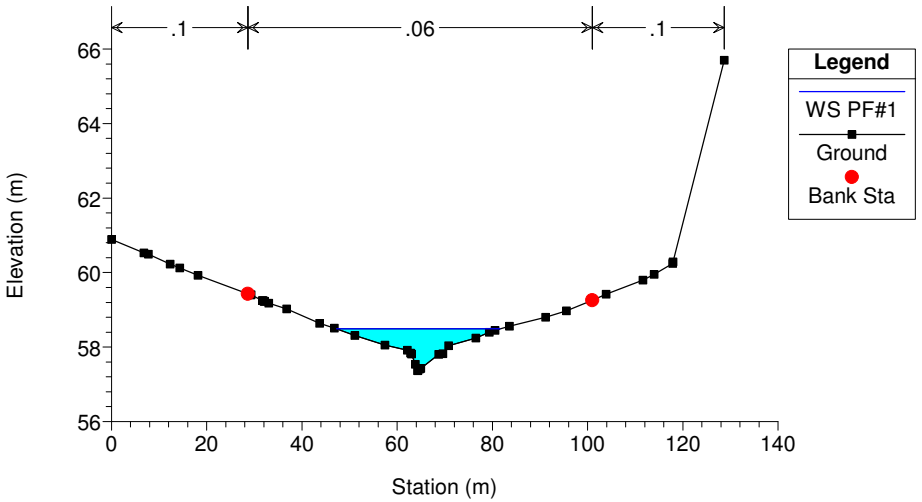
River = eaus Reach = 21 RS = 21.20

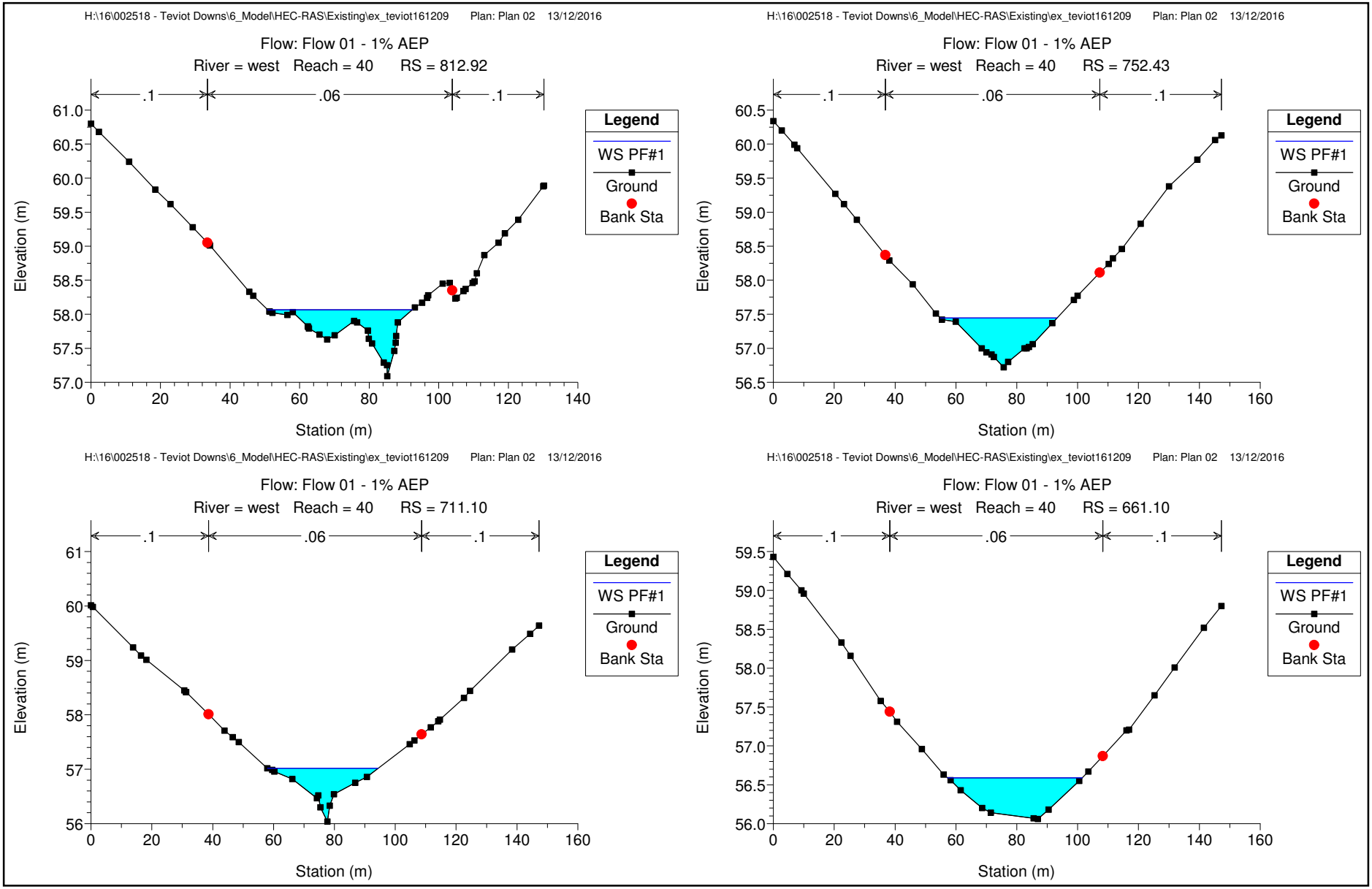


H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Existing\ex_teviot161209 Plan: Plan 02 13/12/2016

Flow: Flow 01 - 1% AEP

River = west Reach = 40 RS = 863.79

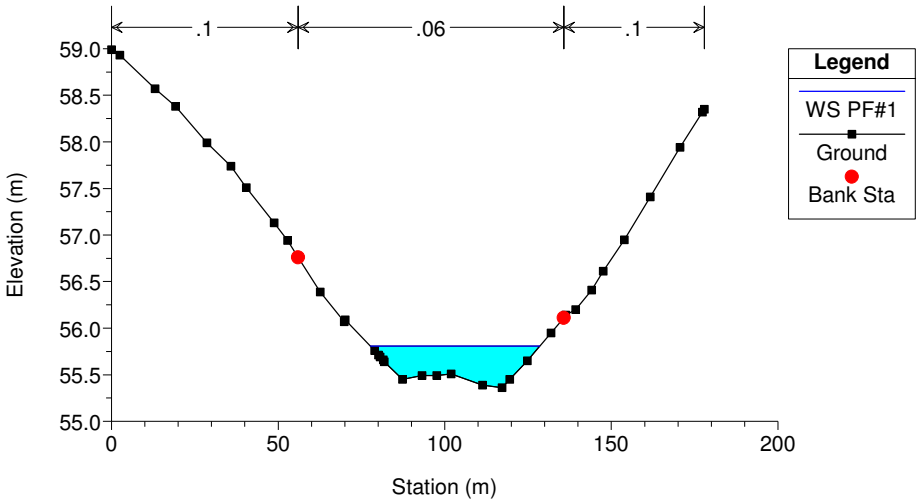



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Existing\ex_teviot161209 Plan: Plan 02 13/12/2016
Flow: Flow 01 - 1% AEP
River = west Reach = 40 RS = 812.92
.1
.06
.1
Legend
WS PF#1
Ground
Bank Sta
Elevation (m)
Station (m)
H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Existing\ex_teviot161209 Plan: Plan 02 13/12/2016
Flow: Flow 01 - 1% AEP
River = west Reach = 40 RS = 752.43
.1
.06
.1
Legend
WS PF#1
Ground
Bank Sta
Elevation (m)
Station (m)
H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Existing\ex_teviot161209 Plan: Plan 02 13/12/2016
Flow: Flow 01 - 1% AEP
River = west Reach = 40 RS = 711.10
.1
.06
.1
Legend
WS PF#1
Ground
Bank Sta
Elevation (m)
Station (m)
H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Existing\ex_teviot161209 Plan: Plan 02 13/12/2016
Flow: Flow 01 - 1% AEP
River = west Reach = 40 RS = 661.10
.1
.06
.1
Legend
WS PF#1
Ground
Bank Sta
Elevation (m)
Station (m)

H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Existing\ex_teviot161209 Plan: Plan 02 13/12/2016

Flow: Flow 01 - 1% AEP

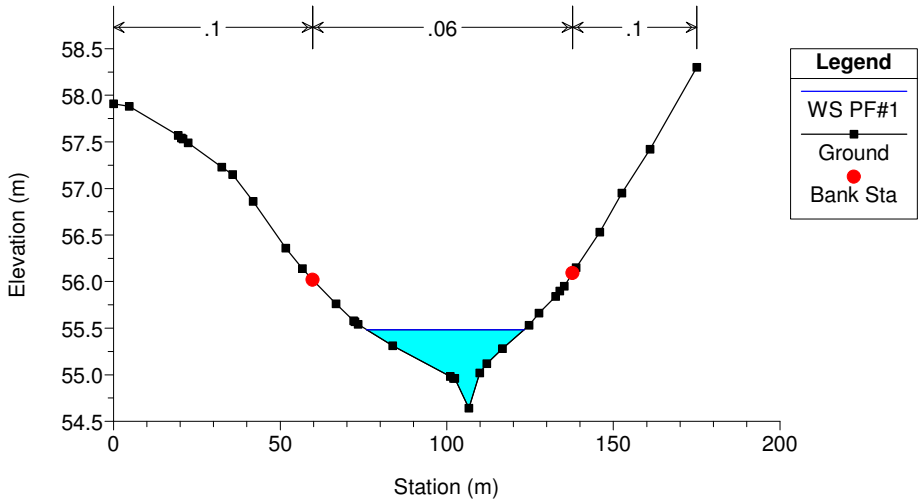
River = west Reach = 40 RS = 593.59



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Existing\ex_teviot161209 Plan: Plan 02 13/12/2016

Flow: Flow 01 - 1% AEP

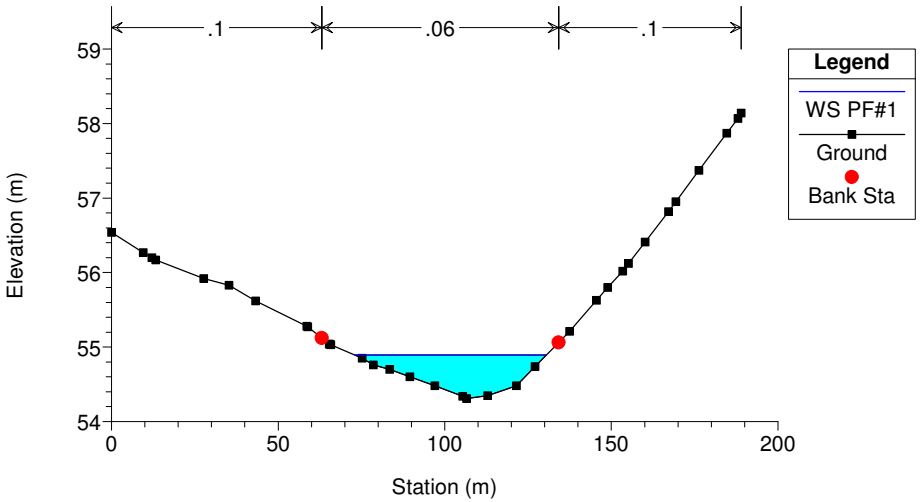
River = west Reach = 40 RS = 573.53



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Existing\ex_teviot161209 Plan: Plan 02 13/12/2016

Flow: Flow 01 - 1% AEP

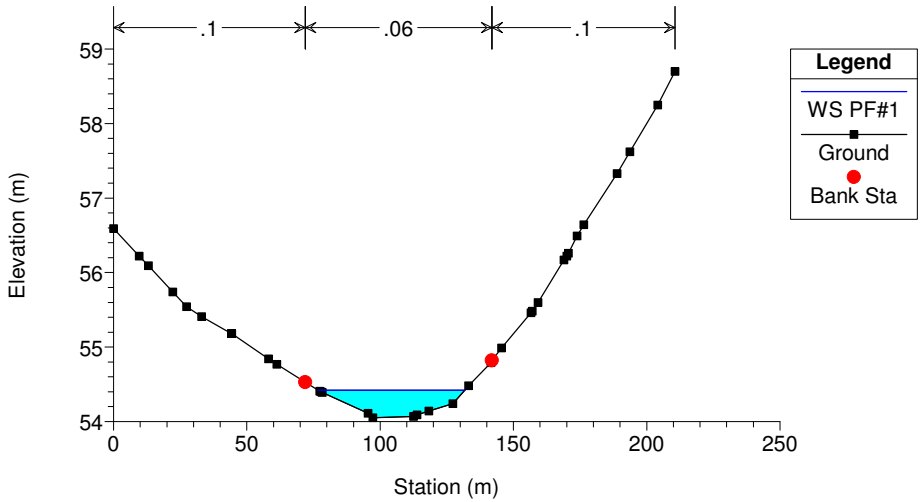
River = west Reach = 40 RS = 518.75

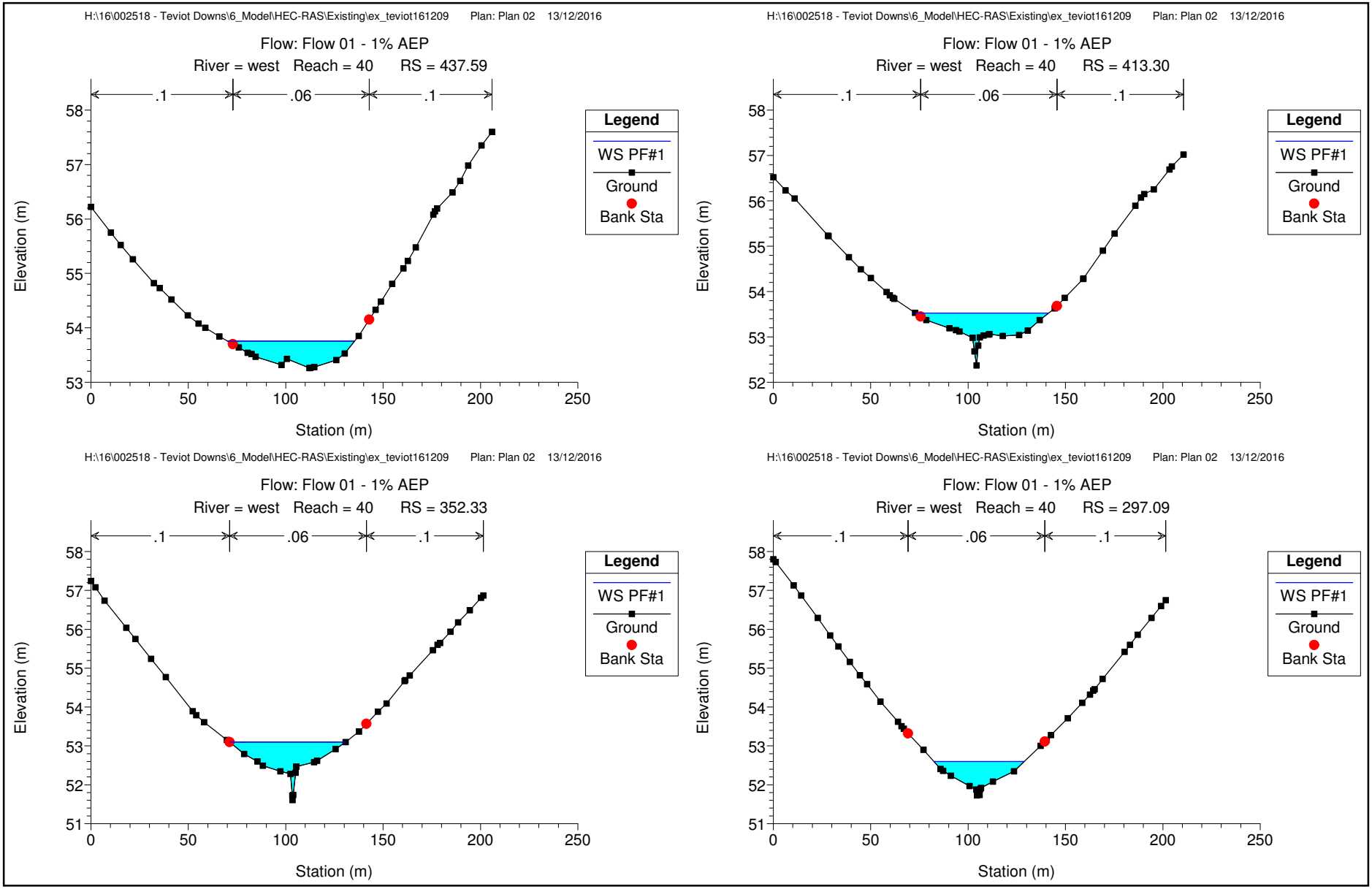


H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Existing\ex_teviot161209 Plan: Plan 02 13/12/2016

Flow: Flow 01 - 1% AEP

River = west Reach = 40 RS = 487.60

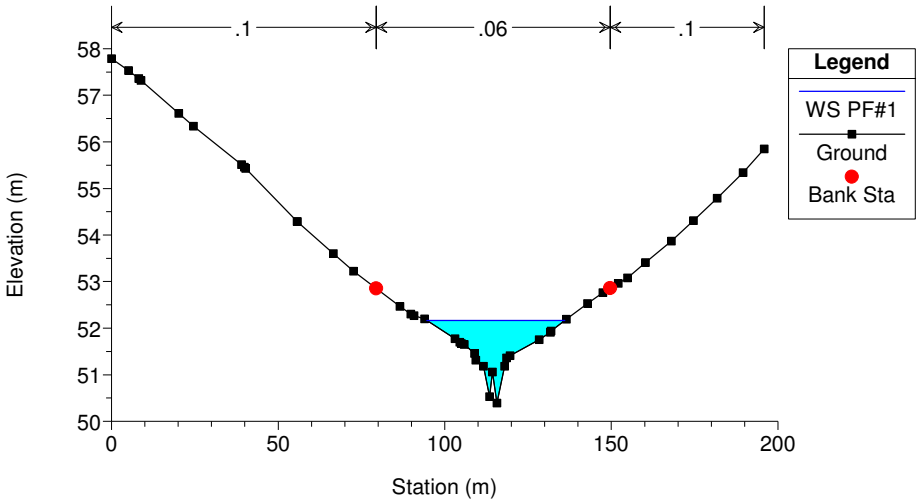



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Existing\ex_teviot161209 Plan: Plan 02 13/12/2016
Flow: Flow 01 - 1% AEP
River = west Reach = 40 RS = 437.59
.1
.06
.1
Legend
WS PF#1
Ground
Bank Sta
Elevation (m)
Station (m)
H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Existing\ex_teviot161209 Plan: Plan 02 13/12/2016
Flow: Flow 01 - 1% AEP
River = west Reach = 40 RS = 413.30
.1
.06
.1
Legend
WS PF#1
Ground
Bank Sta
Elevation (m)
Station (m)
H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Existing\ex_teviot161209 Plan: Plan 02 13/12/2016
Flow: Flow 01 - 1% AEP
River = west Reach = 40 RS = 352.33
.1
.06
.1
Legend
WS PF#1
Ground
Bank Sta
Elevation (m)
Station (m)
H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Existing\ex_teviot161209 Plan: Plan 02 13/12/2016
Flow: Flow 01 - 1% AEP
River = west Reach = 40 RS = 297.09
.1
.06
.1
Legend
WS PF#1
Ground
Bank Sta
Elevation (m)
Station (m)

H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Existing\ex_teviot161209 Plan: Plan 02 13/12/2016

Flow: Flow 01 - 1% AEP

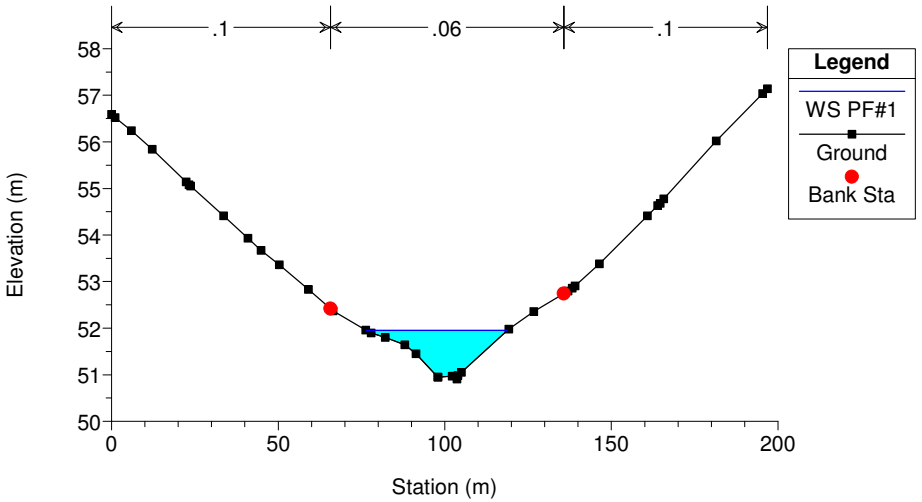
River = west Reach = 40 RS = 246.38



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Existing\ex_teviot161209 Plan: Plan 02 13/12/2016

Flow: Flow 01 - 1% AEP

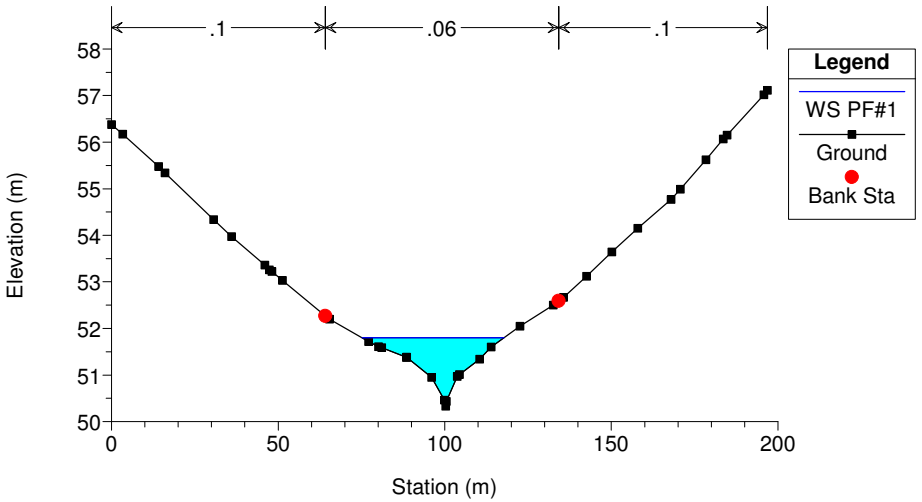
River = west Reach = 40 RS = 218.91



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Existing\ex_teviot161209 Plan: Plan 02 13/12/2016

Flow: Flow 01 - 1% AEP

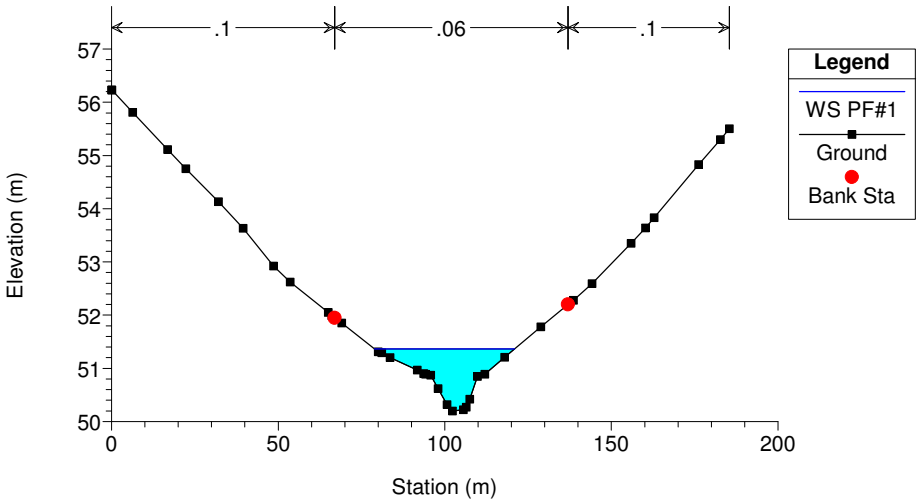
River = west Reach = 40 RS = 200.95



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Existing\ex_teviot161209 Plan: Plan 02 13/12/2016

Flow: Flow 01 - 1% AEP

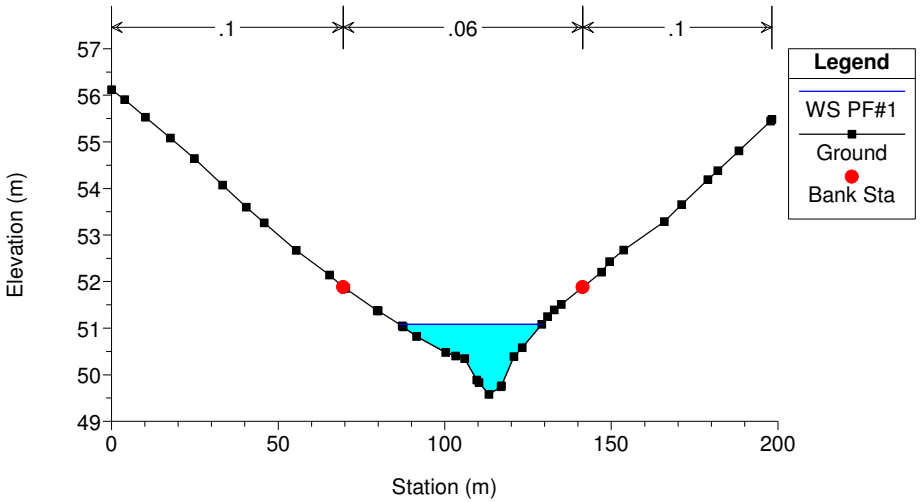
River = west Reach = 40 RS = 152.66



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Existing\ex_teviot161209 Plan: Plan 02 13/12/2016

Flow: Flow 01 - 1% AEP

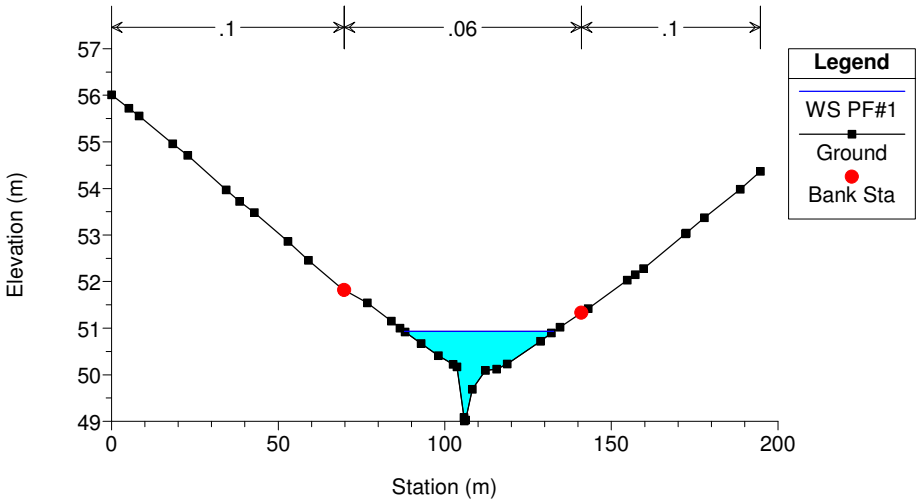
River = west Reach = 40 RS = 102.02



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Existing\ex_teviot161209 Plan: Plan 02 13/12/2016

Flow: Flow 01 - 1% AEP

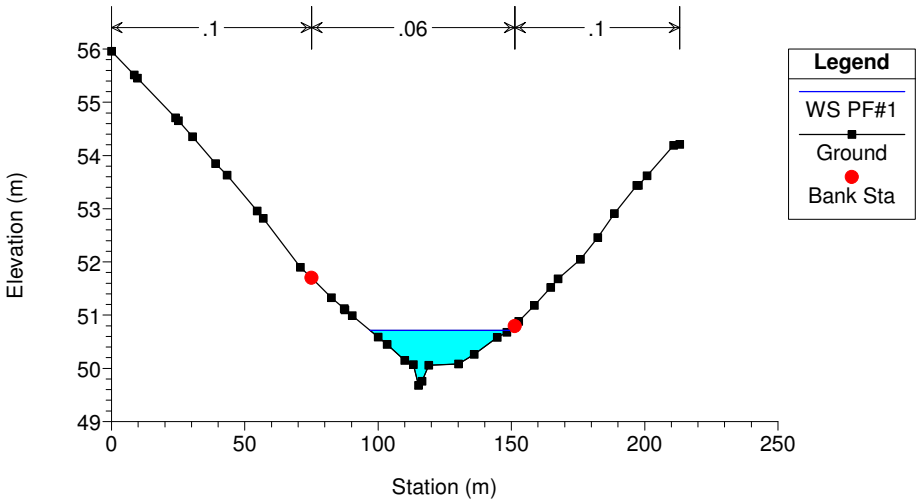
River = west Reach = 40 RS = 69.05



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Existing\ex_teviot161209 Plan: Plan 02 13/12/2016

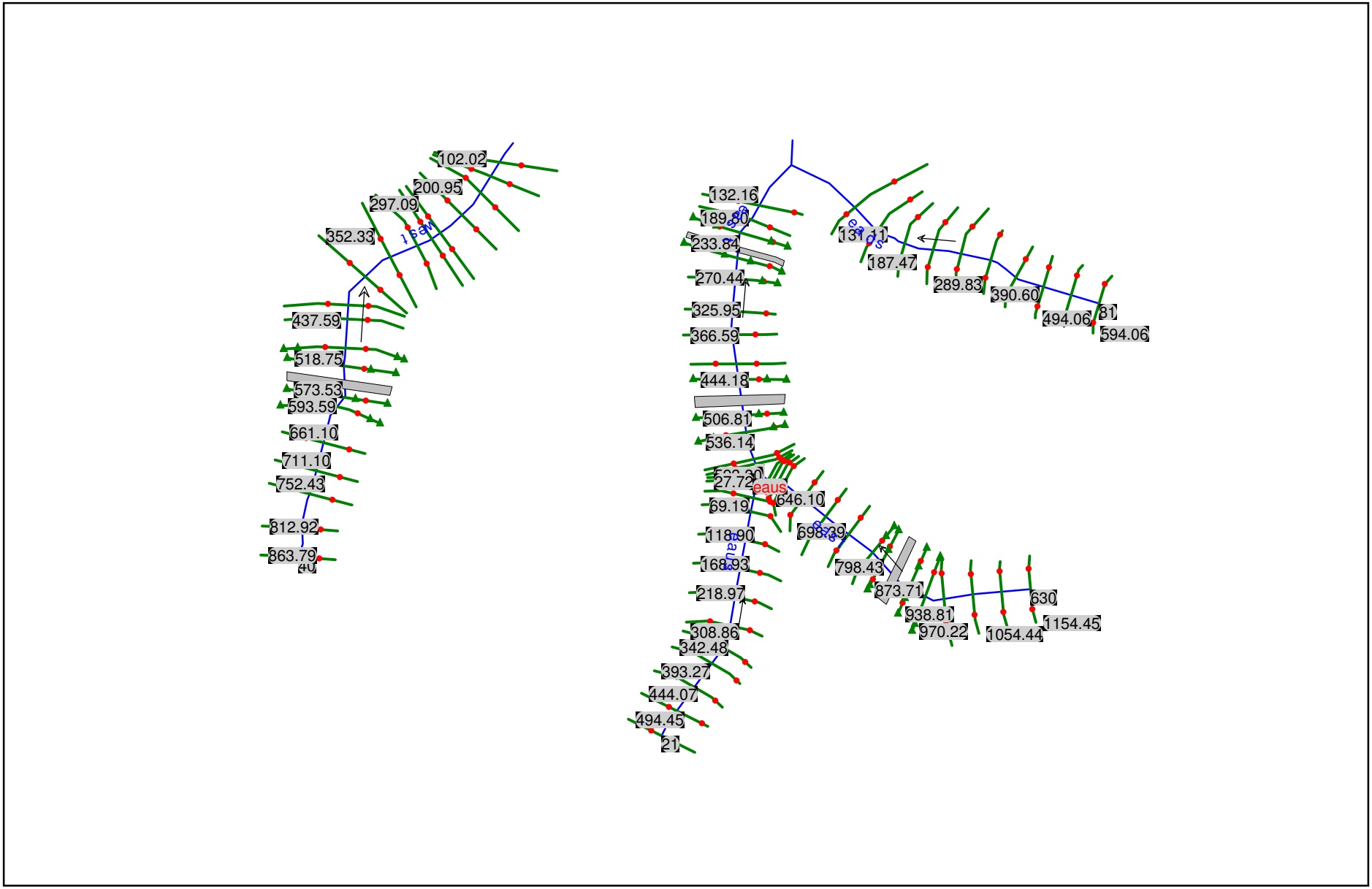
Flow: Flow 01 - 1% AEP

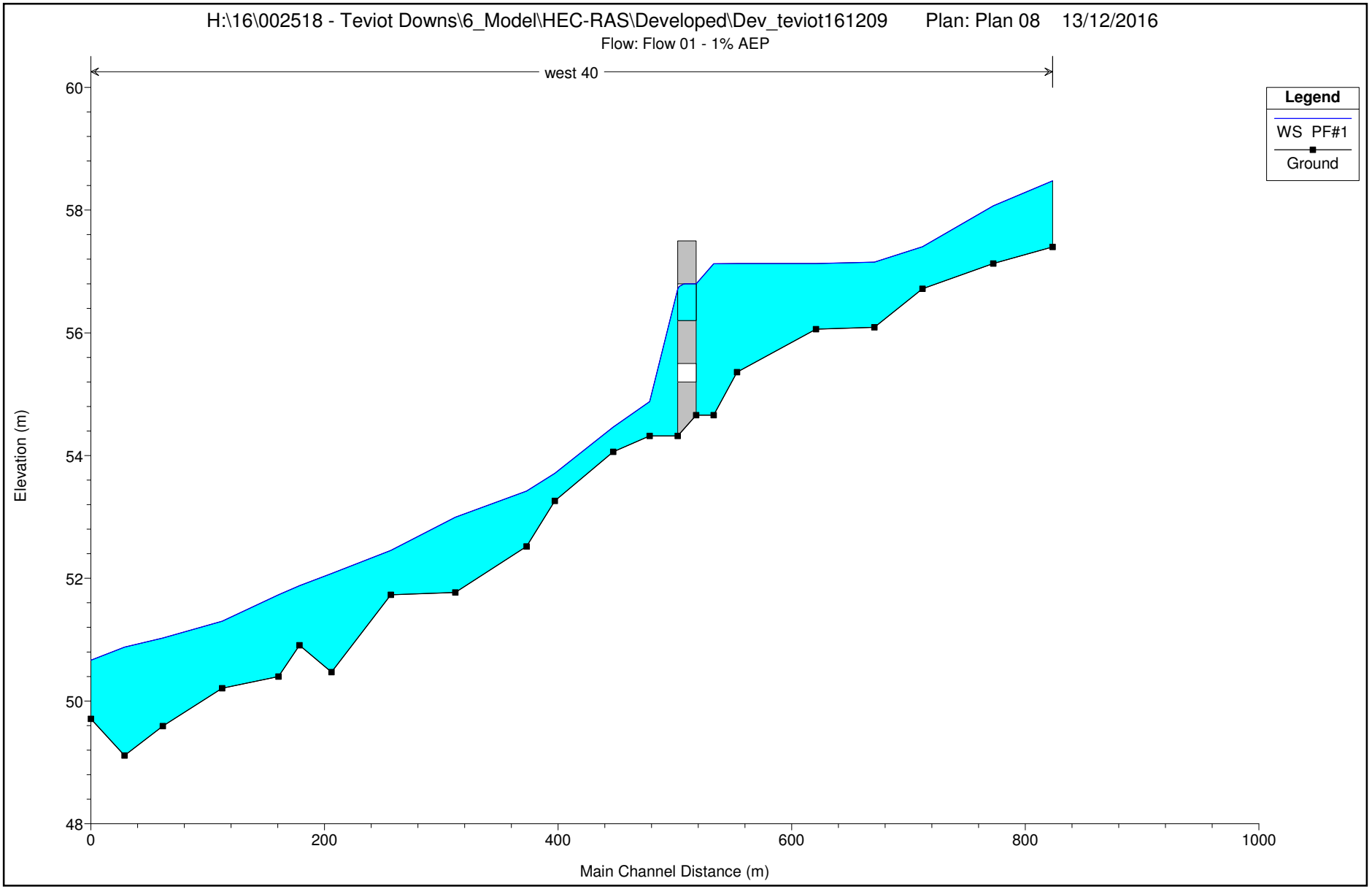
River = west Reach = 40 RS = 40.34

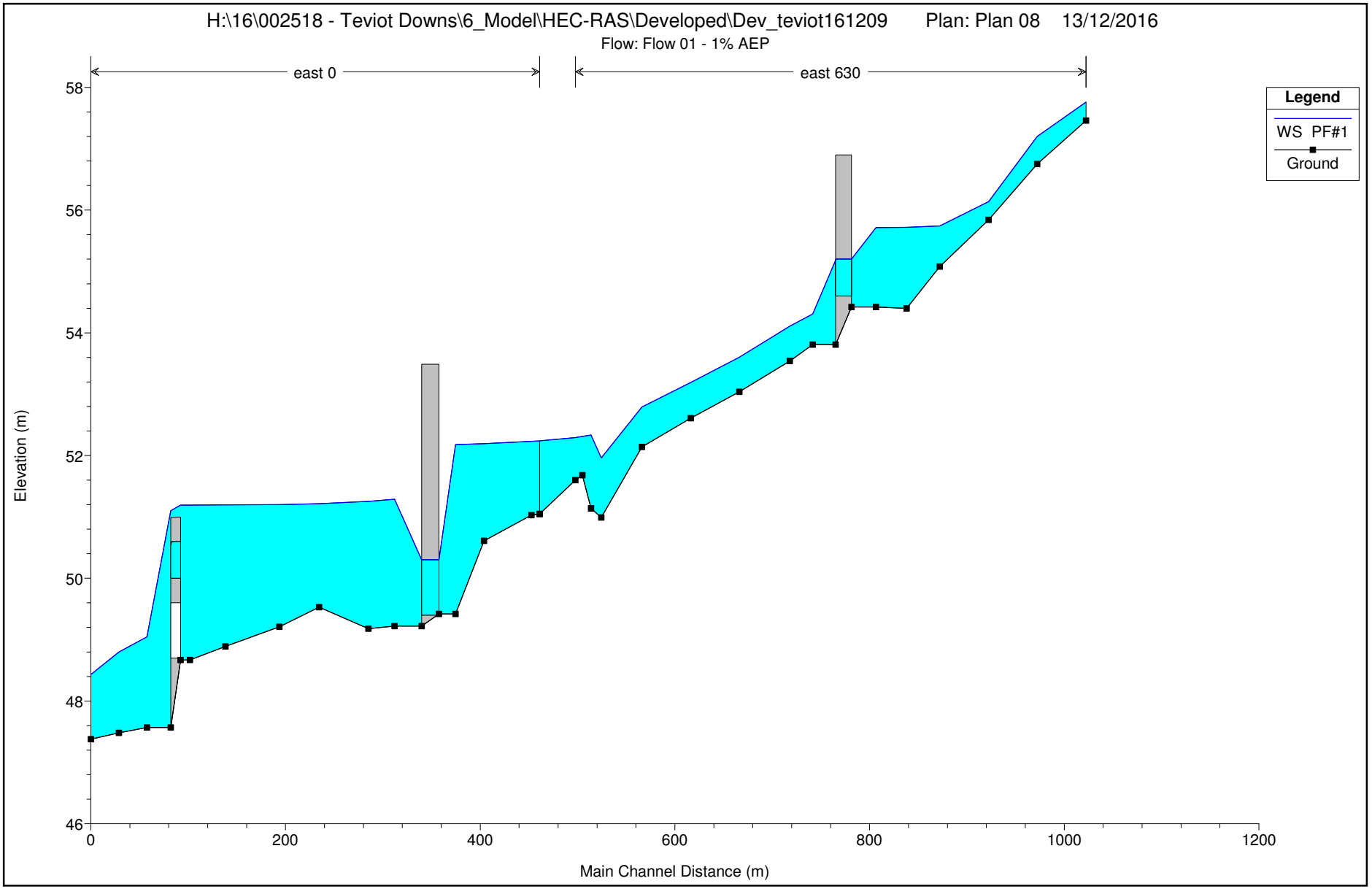


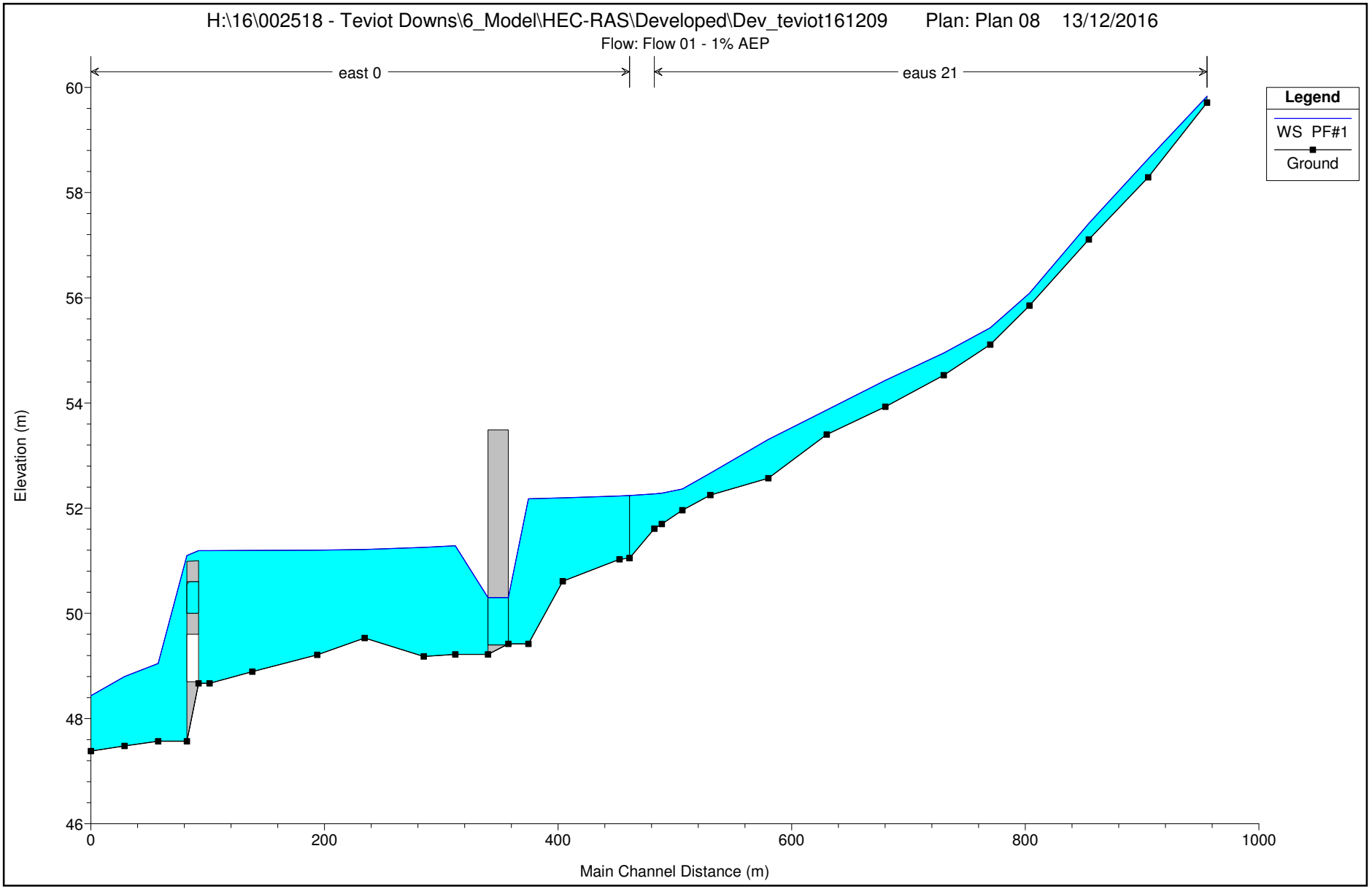
HEC-RAS **Plan: Existing 1% AEP**

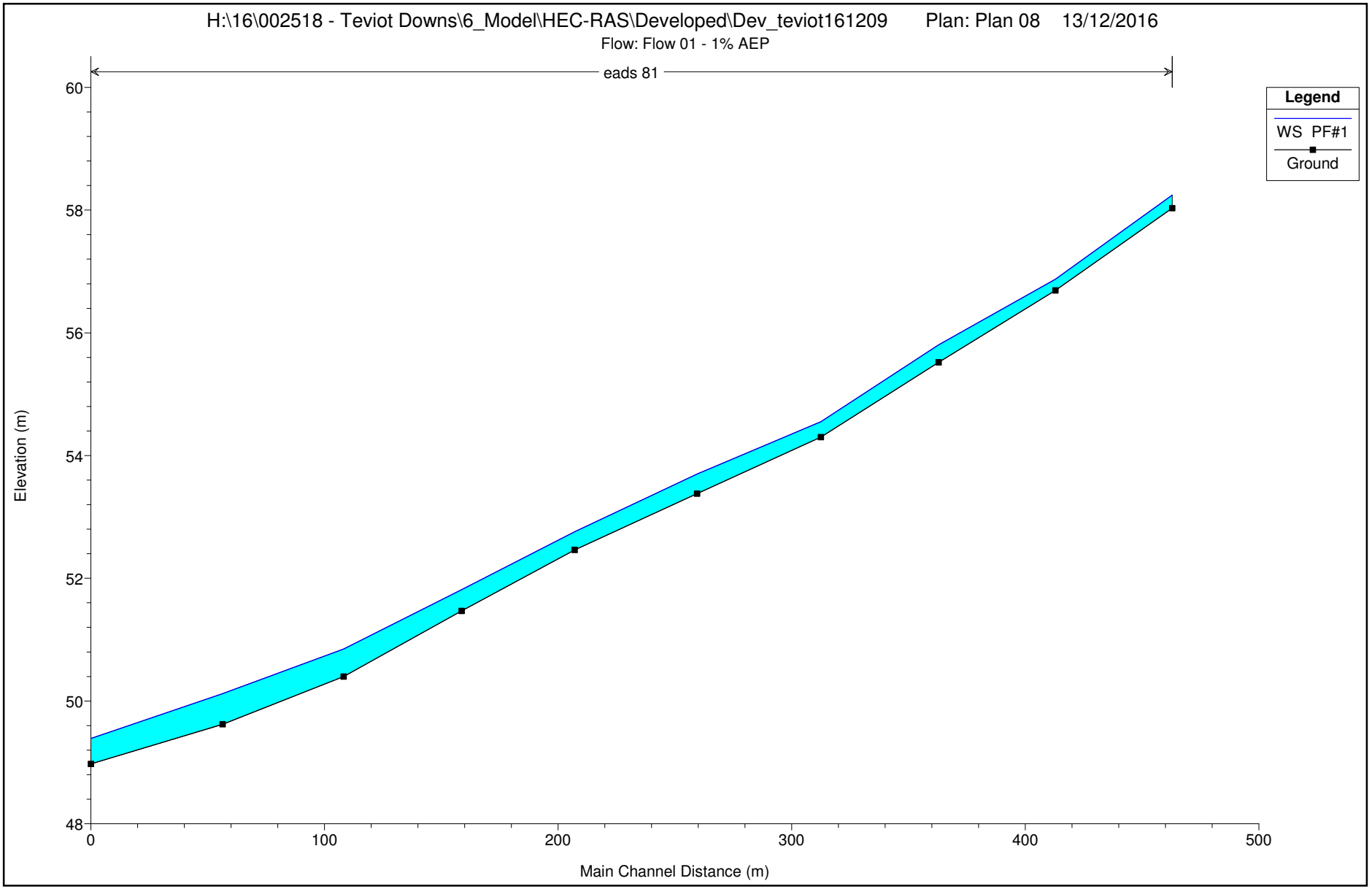
River	Reach	River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
West	0	864	9.89	57.37	58.49	58.19	58.51	0.005681	0.7	14.21	34.33	0.35
West	0	813	9.89	57.09	58.07	57.9	58.1	0.012484	0.82	12.13	41.6	0.48
West	0	752	9.89	56.72	57.44	57.22	57.47	0.008684	0.76	13.06	38.36	0.41
West	0	711	9.89	56.04	57.02	56.84	57.05	0.011963	0.85	11.63	36.34	0.48
West	0	661	9.89	56.06	56.59	56.38	56.61	0.006716	0.66	14.94	44.24	0.36
West	0	594	14.49	55.36	55.81	55.7	55.85	0.017378	0.97	14.92	50.75	0.57
West	0	573	14.49	54.64	55.48	55.34	55.53	0.014974	0.95	15.17	47.32	0.54
West	0	528	14.49	54.31	54.89	54.7	54.92	0.008488	0.75	19.44	57.47	0.41
West	0	488	14.49	54.05	54.42	54.36	54.48	0.027247	1.08	13.47	55.08	0.69
West	0	438	14.49	53.26	53.75	53.59	53.78	0.008338	0.72	20.27	65.18	0.4
West	0	413	21.59	52.37	53.53	53.34	53.56	0.009347	0.85	25.44	68.44	0.44
West	0	352	21.59	51.61	53.1	52.79	53.13	0.005522	0.76	28.58	59.64	0.35
West	0	297	21.59	51.73	52.6	52.44	52.66	0.014158	1.11	19.45	46.38	0.55
West	0	246	21.59	50.39	52.17	51.77	52.21	0.006066	0.9	24.11	41.41	0.37
West	0	219	21.59	50.91	51.95	51.64	52	0.009191	1.01	21.34	42.28	0.45
West	0	201	21.59	50.33	51.8	51.48	51.85	0.00804	0.97	22.3	42.62	0.43
West	0	153	21.59	50.2	51.37	51.09	51.42	0.00976	1.03	20.93	42.13	0.47
West	0	102	23.47	49.58	51.09	50.57	51.12	0.004013	0.81	28.89	42.67	0.32
West	0	69	23.47	49.01	50.93	50.5	50.97	0.005197	0.86	27.33	44.78	0.35
West	0	40	23.47	49.68	50.72	50.48	50.77	0.010003	0.98	23.84	52.42	0.47
East	21	494	4.22	59.36	59.7	59.62	59.73	0.014878	0.67	6.28	32.96	0.49
East	21	444	4.22	58.26	58.52	58.49	58.56	0.040432	0.92	4.58	31.78	0.77
East	21	393	4.22	57.11	57.39	57.31	57.4	0.014479	0.59	7.16	45.42	0.47
East	21	342	4.22	55.85	56.01	56	56.06	0.063096	0.96	4.42	40.46	0.92
East	21	309	4.22	55.11	55.4	55.3	55.41	0.008944	0.5	8.45	47.32	0.38
East	21	269	9.21	54.52	54.99	54.84	55.02	0.010213	0.74	12.48	43.03	0.44
East	21	219	9.21	53.92	54.47	54.31	54.5	0.010545	0.76	12.05	40.31	0.45
East	21	169	9.21	53.39	53.91	53.77	53.95	0.011648	0.79	11.63	39.81	0.47
East	21	119	9.21	52.55	53.35	53.18	53.39	0.010797	0.82	11.17	33.96	0.46
East	21	69	9.21	52.24	52.71	52.6	52.75	0.015547	0.83	11.12	44.15	0.53
East	21	45	9.21	51.96	52.39	52.27	52.42	0.012182	0.77	11.91	43.47	0.47
East	21	28	9.21	51.7	52.17	52.03	52.2	0.012224	0.84	10.99	35.55	0.48
East	21	21	9.21	51.61	52.1	51.93	52.13	0.01037	0.82	11.25	33.22	0.45
East	630	1154	5.47	57.46	57.77	57.67	57.79	0.012328	0.64	8.6	42.69	0.45
East	630	1104	5.47	56.74	57.09	57	57.11	0.01505	0.68	8.01	41.45	0.5
East	630	1054	5.47	55.84	56.14	56.08	56.17	0.024042	0.83	6.61	36.51	0.62
East	630	1004	5.47	55.08	55.41	55.3	55.43	0.009977	0.56	9.75	49.77	0.4
East	630	970	7.62	54.4	55.1	54.95	55.12	0.008279	0.63	12.17	45.8	0.39
East	630	933	7.62	54.42	54.79	54.68	54.82	0.011817	0.69	11.09	47.48	0.45
East	630	873	7.62	53.81	54.23	54.05	54.24	0.006739	0.59	12.88	45.33	0.35
East	630	850	7.62	53.54	54.08	53.88	54.09	0.006059	0.57	13.25	44.91	0.34
East	630	798	14.24	53.03	53.67	53.46	53.7	0.008543	0.79	17.94	48.48	0.42
East	630	748	14.24	52.61	53.21	53.01	53.25	0.009769	0.85	16.76	45.26	0.45
East	630	698	14.24	52.14	52.77	52.54	52.8	0.008201	0.76	18.62	51.61	0.41
East	630	657	14.24	50.95	51.94	51.94	52.08	0.053379	1.68	8.5	29.43	1
East	630	646	14.24	51.06	52.23	51.97	52.25	0.004265	0.58	24.56	62.81	0.3
East	630	637	14.24	51.68	52.19	51.97	52.21	0.005428	0.65	22.01	58.51	0.33
East	630	630	14.24	51.6	52.15	51.9	52.17	0.004297	0.63	22.62	53.4	0.3
East	109	593	23.45	51.04	51.99	51.62	52.02	0.004048	0.7	33.64	65.41	0.31
East	109	585	23.45	51.02	51.96	51.58	51.99	0.003823	0.69	33.85	63.12	0.3
East	109	536	29.56	50.6	51.62	51.36	51.68	0.010362	1.1	26.92	51.65	0.49
East	109	510	29.56	49.38	51.38	50.98	51.43	0.006872	0.99	29.8	48	0.4
East	109	438	29.56	49.22	51.05	50.47	51.09	0.004394	0.86	34.18	49.06	0.33
East	109	417	29.56	49.15	50.9	50.5	50.95	0.006201	0.95	31.06	50.1	0.39
East	109	367	29.56	49.53	50.54	50.22	50.59	0.007819	1.01	29.22	51.34	0.43
East	109	326	29.56	49.21	50.25	49.88	50.3	0.006821	0.97	30.44	51.34	0.4
East	109	270	33.17	48.88	49.78	49.54	49.84	0.009993	1.07	31.12	60.76	0.48
East	109	238	33.17	48.66	49.44	49.19	49.49	0.008666	0.99	33.54	66.7	0.44
East	109	191	33.17	47.54	49.07	48.81	49.12	0.008224	0.98	33.95	67.29	0.43
East	109	161	33.76	47.48	48.82	48.56	48.87	0.009347	0.98	34.49	73.04	0.45
East	109	109	33.76	47.37	48.44	48.31	48.51	0.016504	1.2	29.57	79.71	0.59
East	81	594	2.69	58.03	58.24	58.18	58.25	0.017118	0.58	4.67	34.38	0.5
East	81	544	2.69	56.68	56.85	56.83	56.88	0.050611	0.86	3.15	28.84	0.83
East	81	494	2.69	55.52	55.78	55.71	55.8	0.011914	0.51	5.32	36.24	0.42
East	81	444	2.69	54.29	54.52	54.52	54.58	0.072258	1.06	2.54	22	1
East	81	391	2.69	53.38	53.69	53.54	53.7	0.005561	0.43	6.2	29.93	0.31
East	81	338	6.85	52.46	52.79	52.74	52.85	0.030887	1.03	6.68	32.18	0.72
East	81	290	6.85	51.47	51.84	51.73	51.87	0.014058	0.74	9.23	40.02	0.49
East	81	239	6.85	50.4	50.88	50.82	50.92	0.025935	0.92	7.49	37.4	0.65
East	81	187	9.79	49.62	50.19	50.01	50.23	0.009374	0.79	12.38	36.07	0.43
East	81	131	9.79	48.97	49.45	49.35	49.5	0.019005	0.97	10.14	37.2	0.59


102.02
200.95
297.09
352.33
437.59
518.75
573.53
593.59
661.10
711.10
752.43
812.92
863.79
132.16
189.80
233.84
270.44
325.95
366.59
444.18
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536.14
27.72
69.19
118.90
168.93
218.97
308.86
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444.07
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131.11
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289.83
390.60
494.06
594.06
646.10
698.39
798.43
873.71
938.81
970.22
1054.44
1154.45
630


H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016
Flow: Flow 01 - 1% AEP
west 40
Legend
WS PF#1
Ground
Elevation (m)
60
58
56
54
52
50
48
0
200
400
600
800
1000
Main Channel Distance (m)


H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016
Flow: Flow 01 - 1% AEP
east 0
east 630
Legend
WS PF#1
Ground
Elevation (m)
58
56
54
52
50
48
46
0
200
400
600
800
1000
1200
Main Channel Distance (m)

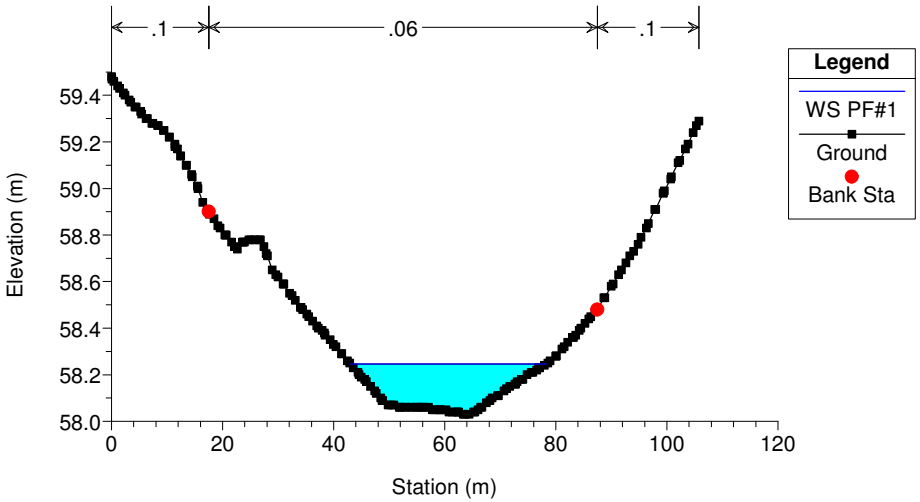

H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016
Flow: Flow 01 - 1% AEP
east 0
eaus 21
Legend
WS PF#1
Ground
Elevation (m)
60
58
56
54
52
50
48
46
0
200
400
600
800
1000
Main Channel Distance (m)


H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016
Flow: Flow 01 - 1% AEP
eads 81
Legend
WS PF#1
Ground
Elevation (m)
60
58
56
54
52
50
48
0
100
200
300
400
500
Main Channel Distance (m)

H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

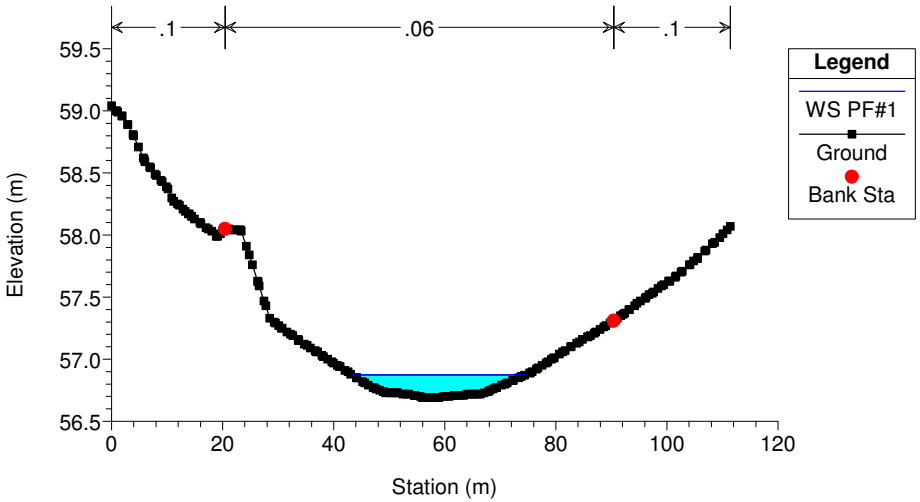
River = eads Reach = 81 RS = 594.06



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

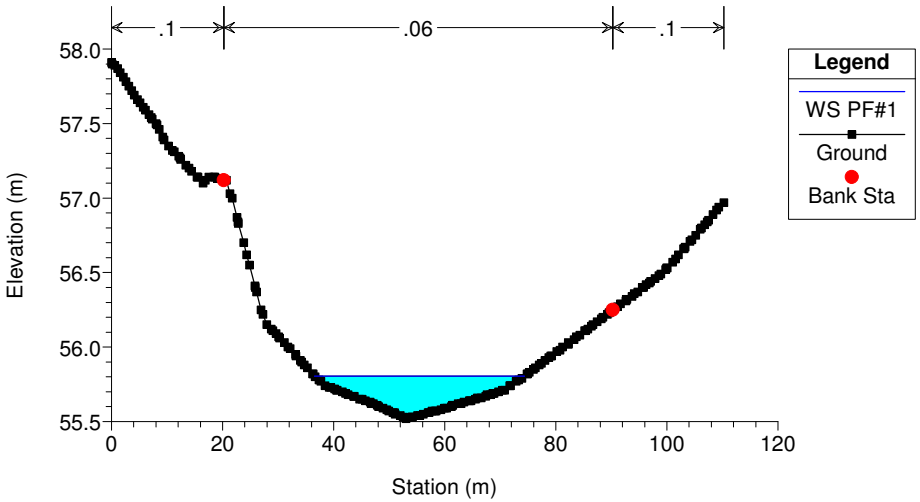
River = eads Reach = 81 RS = 544.06



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

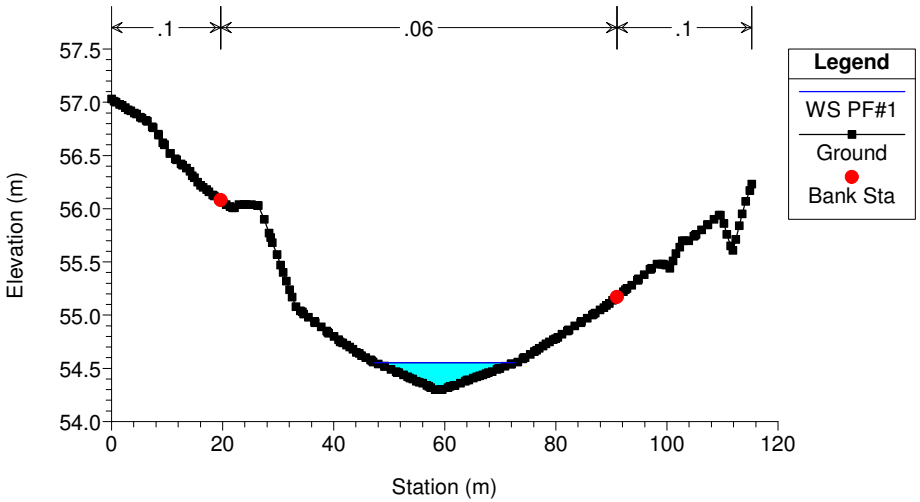
River = eads Reach = 81 RS = 494.06



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

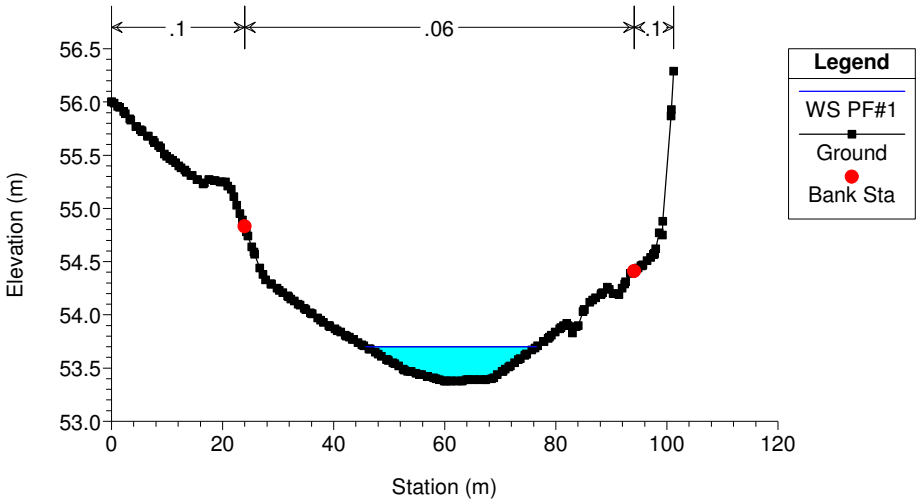
River = eads Reach = 81 RS = 443.62



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

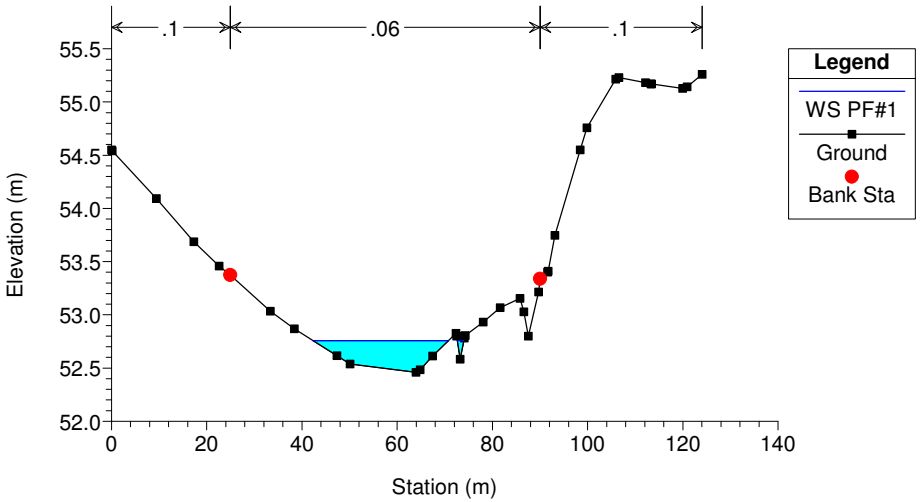
River = eads Reach = 81 RS = 390.60



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

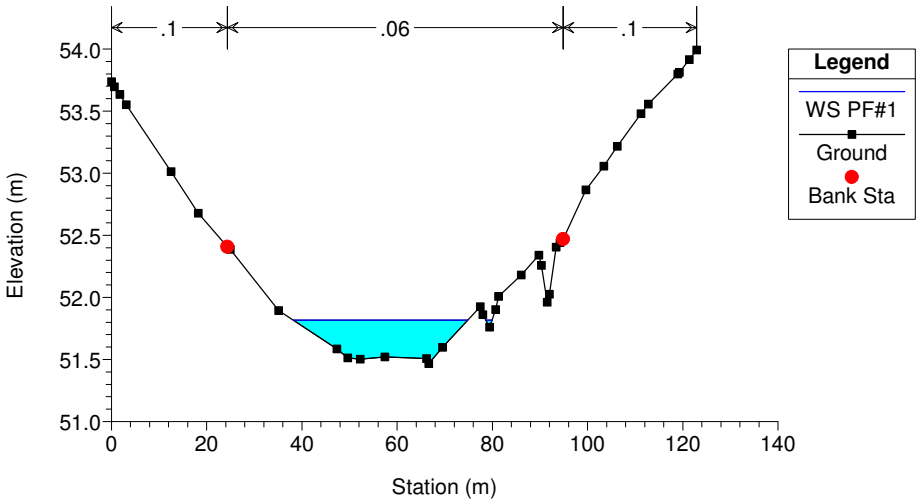
River = eads Reach = 81 RS = 338.23



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

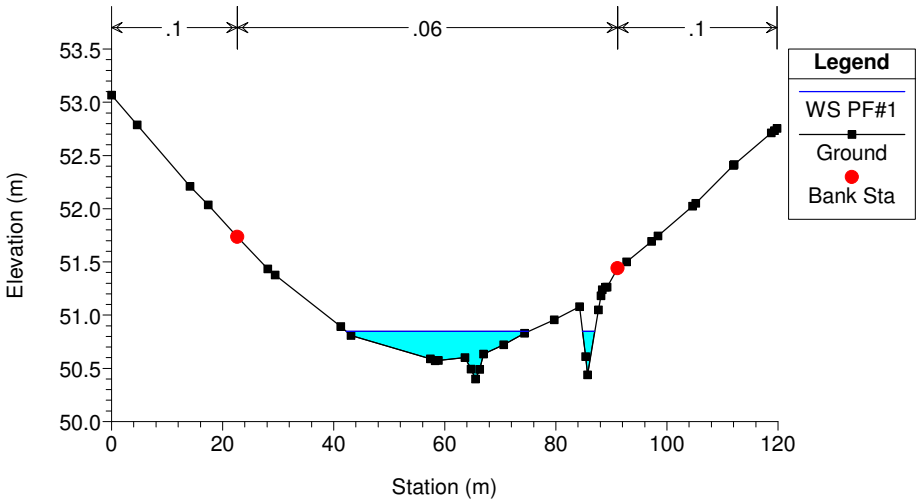
River = eads Reach = 81 RS = 289.83



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

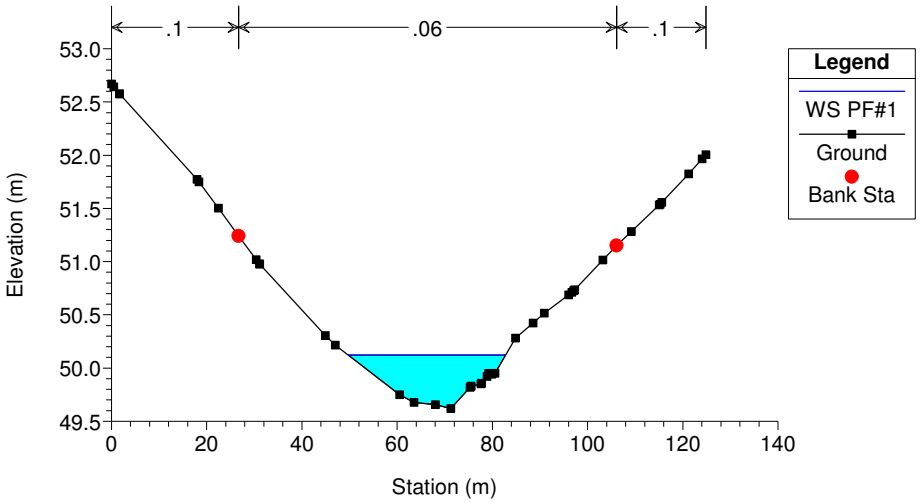
River = eads Reach = 81 RS = 239.28



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

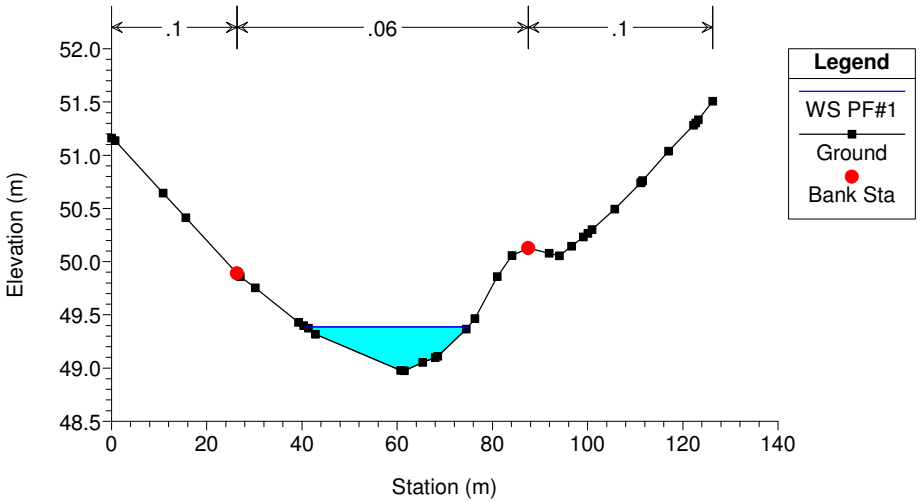
River = eads Reach = 81 RS = 187.47



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

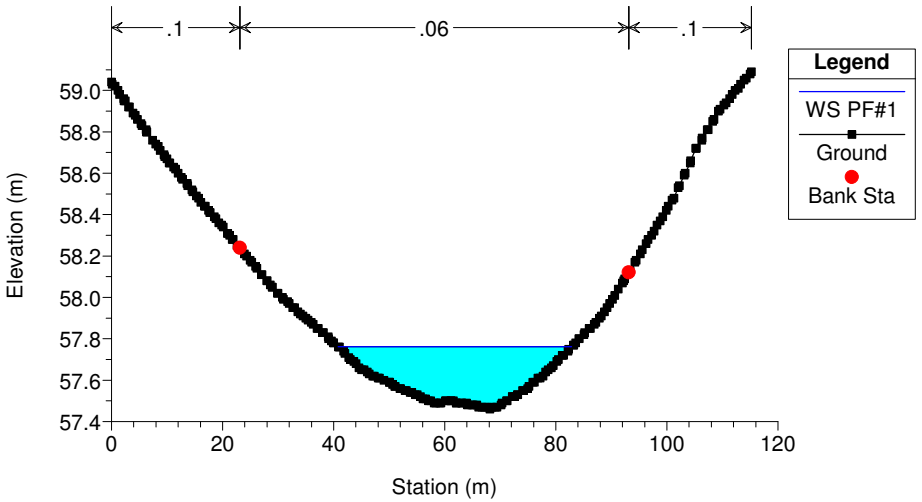
River = eads Reach = 81 RS = 131.11



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

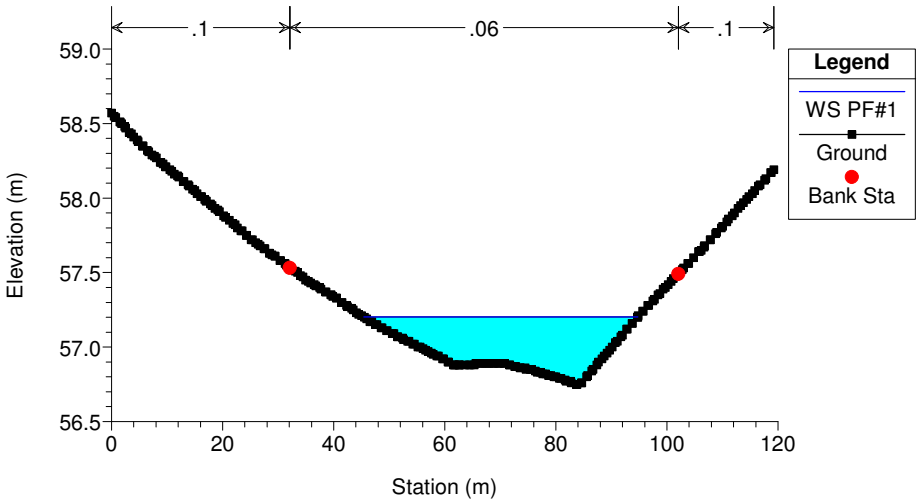
River = east Reach = 630 RS = 1154.45



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

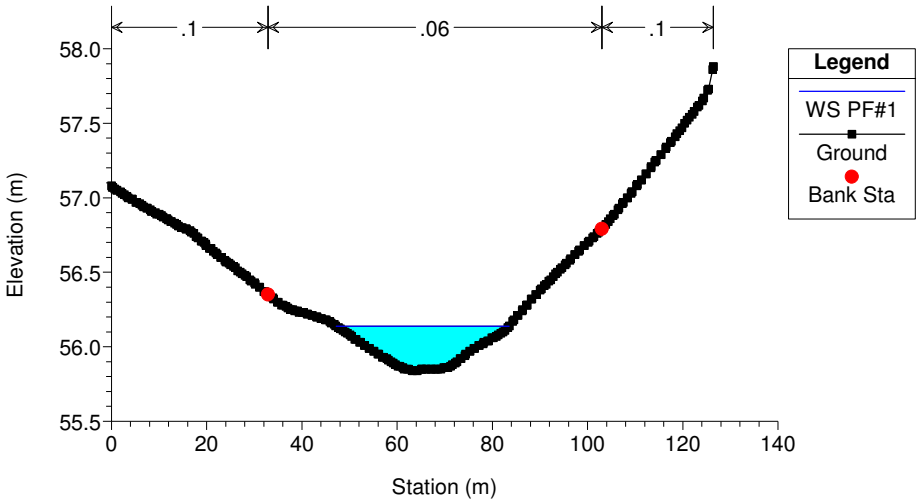
River = east Reach = 630 RS = 1104.45



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

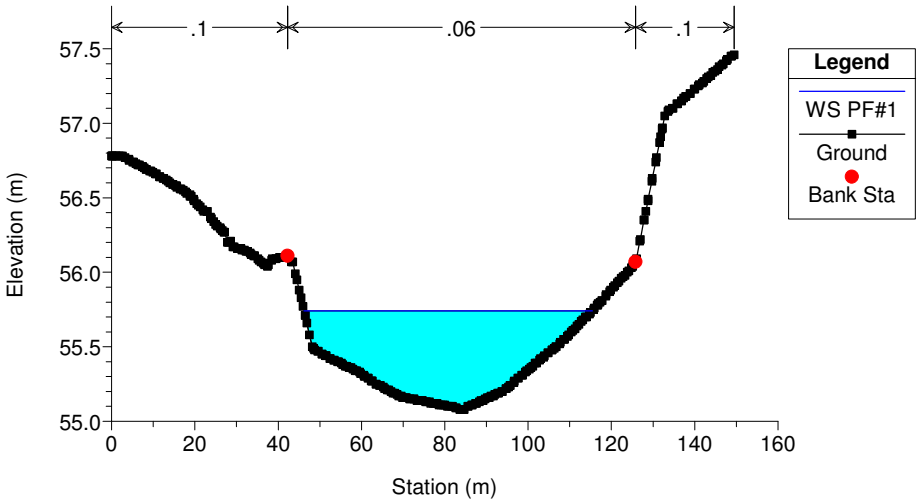
River = east Reach = 630 RS = 1054.44



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

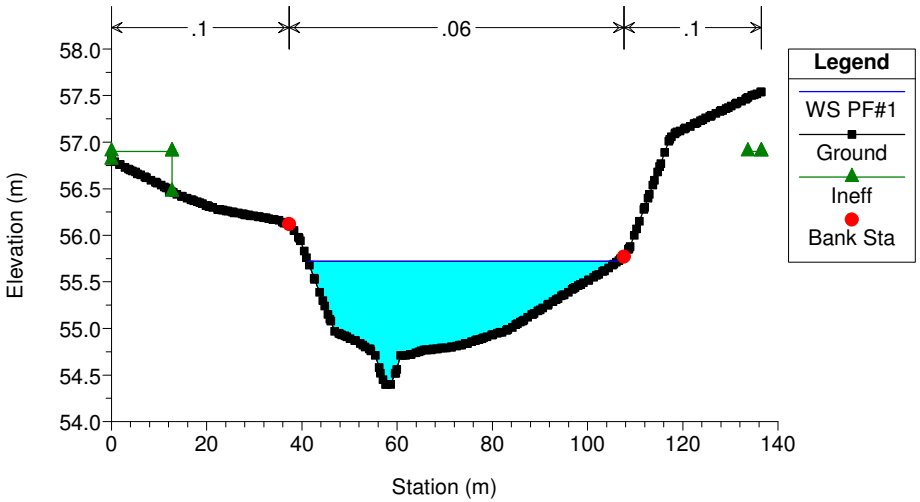
River = east Reach = 630 RS = 1004.33



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

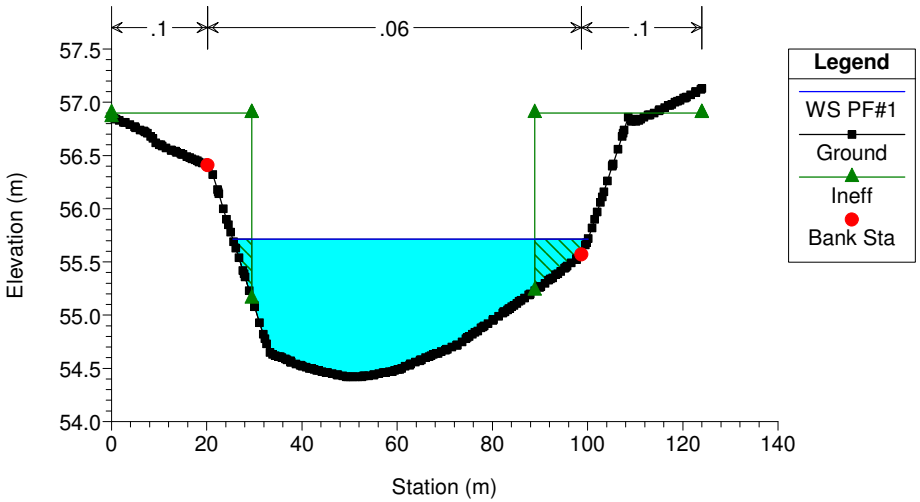
River = east Reach = 630 RS = 970.22



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

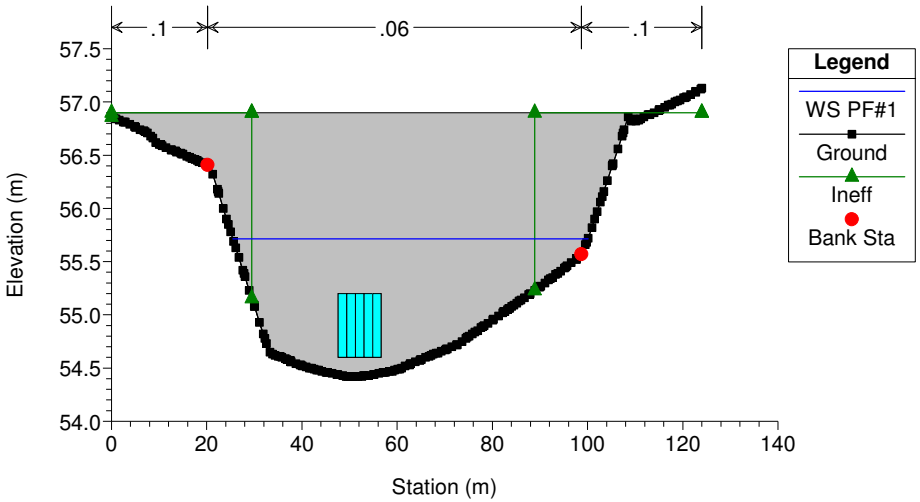
River = east Reach = 630 RS = 938.81



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

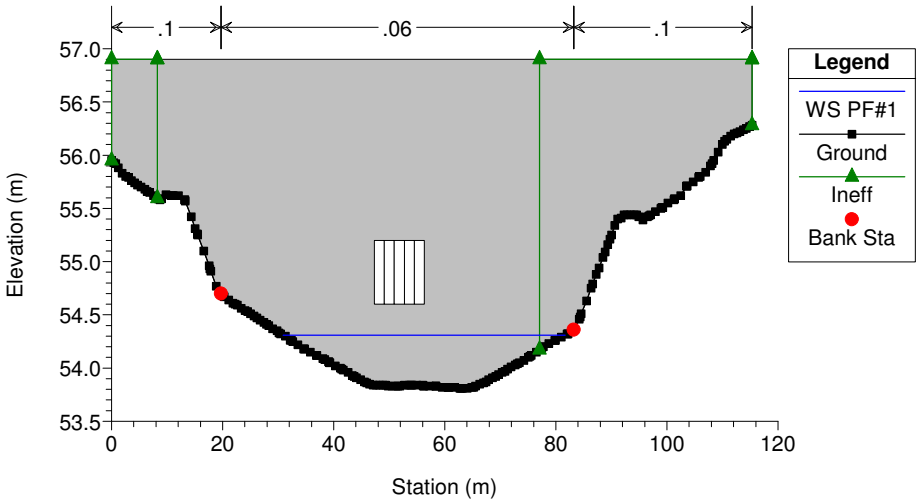
River = east Reach = 630 RS = 905.44 Culv



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

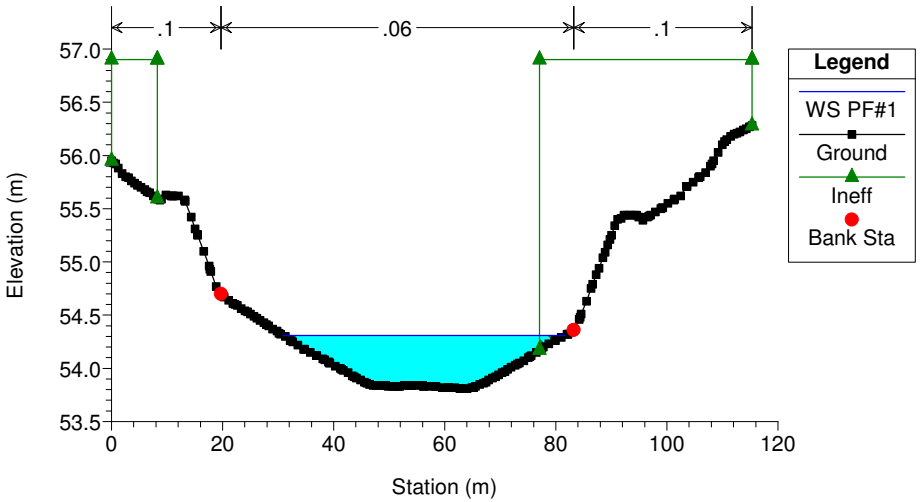
River = east Reach = 630 RS = 905.44 Culv



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

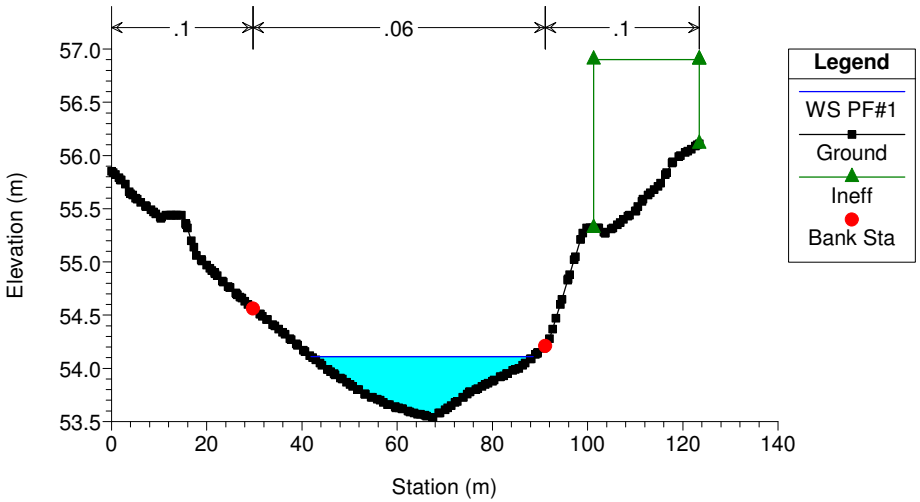
River = east Reach = 630 RS = 873.71



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

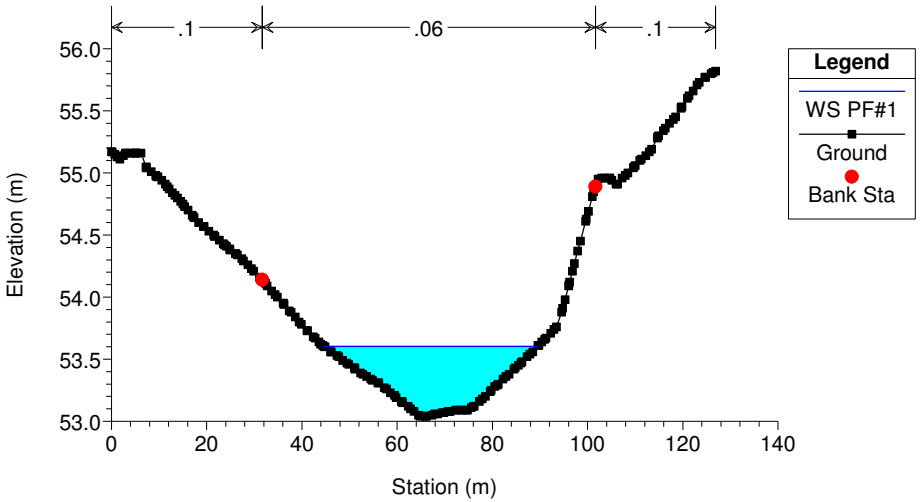
River = east Reach = 630 RS = 850.21



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

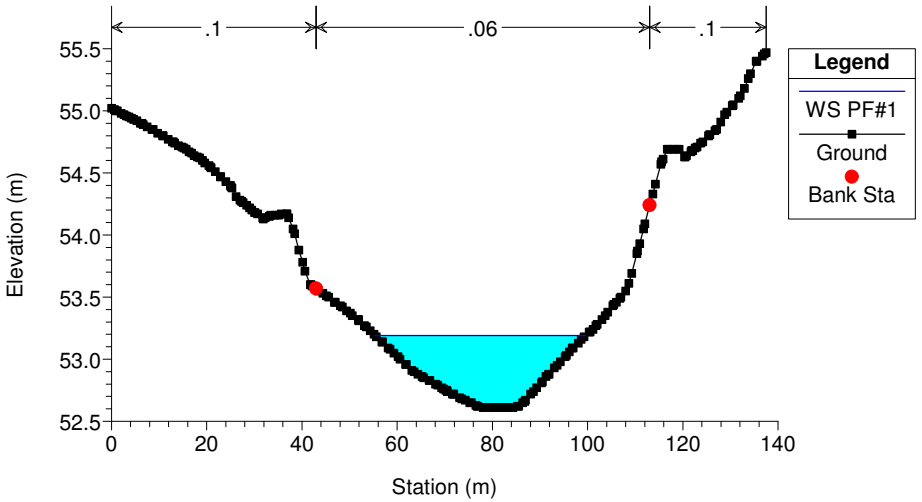
River = east Reach = 630 RS = 798.43



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

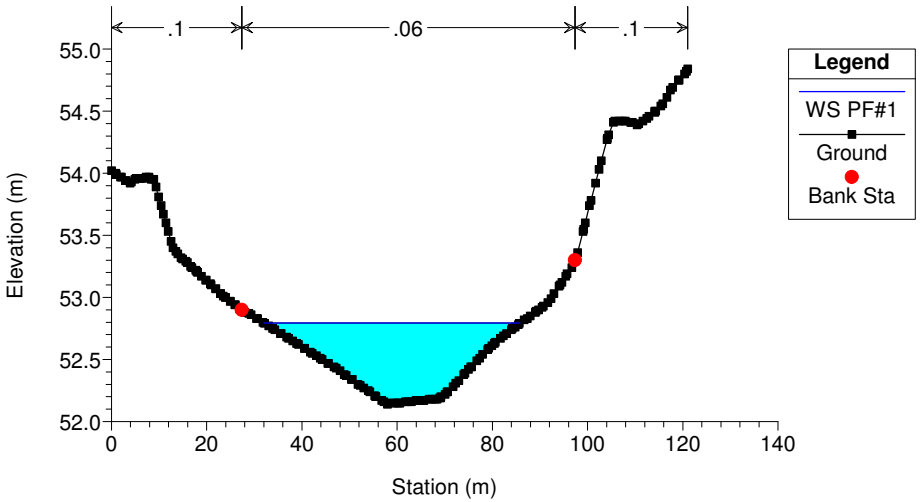
River = east Reach = 630 RS = 748.41



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

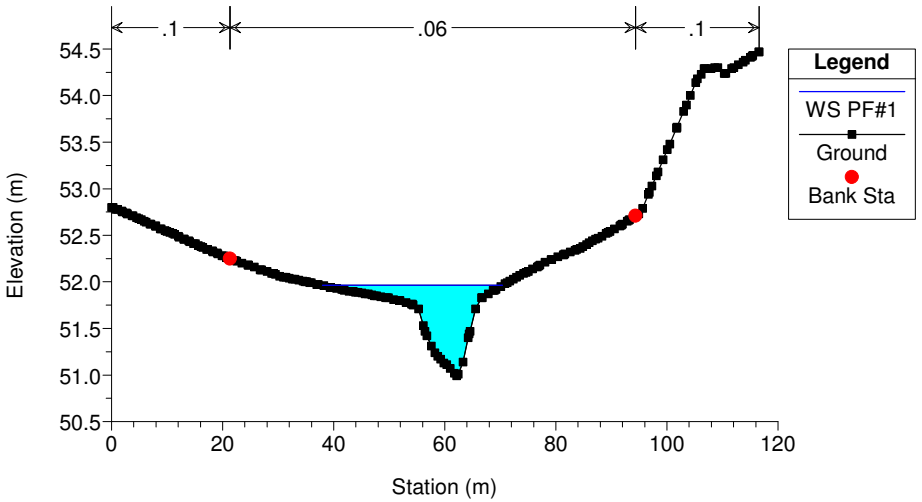
River = east Reach = 630 RS = 698.39



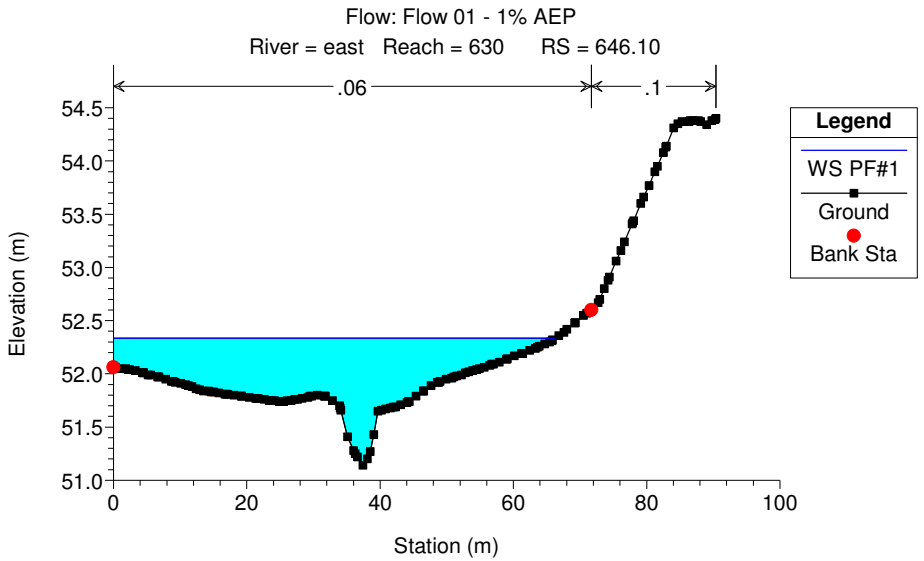
H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

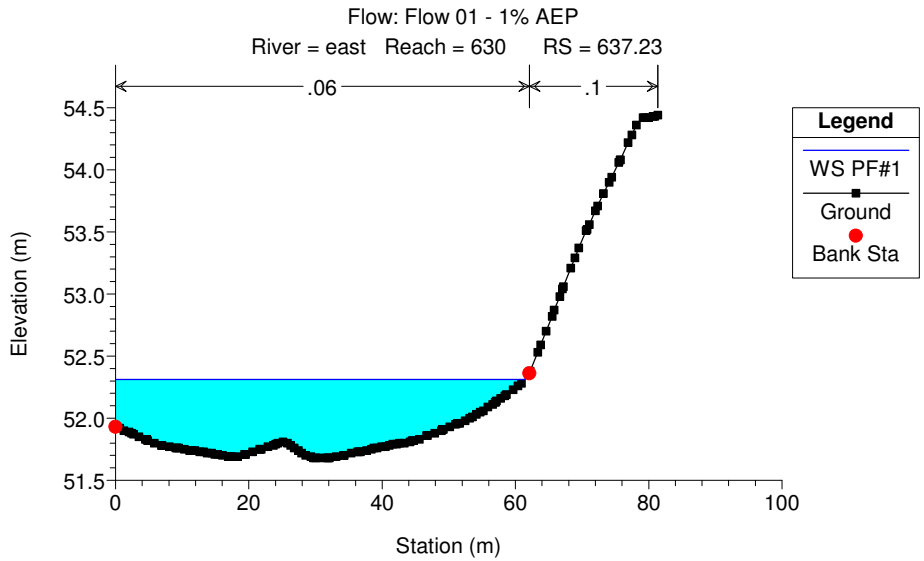
River = east Reach = 630 RS = 656.66



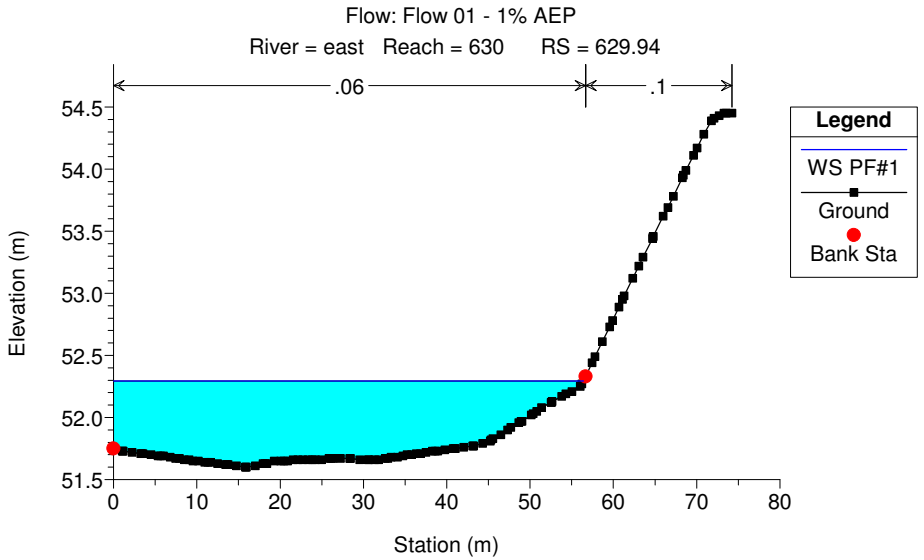
H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016



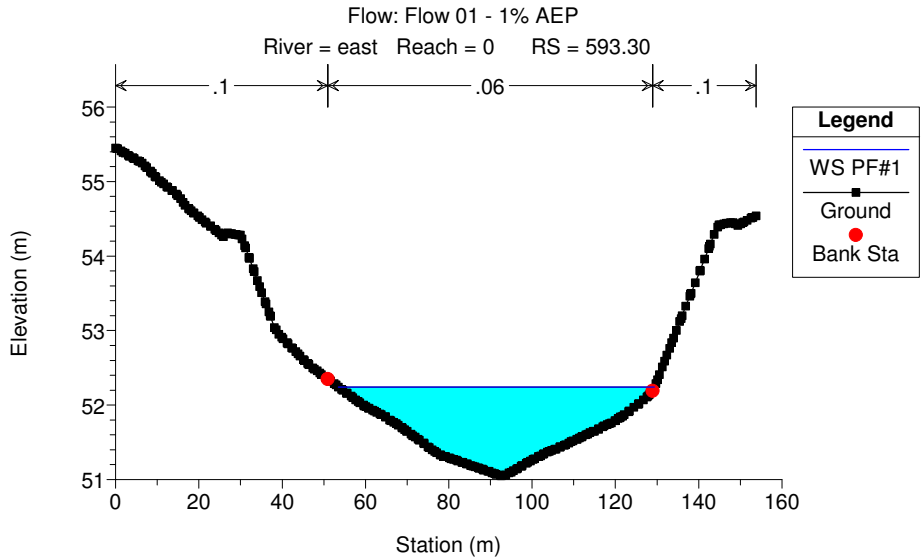
H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016



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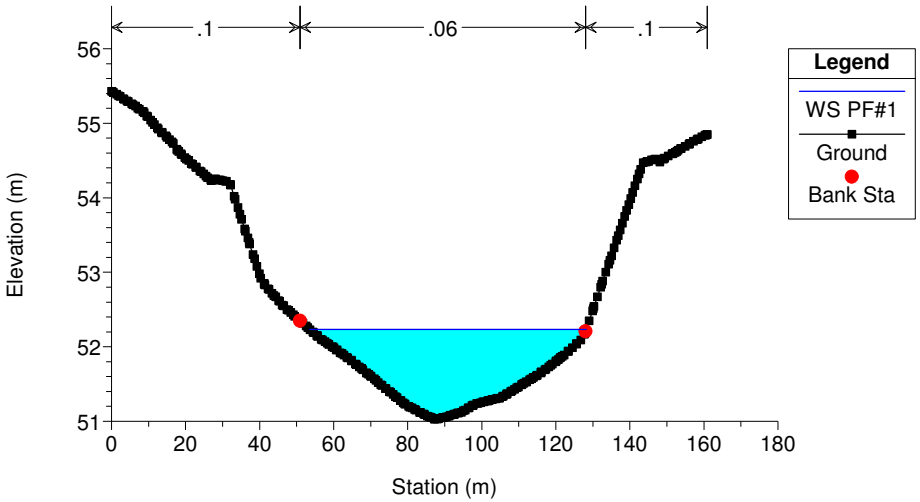
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Flow: Flow 01 - 1% AEP

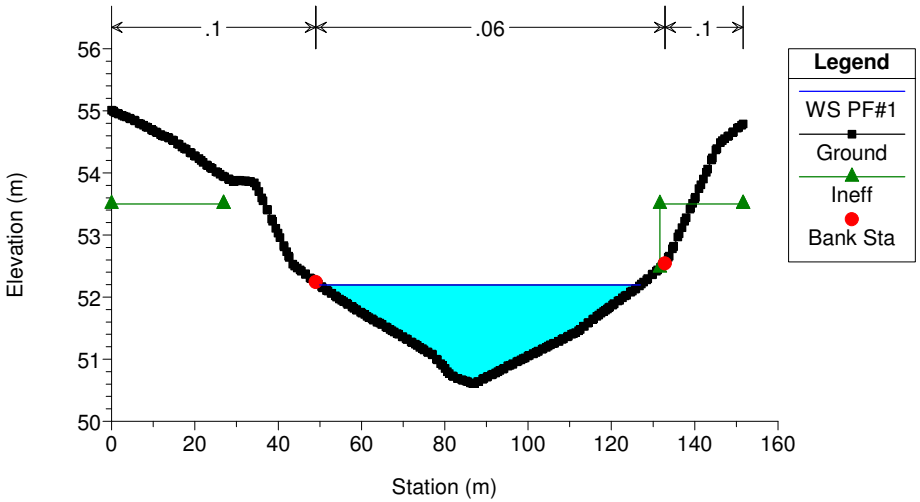
River = east Reach = 0 RS = 584.73



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

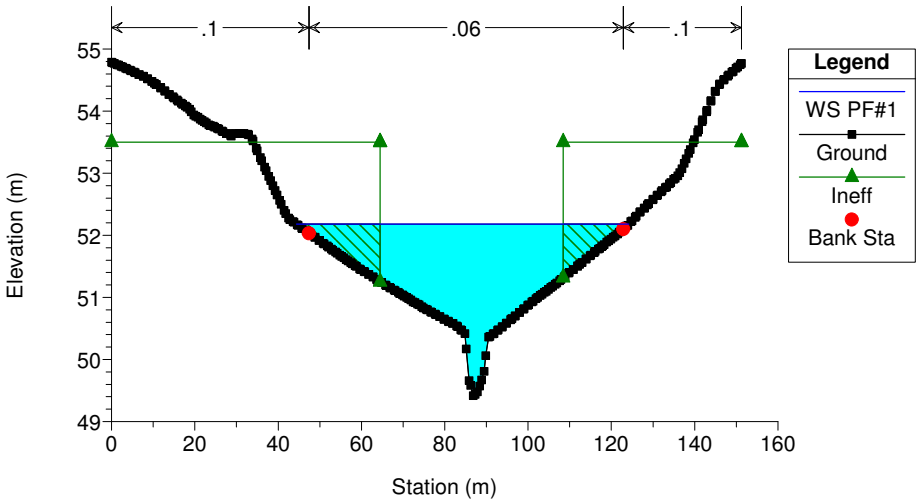
River = east Reach = 0 RS = 536.14



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Flow: Flow 01 - 1% AEP

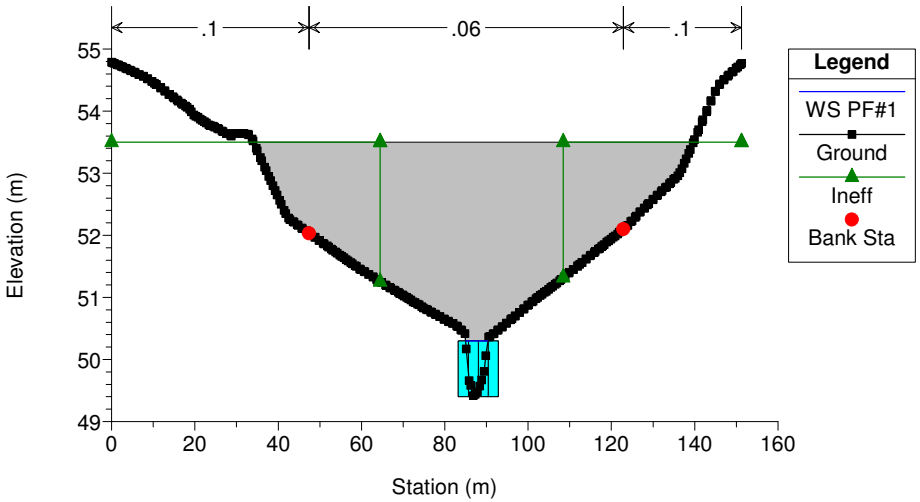
River = east Reach = 0 RS = 506.81



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

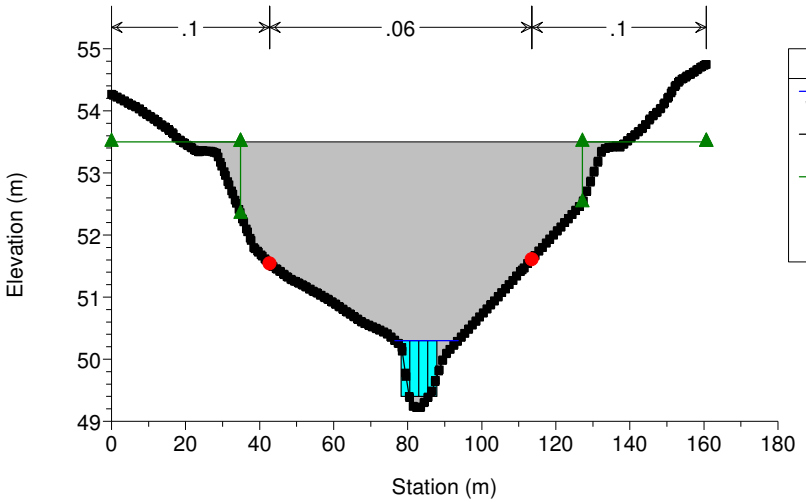
River = east Reach = 0 RS = 480.86 Culv



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

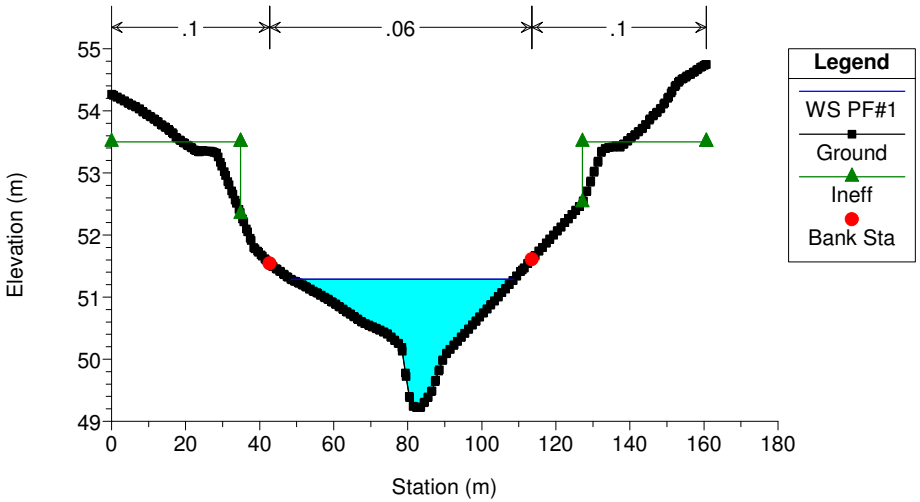
River = east Reach = 0 RS = 480.86 Culv



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

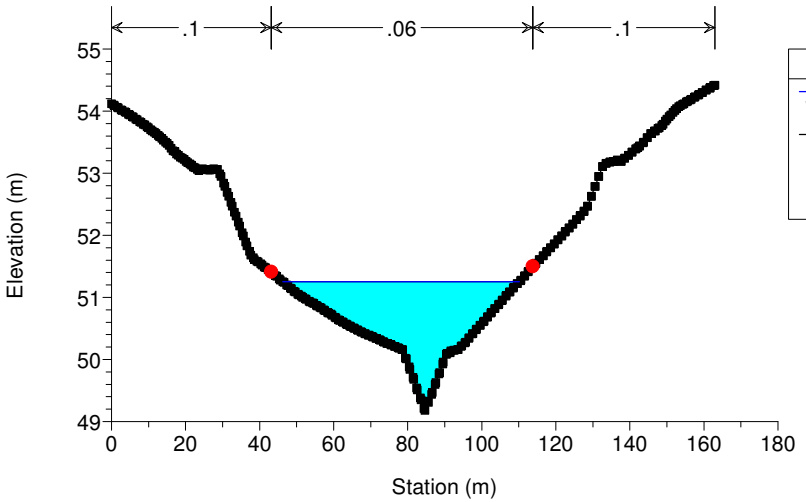
River = east Reach = 0 RS = 444.18



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Flow: Flow 01 - 1% AEP

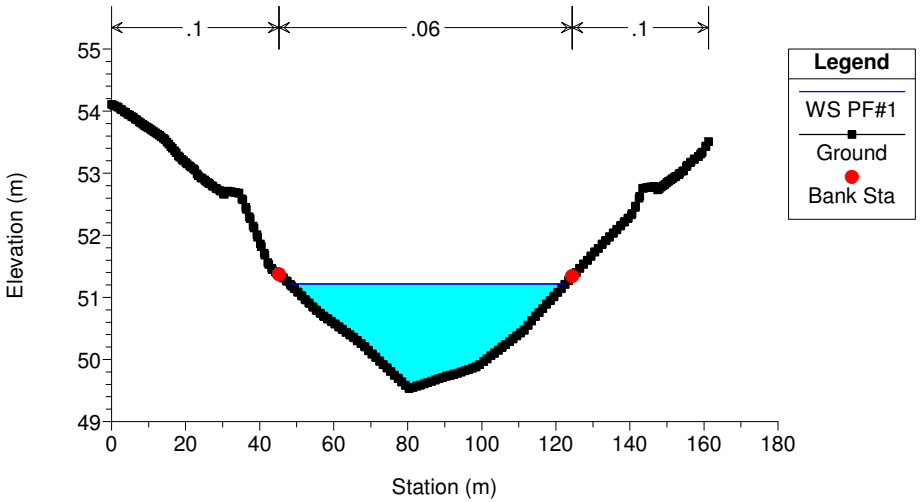
River = east Reach = 0 RS = 417.24



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

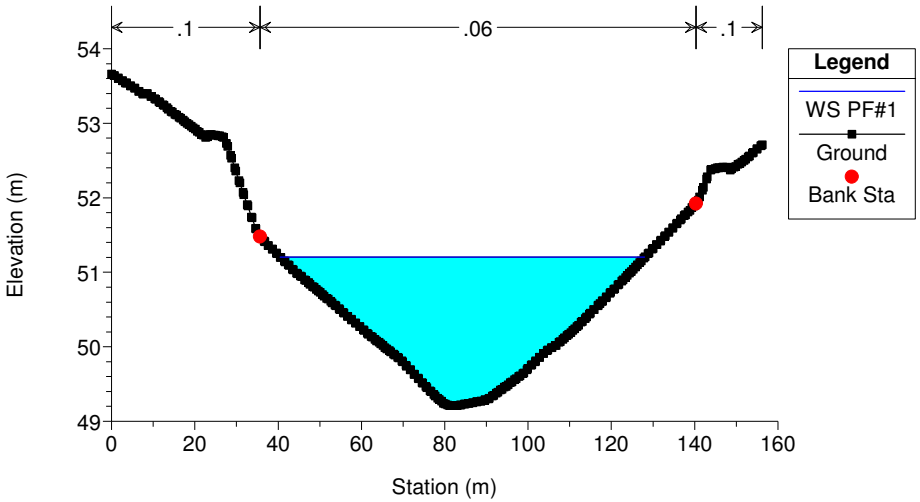
River = east Reach = 0 RS = 366.59



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

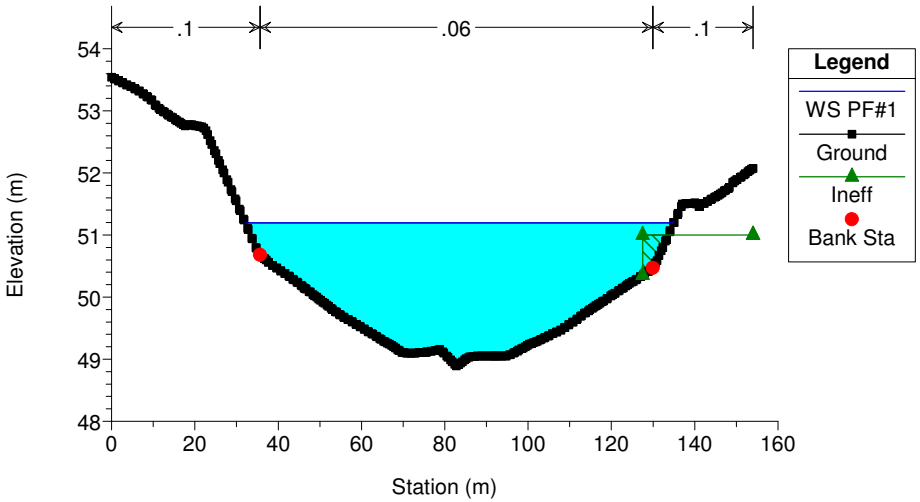
River = east Reach = 0 RS = 325.95



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

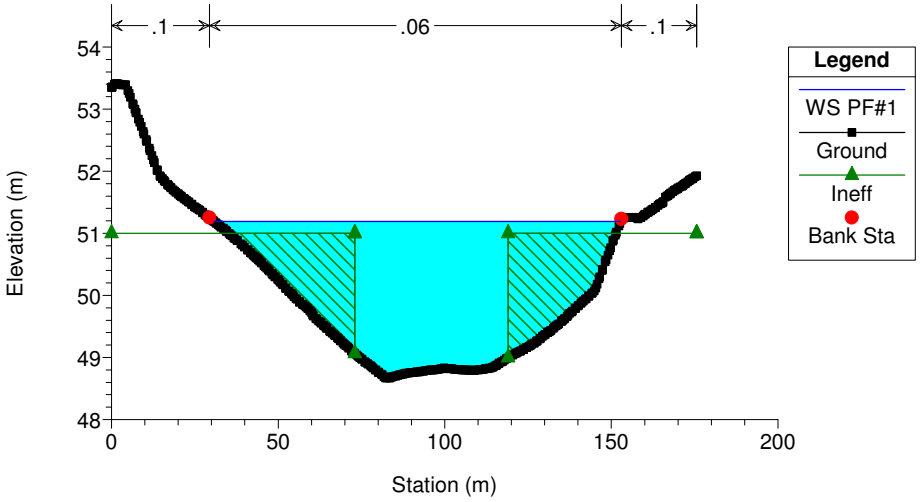
River = east Reach = 0 RS = 270.44



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

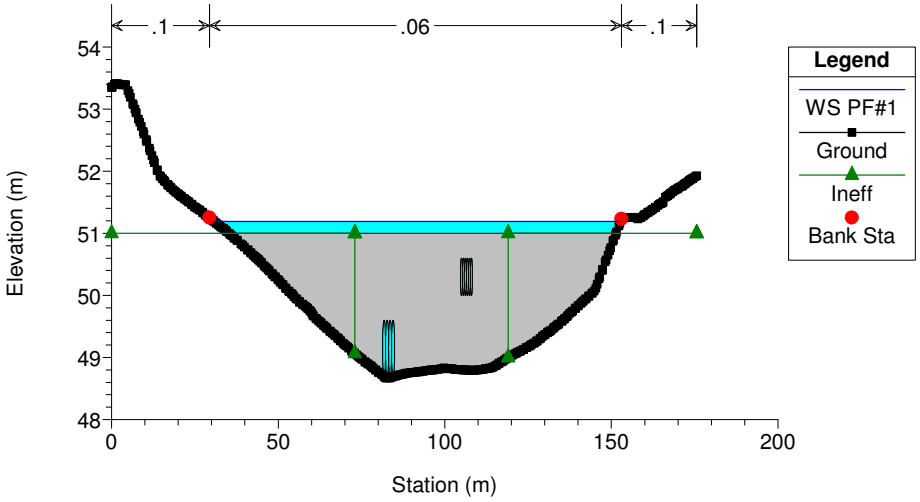
River = east Reach = 0 RS = 233.84



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

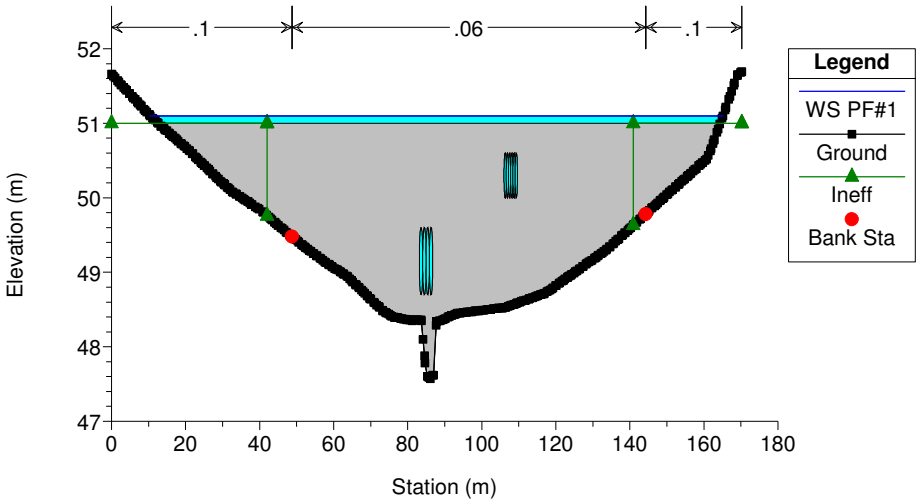
River = east Reach = 0 RS = 219.34 Culv



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

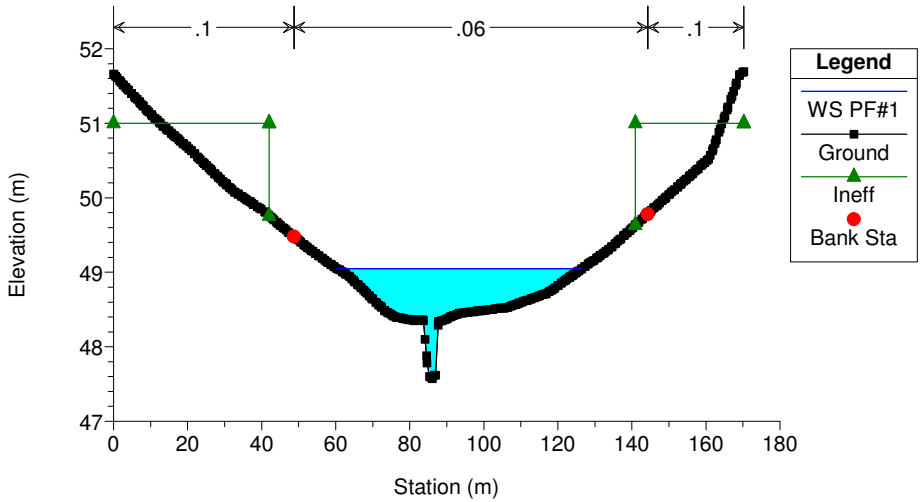
River = east Reach = 0 RS = 219.34 Culv



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

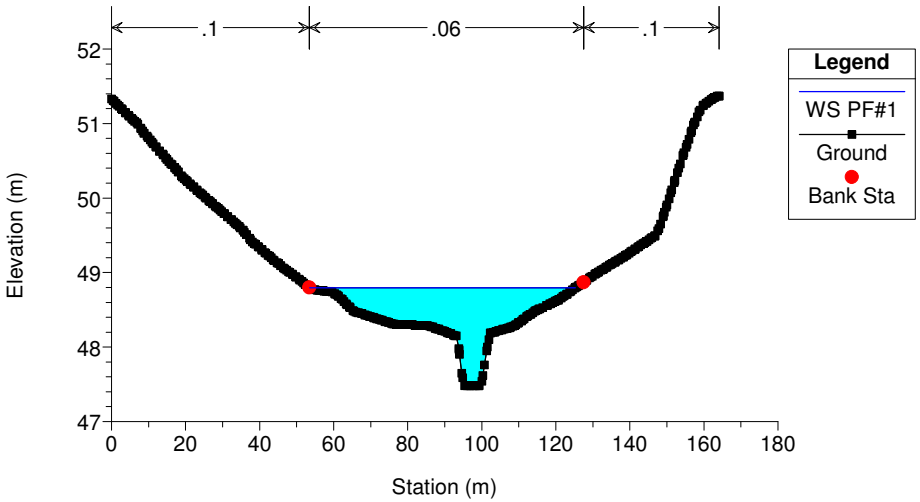
River = east Reach = 0 RS = 189.80



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

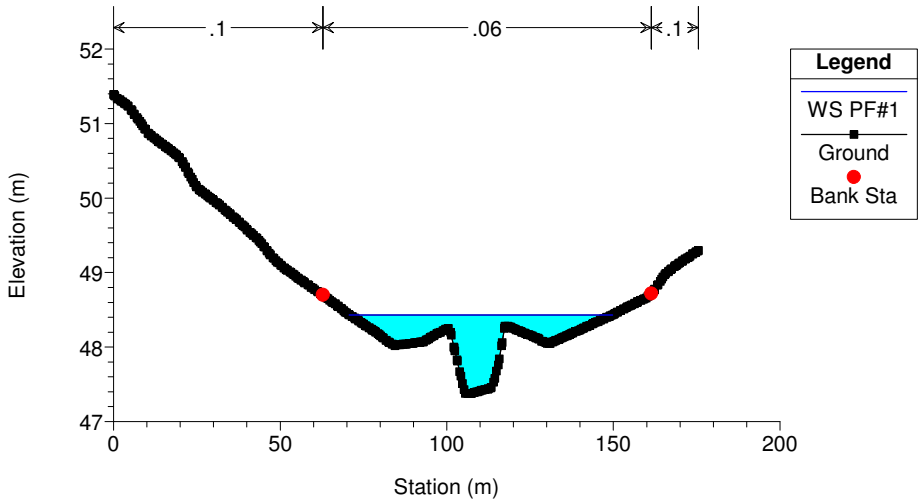
River = east Reach = 0 RS = 160.86



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

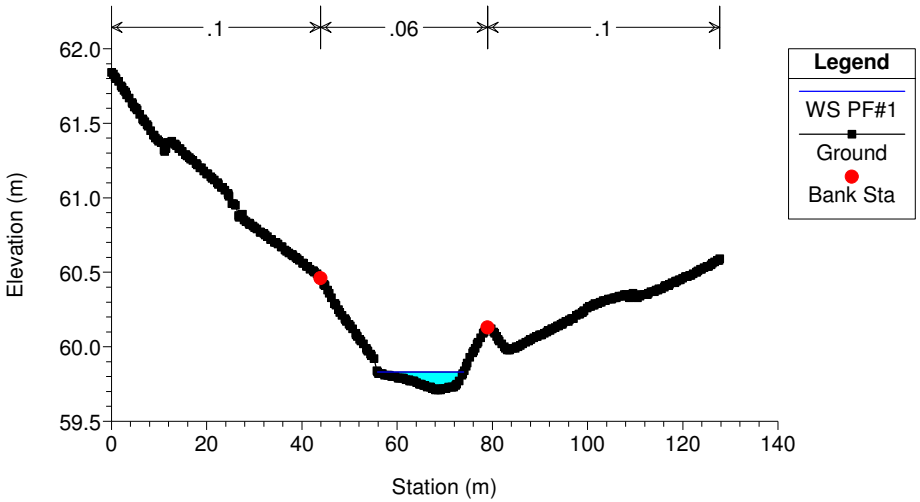
River = east Reach = 0 RS = 132.16



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Flow: Flow 01 - 1% AEP

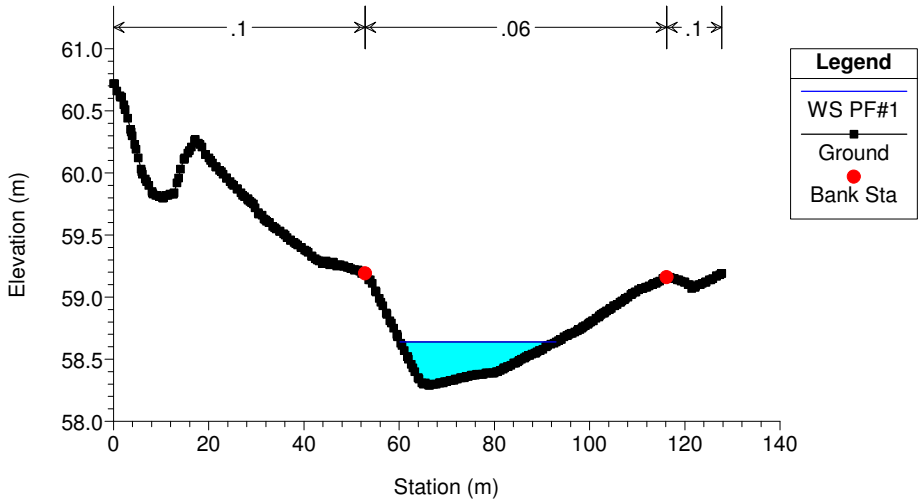
River = eaus Reach = 21 RS = 494.45



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

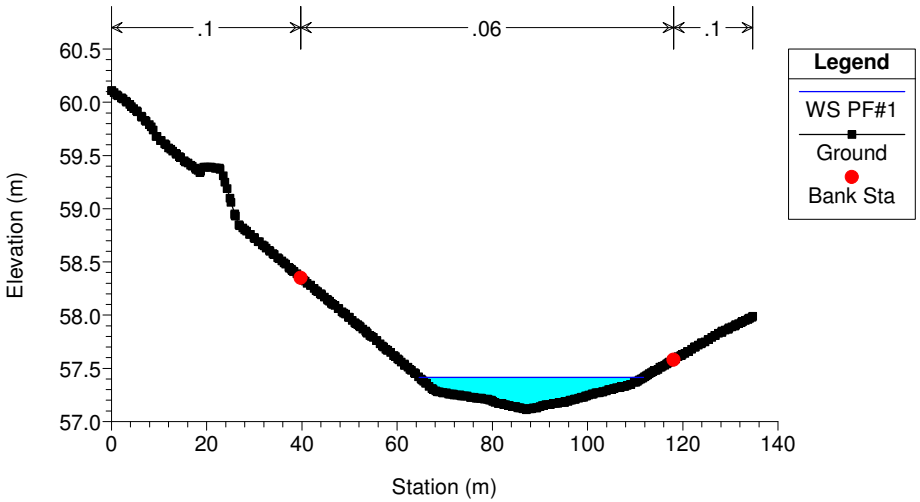
River = eaus Reach = 21 RS = 444.07



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Flow: Flow 01 - 1% AEP

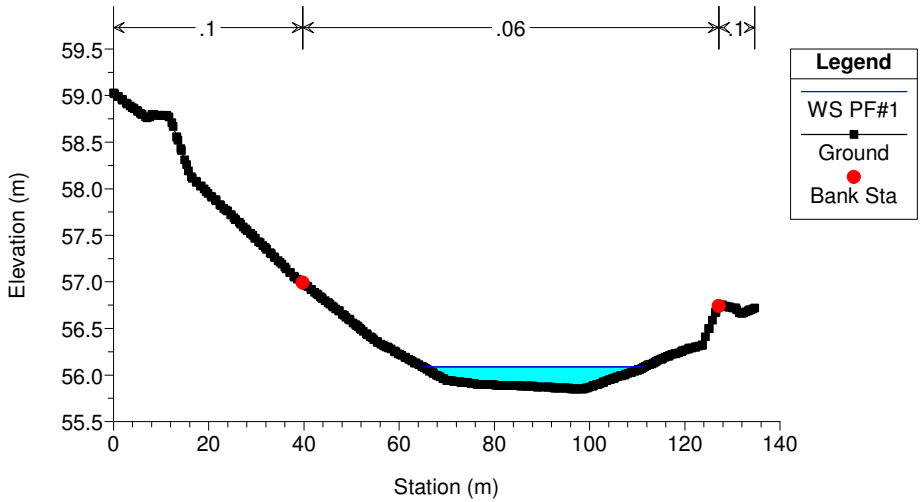
River = eaus Reach = 21 RS = 393.27



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Flow: Flow 01 - 1% AEP

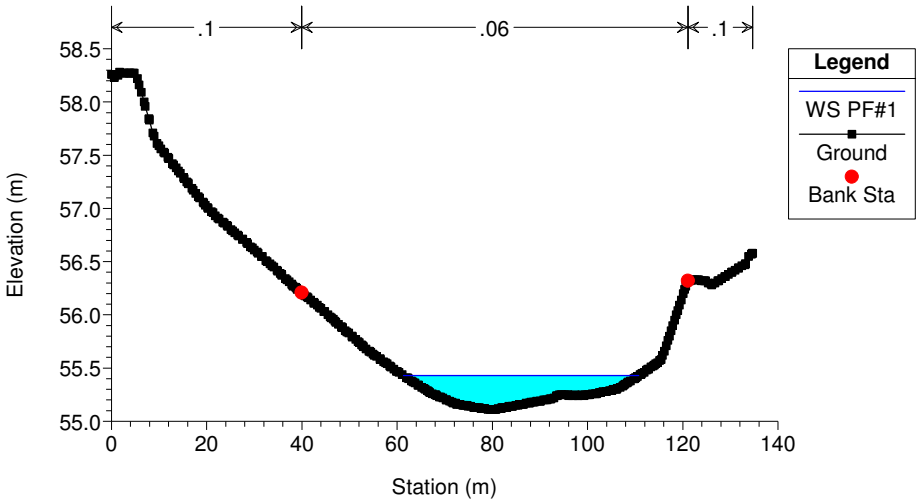
River = eaus Reach = 21 RS = 342.48



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

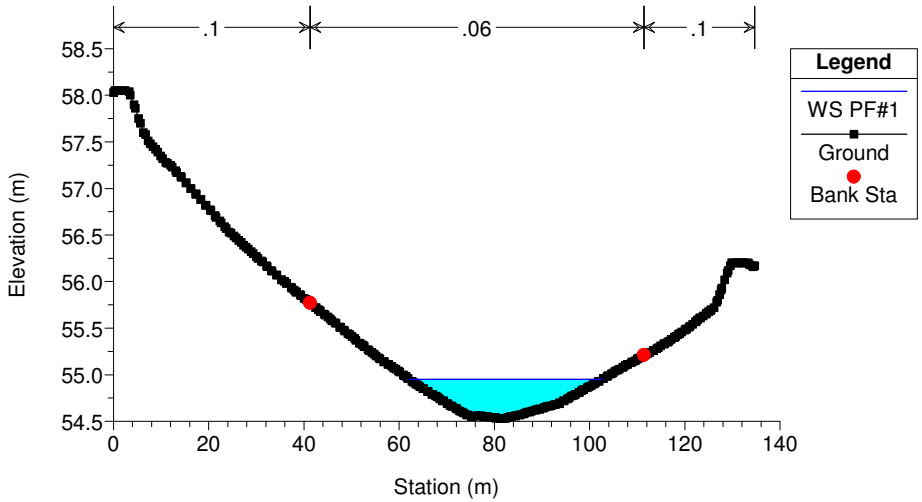
River = eaus Reach = 21 RS = 308.86



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Flow: Flow 01 - 1% AEP

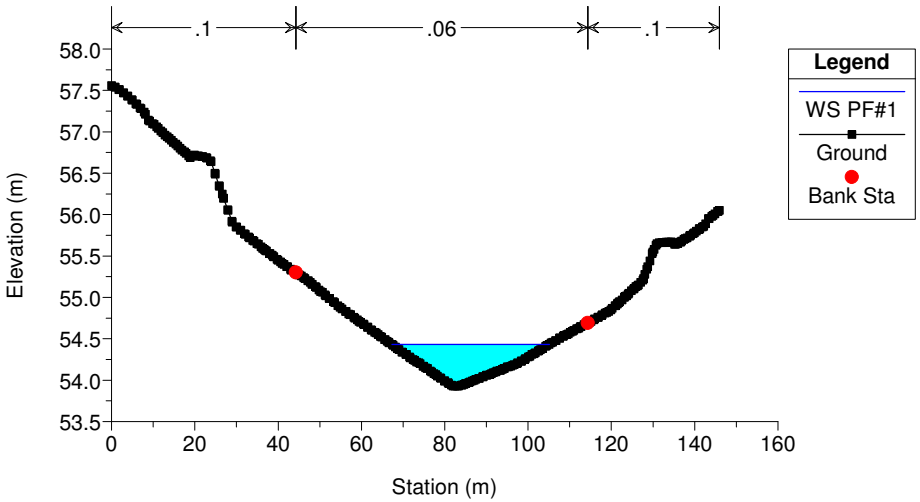
River = eaus Reach = 21 RS = 269.04



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Flow: Flow 01 - 1% AEP

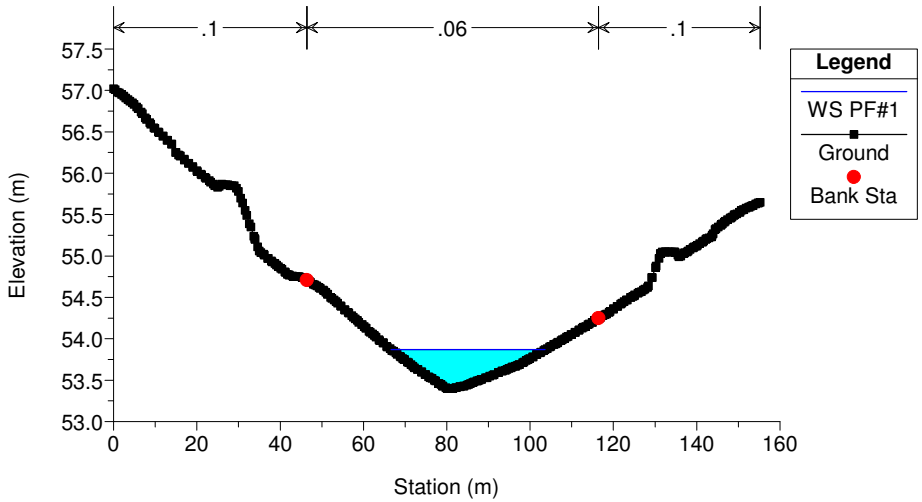
River = eaus Reach = 21 RS = 218.97



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Flow: Flow 01 - 1% AEP

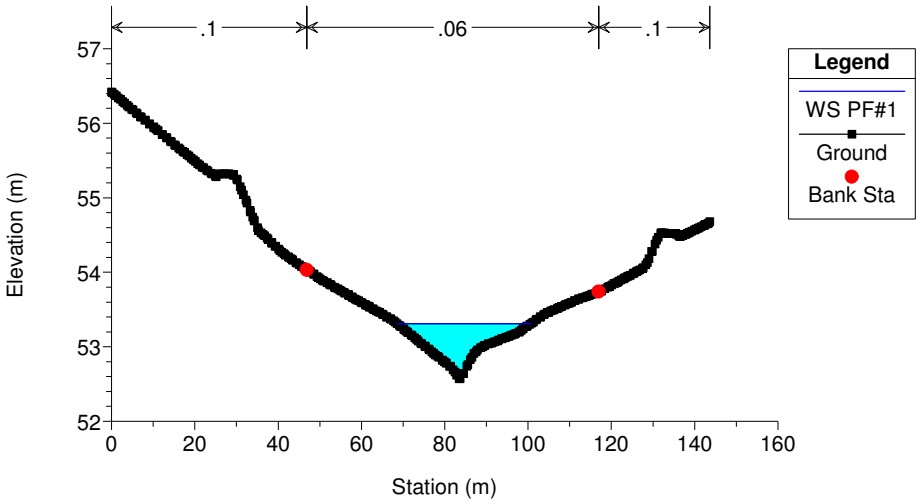
River = eaus Reach = 21 RS = 168.93



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

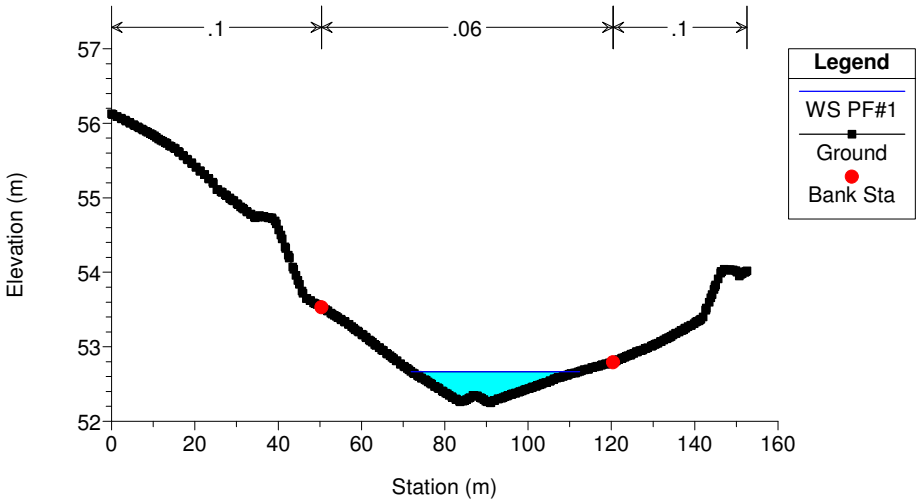
River = eaus Reach = 21 RS = 118.90



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

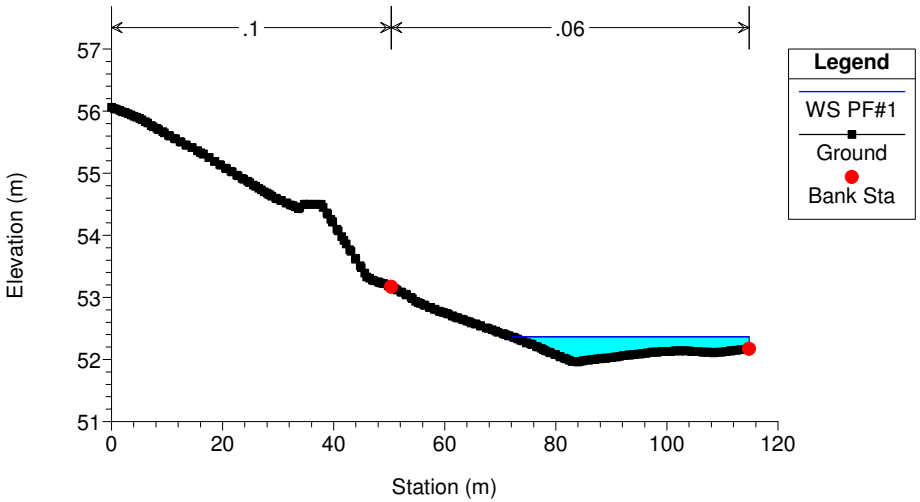
River = eaus Reach = 21 RS = 69.19



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

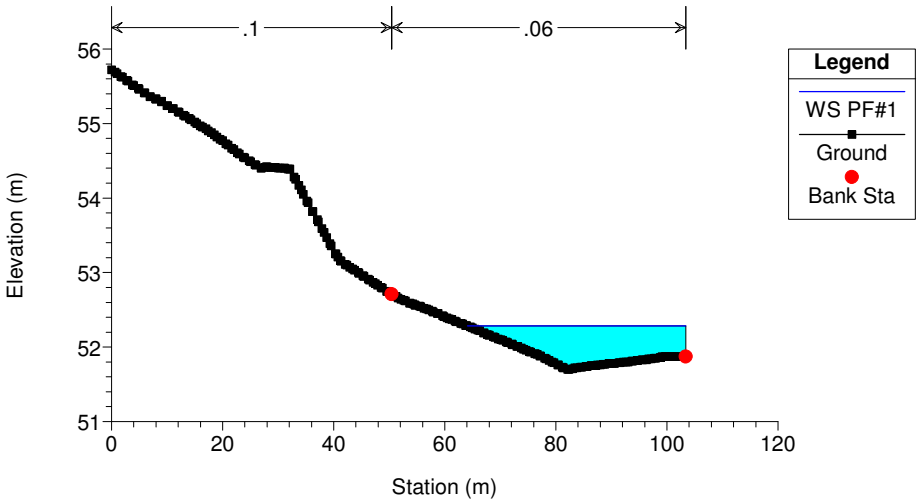
River = eaus Reach = 21 RS = 45.34



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

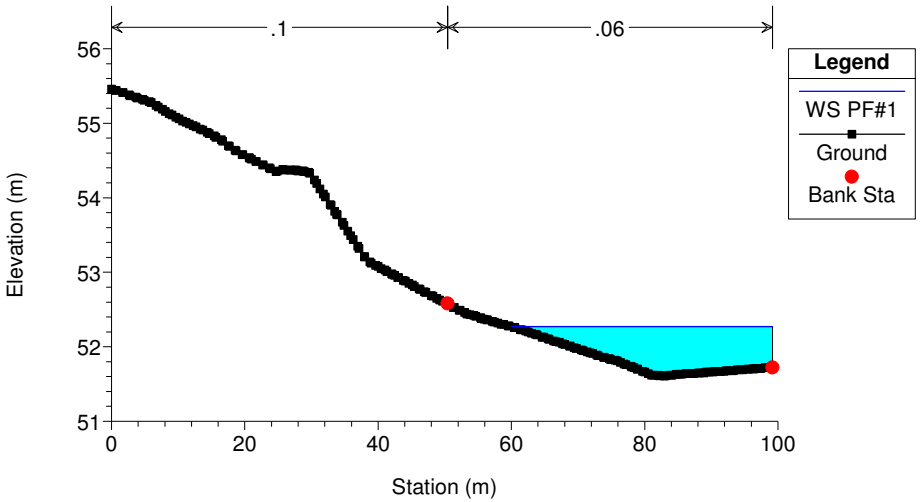
River = eaus Reach = 21 RS = 27.72



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

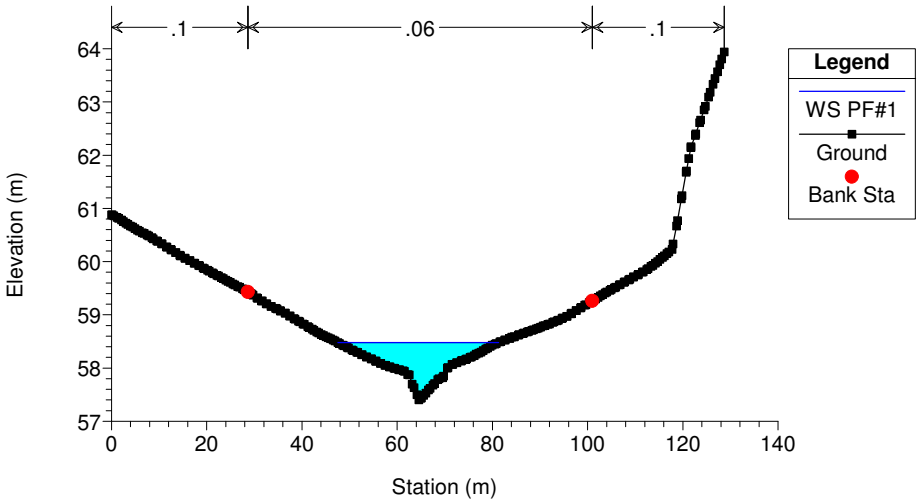
River = eaus Reach = 21 RS = 21.20



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

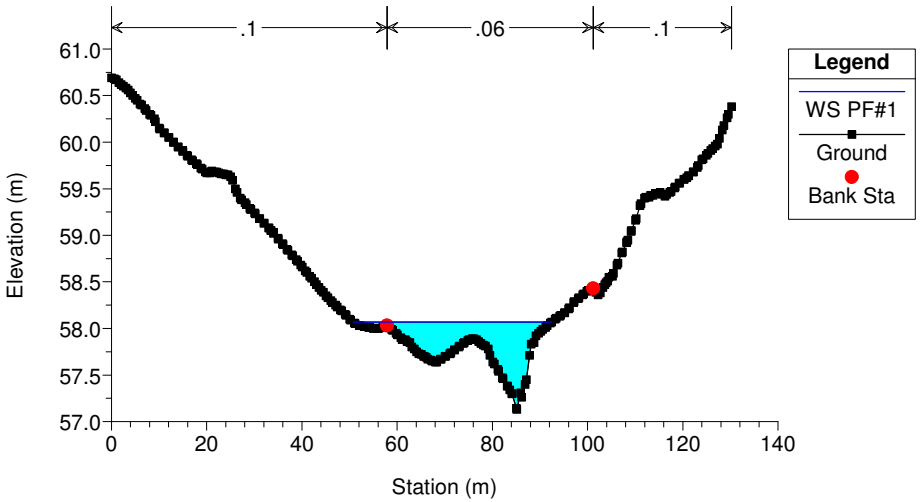
River = west Reach = 40 RS = 863.79



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

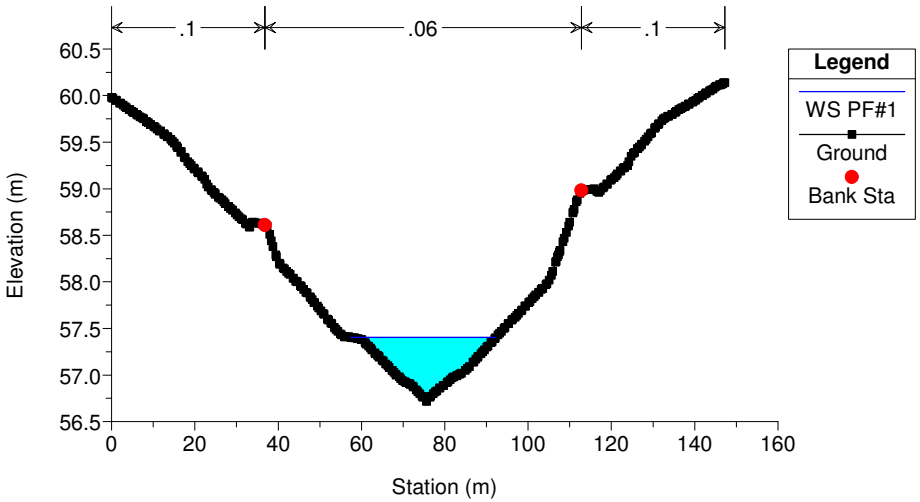
River = west Reach = 40 RS = 812.92



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

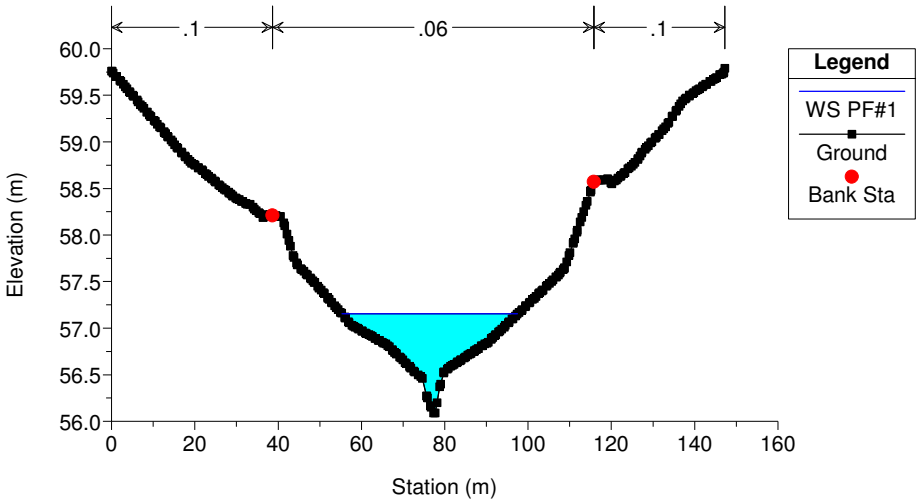
River = west Reach = 40 RS = 752.43



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

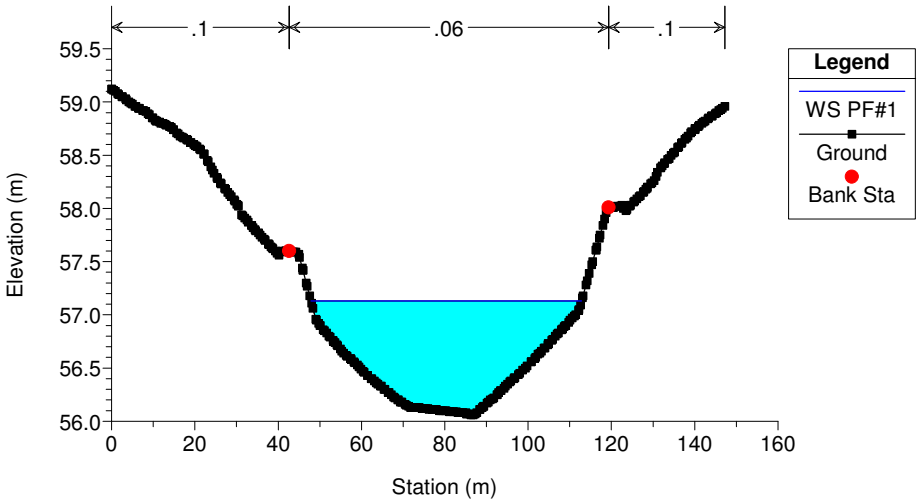
River = west Reach = 40 RS = 711.10



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

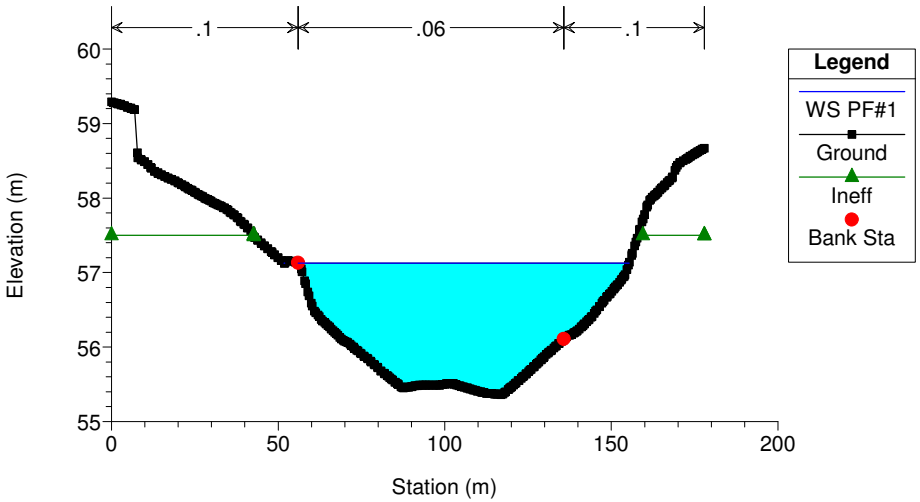
River = west Reach = 40 RS = 661.10



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

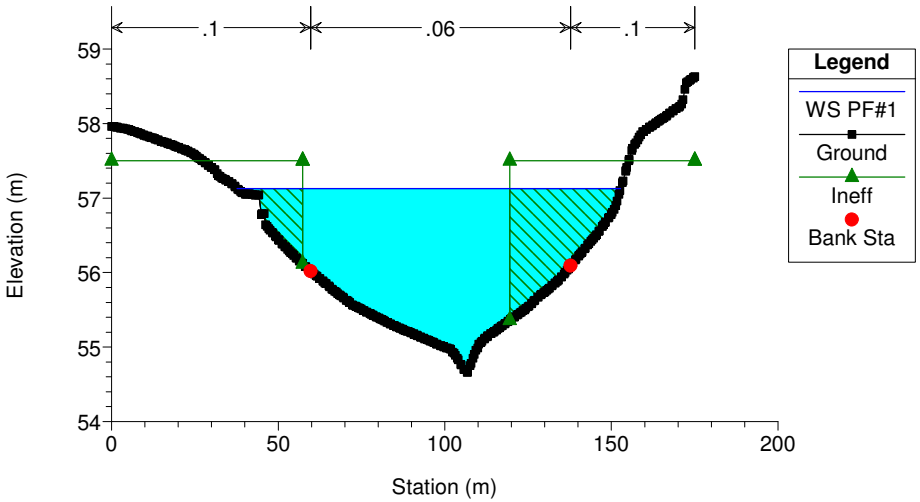
River = west Reach = 40 RS = 593.59



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

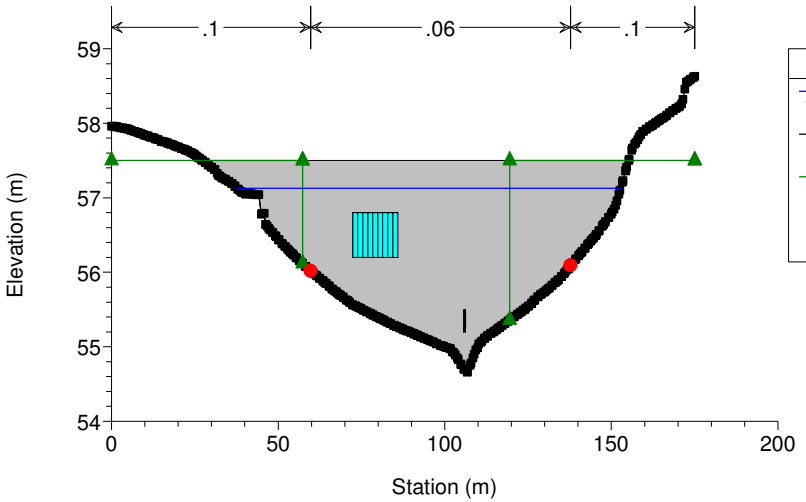
River = west Reach = 40 RS = 573.53



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

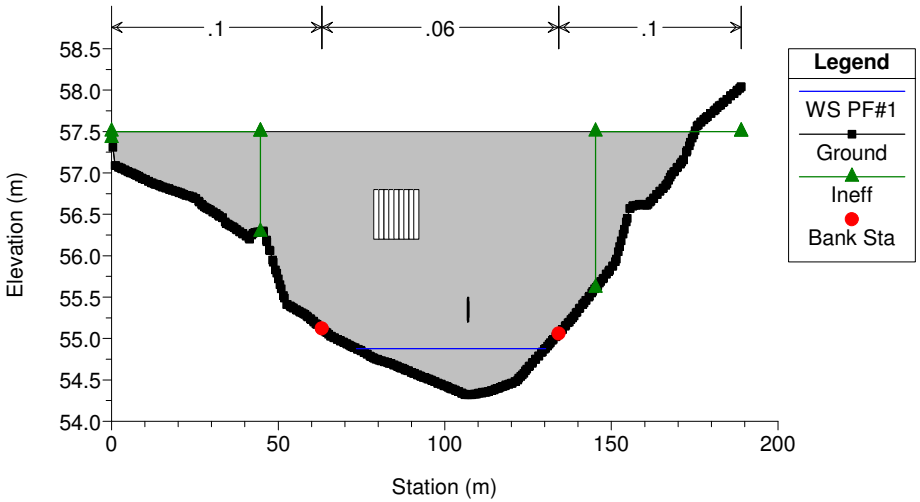
River = west Reach = 40 RS = 550.58 Culv



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

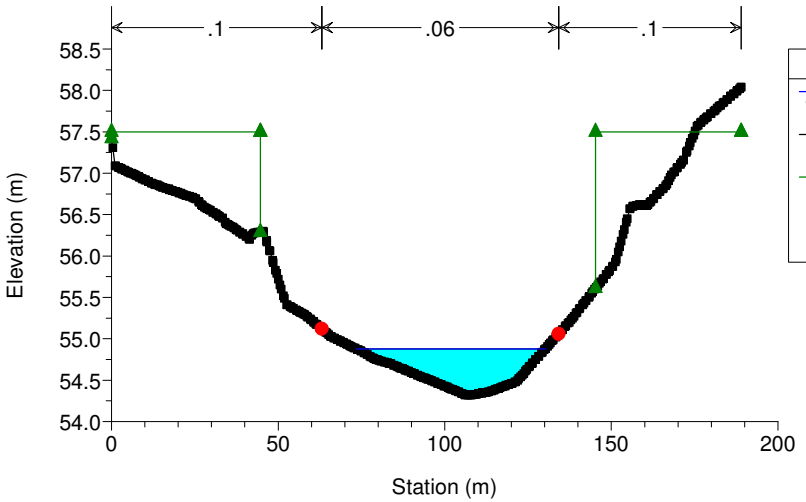
River = west Reach = 40 RS = 550.58 Culv



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

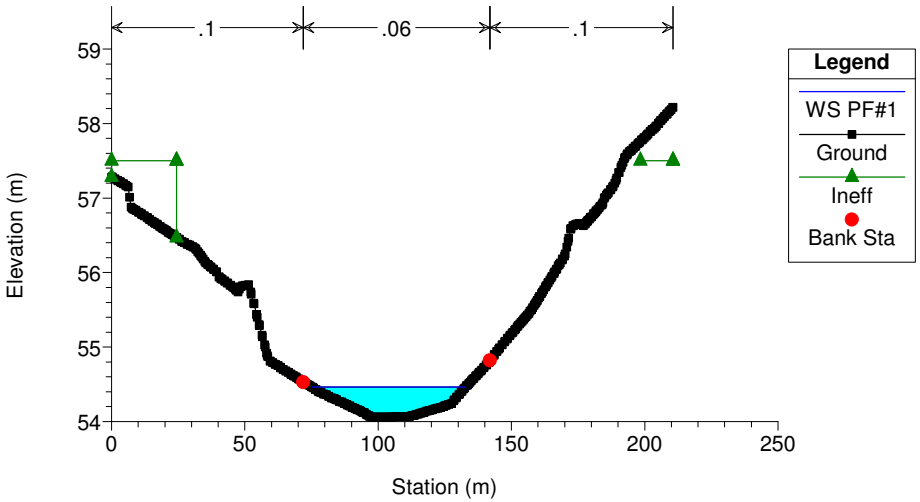
River = west Reach = 40 RS = 518.75



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

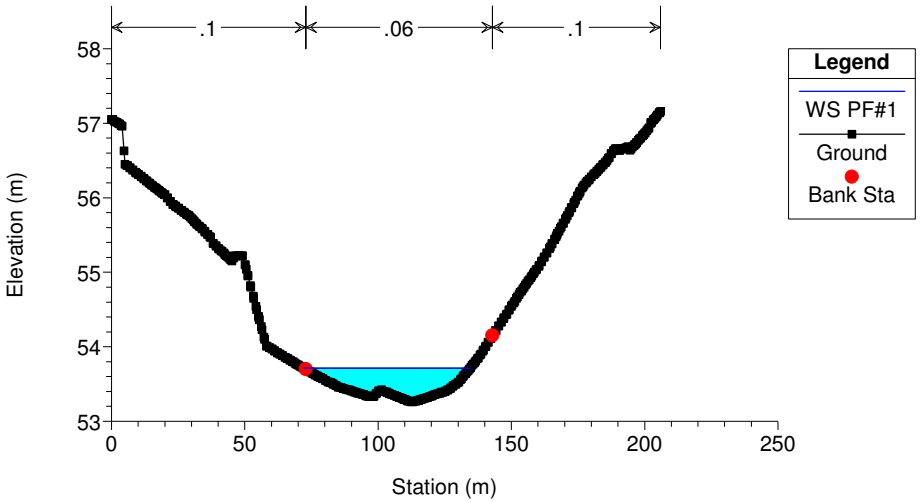
River = west Reach = 40 RS = 487.60



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

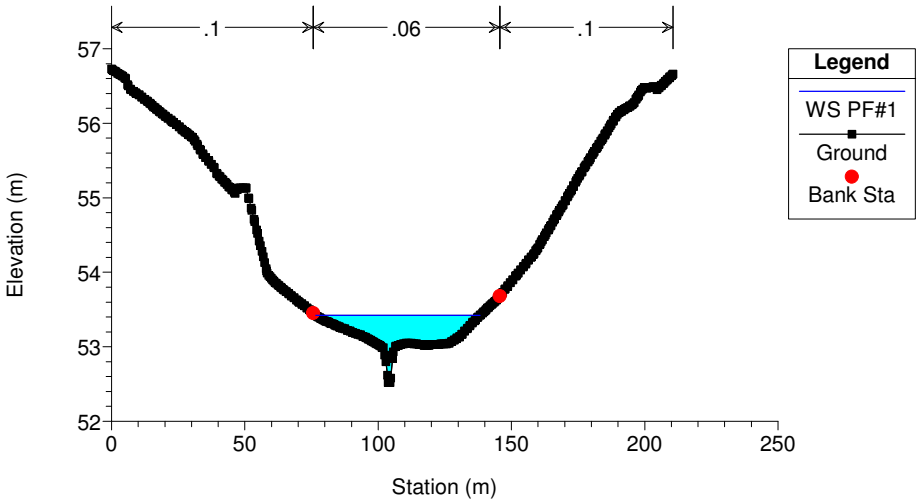
River = west Reach = 40 RS = 437.59



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

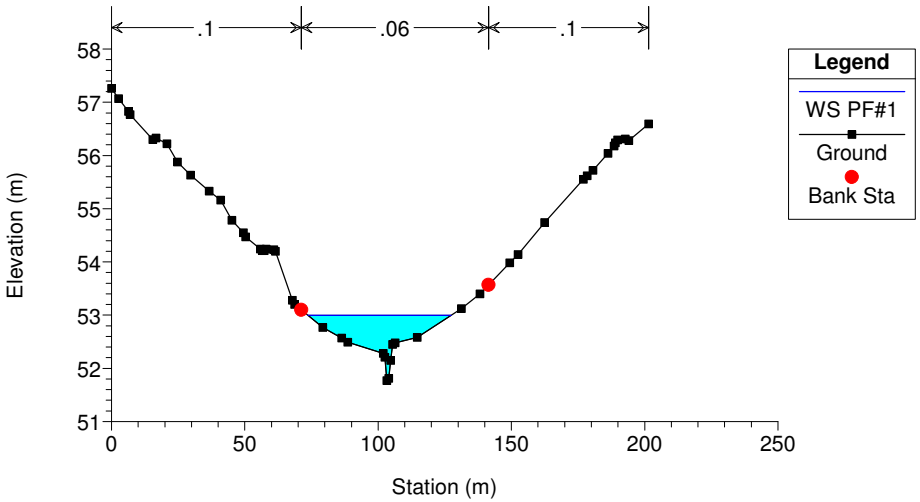
River = west Reach = 40 RS = 413.30



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

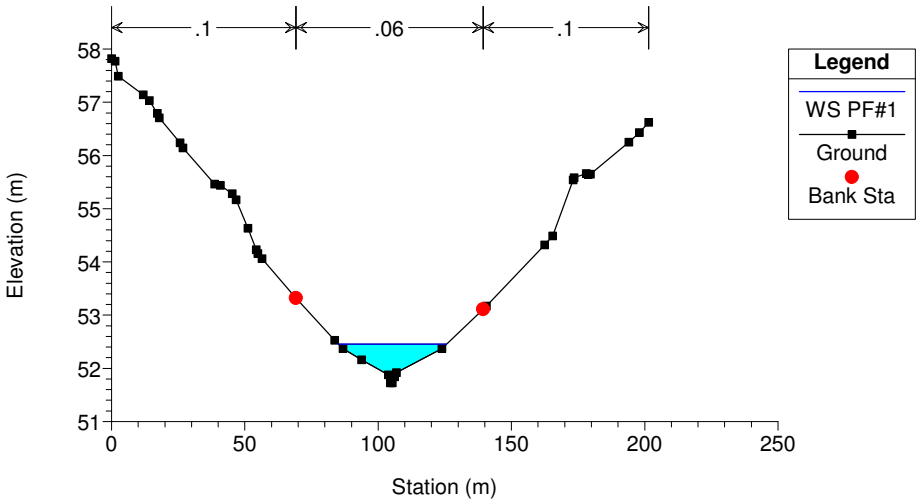
River = west Reach = 40 RS = 352.33



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

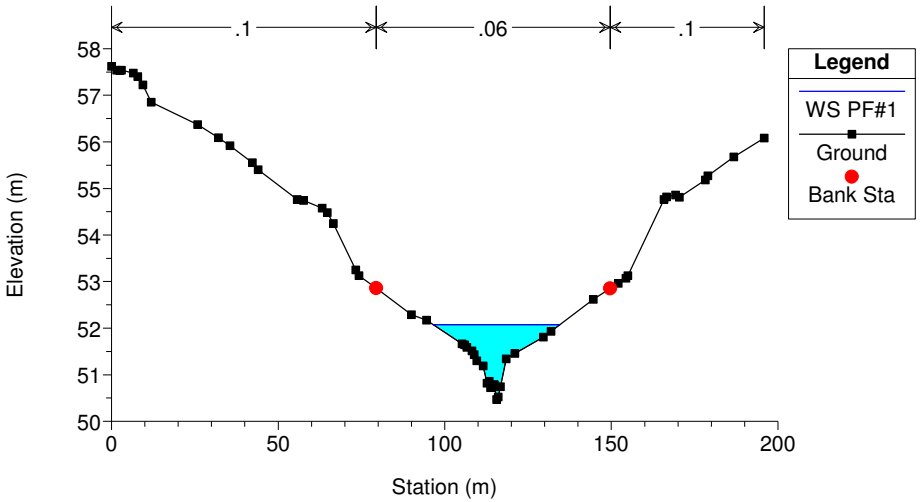
River = west Reach = 40 RS = 297.09



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

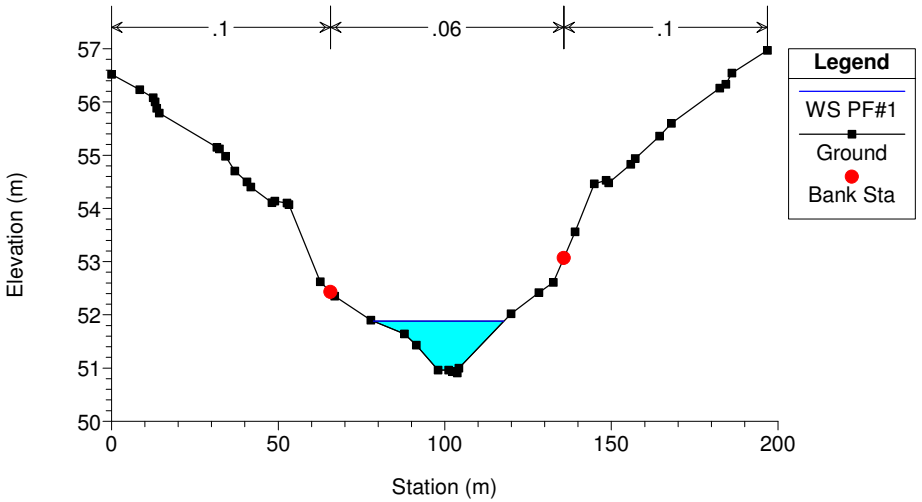
River = west Reach = 40 RS = 246.38



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

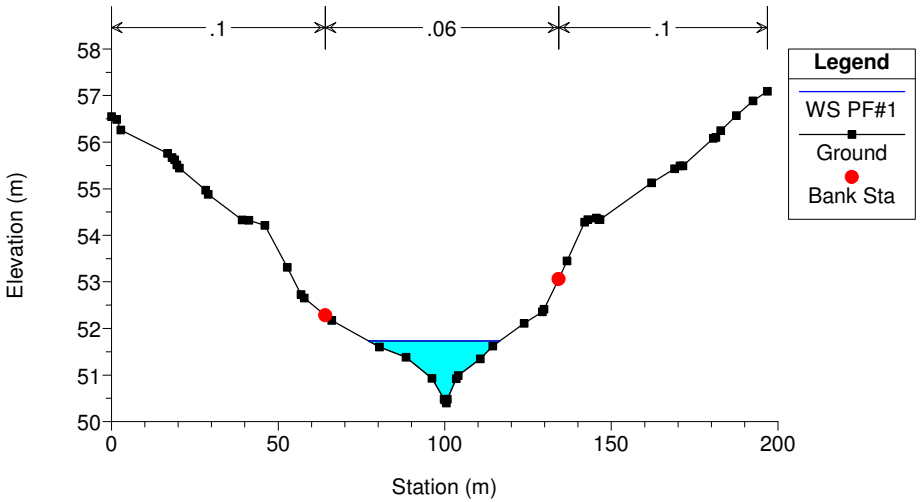
River = west Reach = 40 RS = 218.91



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

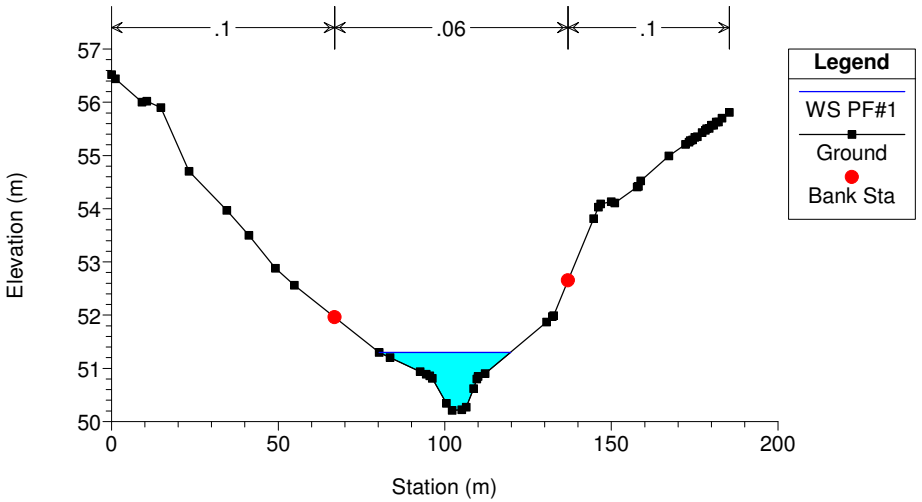
River = west Reach = 40 RS = 200.95



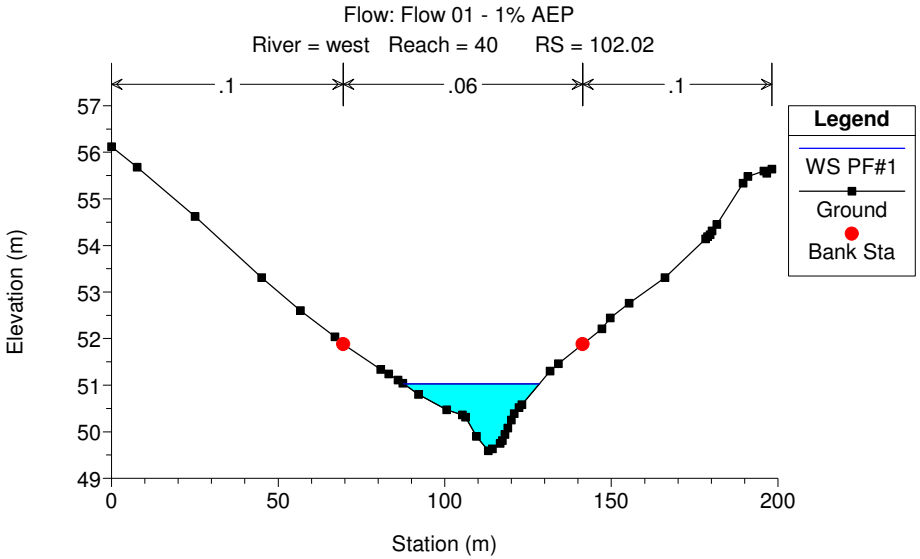
H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016

Flow: Flow 01 - 1% AEP

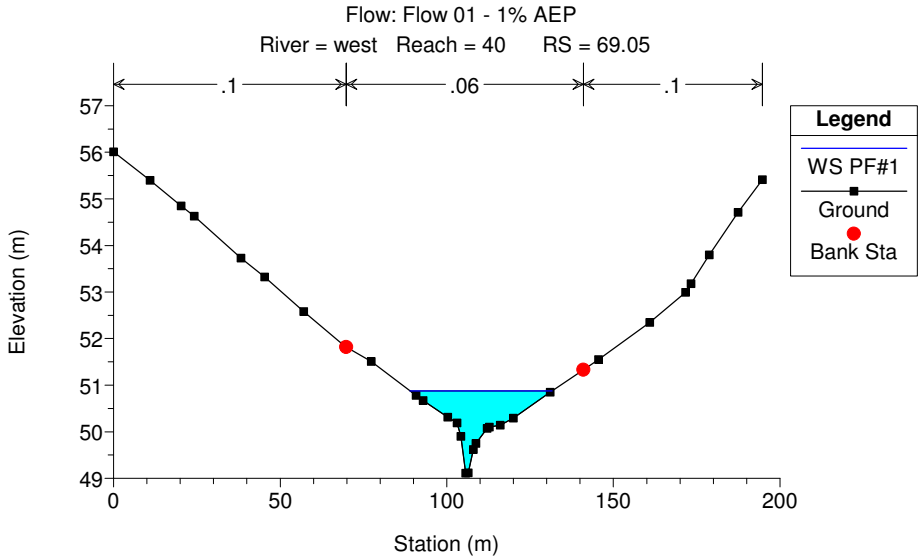
River = west Reach = 40 RS = 152.66



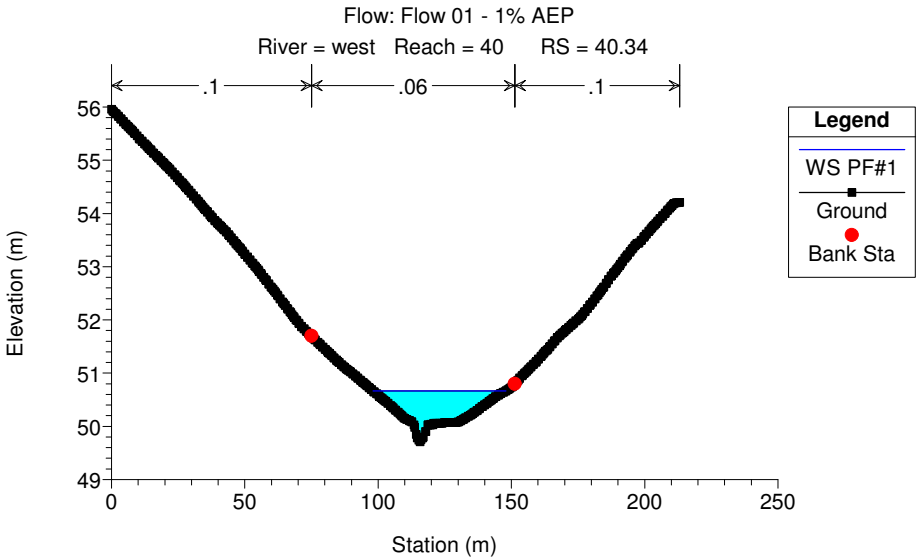
H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016



H:\16\002518 - Teviot Downs\6_Model\HEC-RAS\Developed\Dev_teviot161209 Plan: Plan 08 13/12/2016



HEC-RAS **Plan: Developed Mitigated 1% AEP**

River	Reach	River Sta	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)	
West	**0**	864	9.84	57.4	58.48	58.19	58.5	0.006016	0.71	13.83	33.75	0.35
West	**0**	813	9.84	57.13	58.07	57.9	58.1	0.010632	0.83	12.1	41.62	0.46
West	**0**	752	9.84	56.72	57.4	57.22	57.44	0.011333	0.85	11.57	34.84	0.47
West	**0**	711	9.84	56.09	57.15	56.84	57.17	0.004082	0.58	16.96	42.1	0.29
West	**0**	661	9.84	56.06	57.13	56.38	57.13	0.000271	0.22	45.46	64.95	0.08
West	**0**	594	9.84	55.36	57.13	55.65	57.13	0.000018	0.09	120.73	99.63	0.02
West	**0**	573	15.93	54.66	57.13	55.36	57.13	0.000034	0.14	111.71	115.07	0.03
West	**0**	550	Culvert									
West	**0**	528	14.68	54.32	54.88	54.7	54.91	0.009869	0.79	18.64	56.8	0.44
West	**0**	488	14.68	54.06	54.46	54.36	54.51	0.017518	0.93	15.78	57.58	0.57
West	**0**	438	14.68	53.26	53.71	53.59	53.75	0.013245	0.83	17.64	62.46	0.5
West	**0**	413	14.68	52.52	53.42	53.27	53.45	0.010966	0.79	18.67	61.6	0.46
West	**0**	352	14.68	51.77	53	52.71	53.02	0.004975	0.65	22.43	53.7	0.32
West	**0**	297	14.68	51.73	52.45	52.36	52.52	0.020717	1.13	13.04	40.51	0.63
West	**0**	246	14.68	50.47	52.08	51.62	52.1	0.004205	0.71	20.58	38.03	0.31
West	**0**	219	18.07	50.91	51.88	51.58	51.93	0.009209	0.97	18.57	39.08	0.45
West	**0**	201	18.07	50.4	51.73	51.41	51.77	0.007784	0.92	19.61	39.42	0.42
West	**0**	153	18.07	50.21	51.3	51.03	51.35	0.009912	0.99	18.24	39.47	0.46
West	**0**	102	20.34	49.59	51.03	50.52	51.06	0.003882	0.77	26.28	40.74	0.31
West	**0**	47	20.34	49.11	50.88	50.45	50.91	0.00503	0.82	24.8	42.56	0.34
East	**0**	0	20.34	49.71	50.67	50.44	50.71	0.010003	0.95	21.44	49.87	0.46
East	**21**	494	0	59.71	59.83	59.72	59.83	0	0	1.2	18.07	0
East	**21**	444	6.66	58.29	58.64	58.58	58.69	0.026355	0.96	6.93	32.73	0.67
East	**21**	393	6.66	57.11	57.41	57.36	57.45	0.022496	0.79	8.41	47.11	0.6
East	**21**	342	6.66	55.85	56.09	56.05	56.12	0.030396	0.87	7.64	46.46	0.69
East	**21**	309	6.66	55.11	55.43	55.34	55.45	0.013974	0.67	9.89	49.4	0.48
East	**21**	269	7.48	54.53	54.95	54.81	54.98	0.010538	0.7	10.65	40.47	0.44
East	**21**	219	7.48	53.93	54.43	54.28	54.46	0.01017	0.71	10.47	37.79	0.43
East	**21**	169	7.48	53.4	53.87	53.74	53.9	0.012337	0.76	9.79	36.95	0.47
East	**21**	119	7.48	52.57	53.31	53.14	53.34	0.010189	0.76	9.8	32	0.44
East	**21**	69	7.48	52.25	52.67	52.57	52.7	0.016601	0.81	9.29	40.4	0.54
East	**21**	45	7.48	51.96	52.37	52.25	52.39	0.010345	0.68	10.96	42.69	0.43
East	**21**	28	7.48	51.7	52.28	52	52.3	0.003004	0.49	15.4	39.31	0.25
East	**21**	21	7.48	51.61	52.27	51.9	52.28	0.001912	0.42	17.64	39.19	0.2
East	**630**	1154	5.47	57.46	57.76	57.68	57.79	0.014899	0.68	8.07	42.02	0.49
East	**630**	1104	8.8	56.75	57.2	57.06	57.23	0.00955	0.67	13.09	49.34	0.42
East	**630**	1054	8.8	55.84	56.14	56.14	56.23	0.062788	1.34	6.58	36.37	1
East	**630**	1004	8.8	55.08	55.74	55.35	55.75	0.000951	0.29	29.94	69.19	0.14
East	**630**	970	12.5	54.4	55.72	55.02	55.72	0.00047	0.28	44.55	65.06	0.11
East	**630**	933	12.5	54.42	55.71	54.74	55.72	0.000139	0.2	61.97	74.62	0.06
East	**630**	910	Culvert									
East	**630**	873	11.48	53.81	54.31	54.11	54.33	0.006808	0.69	16.54	50.74	0.37
East	**630**	850	11.48	53.54	54.11	53.94	54.14	0.010064	0.78	14.78	46.67	0.44
East	**630**	798	11.48	53.04	53.6	53.42	53.63	0.009511	0.78	14.79	44.82	0.43
East	**630**	748	11.58	52.61	53.19	52.97	53.22	0.007337	0.72	15.98	44.14	0.38
East	**630**	698	15.68	52.14	52.79	52.57	52.82	0.008215	0.78	20.04	53.75	0.41
East	**630**	657	15.68	50.99	51.96	51.96	52.11	0.05343	1.68	9.35	32.43	1
East	**630**	646	15.68	51.14	52.34	51.98	52.35	0.002494	0.5	31.23	66.25	0.23
East	**630**	637	15.68	51.68	52.31	51.99	52.33	0.002676	0.53	29.66	61.36	0.24
East	**630**	630	15.68	51.6	52.3	51.91	52.31	0.002179	0.51	30.54	56.41	0.22
East	**109**	593	23.16	51.05	52.24	51.62	52.25	0.001237	0.45	51.21	75.85	0.18
East	**109**	585	23.16	51.03	52.23	51.57	52.24	0.001107	0.44	52.65	74.64	0.17
East	**109**	536	23.16	50.61	52.2	51.29	52.2	0.000591	0.36	64.42	77.02	0.13
East	**109**	510	27.4	49.42	52.18	50.94	52.19	0.000388	0.42	64.88	79.75	0.11
East	**109**	479	Culvert									
East	**109**	438	26.03	49.22	51.29	50.39	51.3	0.001519	0.55	47.24	60.2	0.2
East	**109**	417	26.03	49.18	51.25	50.45	51.27	0.001247	0.51	51.32	63.95	0.18
East	**109**	367	28.31	49.53	51.21	50.21	51.22	0.000589	0.39	71.76	74.4	0.13
East	**109**	326	28.31	49.21	51.2	49.87	51.21	0.000269	0.29	96.82	87.5	0.09
East	**109**	270	28.31	48.89	51.2	49.49	51.2	0.000069	0.19	151.94	102.8	0.05
East	**109**	238	29.27	48.67	51.19	49.16	51.19	0.000199	0.24	123.54	122.05	0.08
East	**109**	215	Culvert									
East	**109**	191	29.17	47.57	49.05	48.78	49.09	0.007672	0.9	32.33	66.06	0.41
East	**109**	161	31.44	47.48	48.8	48.54	48.84	0.009319	0.96	32.91	71.72	0.45
East	**109**	109	31.44	47.38	48.43	48.3	48.49	0.016507	1.09	28.81	79.01	0.58
East	**81**	594	2.88	58.03	58.25	58.18	58.26	0.017226	0.59	4.91	35.26	0.5
East	**81**	544	3.44	56.69	56.87	56.85	56.91	0.043214	0.87	3.95	31.36	0.78
East	**81**	494	3.44	55.52	55.8	55.73	55.82	0.013027	0.56	6.1	37.78	0.45
East	**81**	444	3.44	54.3	54.55	54.55	54.61	0.057885	1.03	3.33	25.38	0.91
East	**81**	391	3.44	53.38	53.7	53.57	53.71	0.007771	0.52	6.56	30.72	0.36
East	**81**	338	5.69	52.46	52.76	52.72	52.81	0.034423	1.01	5.61	29.85	0.75
East	**81**	290	5.69	51.47	51.82	51.71	51.84	0.01293	0.69	8.28	37.9	0.47
East	**81**	239	5.69	50.4	50.85	50.8	50.89	0.029679	0.91	6.26	35.02	0.69
East	**81**	187	7.03	49.62	50.12	49.96	50.15	0.009135	0.71	9.87	33.01	0.42
East	**81**	131	7.03	48.97	49.39	49.3	49.43	0.019015	0.88	8.03	34.1	0.58

APPENDIX C : MUSIC SUMMARY

Table D1 - Mateorological and rainfall runoff data reporting table

INPUT	DATA USED IN MODELLING	Reference
Rainfall Station	Greenbank Thompson Rd	*Guideline by Water by Design*
Time Step	6 min	
Modelling Period	1/1/1980 - 31/12/1989	
Mean annual rainfall (mm)	745 mm	
Evapotranspiration (mm)	1448 mm	
Rainfall runoff parameters	*Table 3.7*	
Pollutant export parameters	*Table 3.9*	

Table D2a - Catchments

Name	Catchment Area (ha)	Modelled Area (Total)	Excluded Area *	Area (ha) 15dw	Area (ha) 25dw	Area Neighborhood (ha)	Regional Park (ha)	School (ha)	Spec Use (ha)	Overall Fi
A	16.33	16.327	0	7.048			9.279			37%
B	19.22	19.218	0	12.38			6.838			46%
C	13.53	13.528	0	11.754			1.774			55%
D	13.77	10.764	3.005	10.264			0.5			45%
E	98.69	98.685	0	64.925	3.924	1.318	27.5		1.018	50%
F	31.04	31.039	0	29.71			1.329			58%
G	4.33	4.331	0	2.813			1.518			46%
H	13.70	13.695	0	13.695						60%
I	4.52	4.521	0	4.521						60%
J	1.44	1.439	0	1.439						60%
K	3.77	3.774	0	3.774						60%
L	5.56	5.563	0	5.563						60%
M	17.20	17.195	**0**	5.766	8.092	3.337				71%
N	17.38	17.381	0	1.504	7.51	8.367				79%
O	10.60	10.597	**0**	3.727				6.87		66%
P	17.67	17.671	0	17.671						60%
Q	45.43	45.427	0	36.049			9.378			52%
R	26.26	26.259	0	15.14			11.119			43%
S	18.82	18.818	0	17.85			0.968			58%
T	8.38	8.378	0	6.28			2.098			50%
U	114.32	114.316	0	99.369	1.198	2.06	11.689			57%
V	8.76	8.763	0	8.763						60%
	510.69	**507.689**	**3.005**	**380.005**	**20.724**	**15.082**	**83.99**	**6.87**	**1.018**	

Table D2b - Land use and impervious %

Land use and impervious % *Table 3.6 Guideline by Water by Design*

No.	Category	Type	Imperv.
1	15 dwelling/ha	Residential	60%
2	25 dwelling/ha	Residential	70%
3	Park/Open Space/ Sports	Residential	20%
4	Neighborhood Centre	Commercial	90%
5	School	Commercial	70%
6	Special Use	Commercial	90%

Table D3a - Rainfall Runoff Parameter

PARAMETER	Residential	Commercial	Reference
Rainfall threshold (mm)	1	1	*Table 3.7 Guideline by Water by Design*
Soil Storage capacity (mm)	500	18	
Initial Storge (% capacity)	10	10	
Field Capacity (mm)	200	80	
Infiltration Capacity exponent a	211	243	
Infiltration Capacity exponent b	5	0.6	
Initial Depth (mm)	50	50	
Daily recharge rate (%)	28	0	
Daily baseflow rate (%)	27	31	
Daily deep seepage rate (%)	0	0	

Table D3b - Pollutant export parmeter reporting table

Ref : *Table 3.9 Guideline by Water by Design*

LUMPED CATCHMENT LAND USE							
LAND USE	FLOW TYPE	TSS Log^{10} values		TP Log^{10} values		TN Log^{10} values	
		Mean	St. dev.	Mean	St. dev.	Mean	St. dev.
Residential	Base Flow	1	0.34	`-0.97	0.31	0.2	0.2
	Stormflow	2.18	0.39	`-0.47	0.32	0.26	0.23
Commercial	Base Flow	0.78	0.39	`-0.60	0.5	0.32	0.3
	Stormflow	2.16	0.38	`-0.39	0.34	0.37	0.34

Table 4 -Wetland Node

Reference : Table 3.9 Guideline by Water by Design

INPUT	DATA USED IN MODELLING	Comment
Inlet Pond Volume (m^3)	295	*assume 2.5% of surface area*
Surface area (m^2)	11800	*Estimated*
Extended Detention Depth(m)	0.5	
Permanent Pool Volume (m^3)	9575	*From prelim 12D model*
Exfiltration Rate (mm/hr)	0	
Evaporative Loss as % of PET	125	
Equivalent Pipe Diameter (mm)	144	
Overflow Weir Width (m)	1180	*10% of Surface Area*
Notional Detention Time (hrs)	48	*close to 48 hours*
Number of CSTR cells	4	*Default value*
K and C* values	Default	*Default value*

Table 5a - Bioretention systems

Reference : Guideline by Water by Design

INPUT	DATA USED IN MODELLING	Comment
Surface area (m^2)	Refer table 7b	
Extended Detention Depth(m)	0.3	
Filter area (m^2)	*Assumed same as surface area*	
Unlined Filter Media Perimeters (m)	0.01	
Saturated Hydraulic Conductivity (mm/hr)	200	
Filter Depth (m)	0.5	
TN content of filter media (mg/kg)	400	
Orthophosphate Content of Filter Media (mg/kg)	30	
Number of CSTR cells	2	*Default value*
Is base lined ?	no	
Effectiveness of plant TN removal	effective	
Overflow Weir Width (m)	10% of surface area	
Exfiltration Rate (mm/hr)	0	
Underdrain present ?	yes	
Submerged zonde with carbon present ?	no	
K and C* values	Default	*Default value*

Table D6a - Rainwater Tank Estimation

INPUT	Catchment M Commercial	Catchment M Residential (25dw/ha)	Catchment N Commercial	Catchment N Residential (25dw/ha)	Catchment O School
Total Area (ha)	3.337	8.092	8.367	7.51	6.87
Roof Percentage (%)	50%	33.5%	50%	33.5%	50%
Roof Area (ha)	1.67	2.71	4.18	2.52	3.44
Roof Area connected to Rainwater Tank (ha)	0.83	1.36	2.09	1.26	1.72
Total Rainwater Tank Rate	1.5kL per 50m²	3kL per dwelling	1.5kL per 50m²	3kL per dwelling	1.5kL per 50m²
Total Rainwater Tank Volume (kL)	250	607	628	563	515
Adopted Rainwater Tank Volume (kL)	200	600	600	500	500

Parameters of 3kL tank adopted from *http://www.tanksrus.com.au/store/index.php?route=product/product&product_id=53*
Parameters of 5kL tank adopted from *http://www.tanksrus.com.au/store/index.php?route=product/product&product_id=59*
Parameters of 50kL tank adopted from *http://www.rainwatertanksdirect.com.au/water-tanks/large-tanks.php*

Table D6b - Re-Use Estimation Commercial & School

INPUT	Catchment M Commercial	Catchment N Commercial	Catchment O School
Average Total Water Demand (kL/day)	13.44	35.76	6.87
Percentage of Toilet Flushing Demand	25%	25%	25%
Toilet Flushing Demand (kL/day)	3.36	8.94	1.72
Irrigaton Area (ha)			0.21
Annual Irrigation Value (mm)			548
Annual Irrigation Demand (kL/year)			791

NOTE: A minimum 0.2061ha of school landscape (pervious) area needs to be irrigated in order to meet the flow frequency requirement so that the Developed Scenario average annual runoff volume does not exceed the Existing. Refer to Section 8 for the average annual flow volume calculation.

Table D6c - Re-Use Estimation Residential

INPUT	Catchment M Commercial	Catchment N Commercial
EP per Dwelling	1.6	1.6
Area (ha)	8.092	7.51
No. of Dwellings (25 dwellings/ha)	202	188
Total EP	324	300
Re-Use Rate (kL/EP/day)	0.021	0.021
Toilet Flushing Demand (kL/day)	6.80	6.31

Table D6d - Rainwater Tanks

INPUT	DATA USED IN MODELLING				
	Catchment M Commercial	Catchment M Residential (25dw/ha)	Catchment N Commercial	Catchment N Residential (25dw/ha)	Catchment O School
Number of Tanks	40 x 5kL	200 x 3kL	120 x 5kL	166 x 3kL	10 x 50kL
Total Volume below Overflow Pipe (kL)	200	600	600	498	500
Depth above Overflow (m)	0.18	0.14	0.18	0.14	0.39
Total Surface Area (m^2)	132	380	396	315.4	152
Initial Volume (kL)	200	600	600	498	500
Total Overflow Pipe (mm)	569	1,273	986	1,160	285
Annual Irrigation Demand (kL/year)	0	0	0	0	791
Daily Demand (kL/day)	3.51	6.8	8.79	6.31	6.075

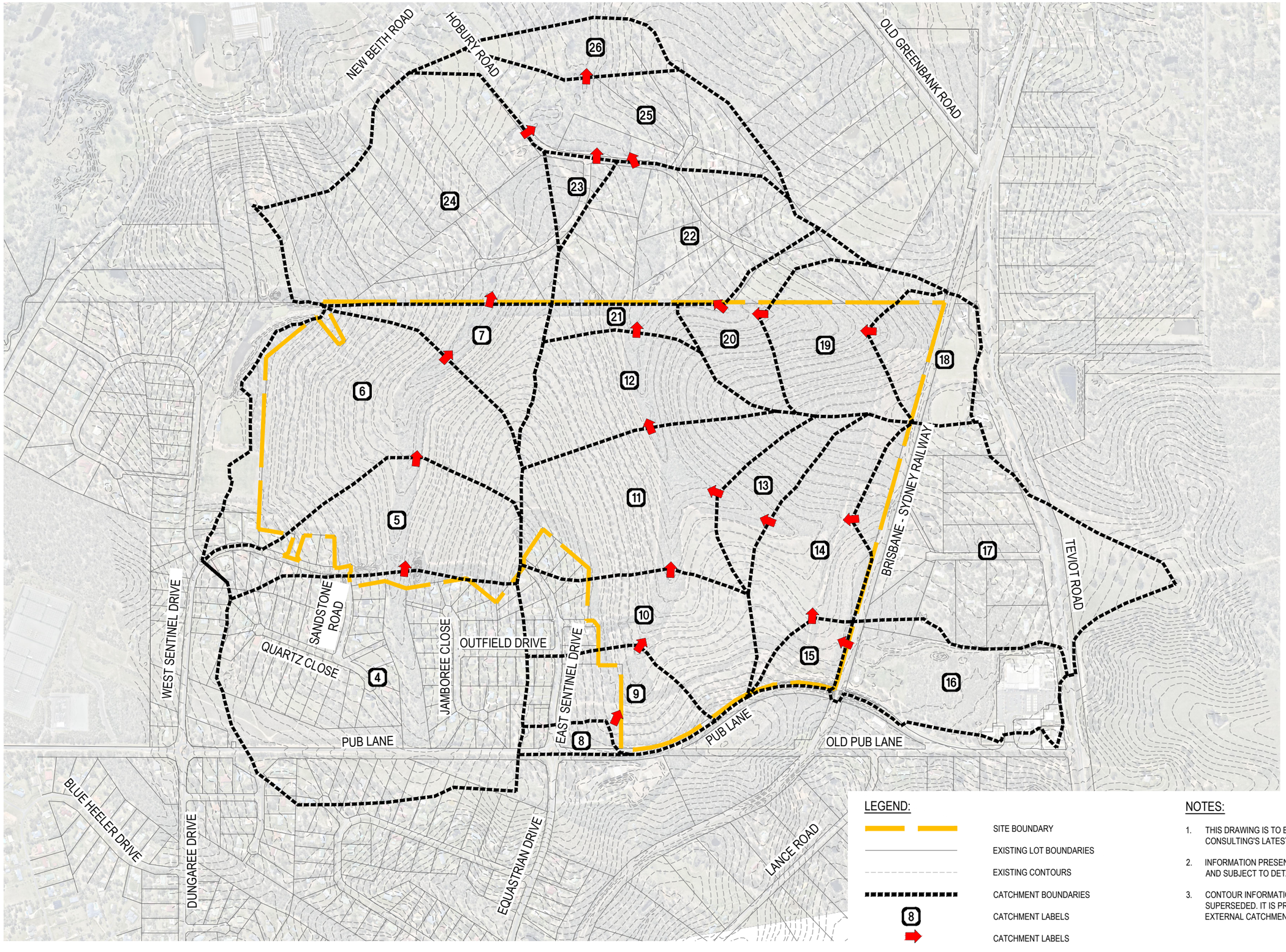
Table D7 - Stormwater quality modelling results

Overall Site with 1.18ha wetland & 5000m^2 Bioretention at Catchment U

POLLUTANT	INFLOWS (KG/YR)	OUTFLOWS (KG/YR)	REDUCTION ACHIEVED (%)	OBJECTIVE (%)	TARGET MET
Total Suspended Solids (kg/yr)	446,000	86,400	81	80	Yes
Total Phosphorus (kg/yr)	903	248	73	60	Yes
Total Nitrogen (kg/yr)	4,530	2,360	48	45	Yes
Gross Pollutants (kg/yr)	62,300	-	100	90	Yes

APPENDIX D : CONCEPT DRAWINGS

- 16-002518-SK10 – Concept Stormwater Management Strategy Existing Catchment Plan
- 16-002518-SK11 – Concept Stormwater Management Strategy Developed Catchment Plan
- 16-002518-SK12 – Concept Stormwater Management Strategy HEC-RAS General Arrangement
- 16-002518-SK13 – Concept Stormwater Quality Management Strategy



CATCHMENT	AREA (ha)
4	46.88
5	18.39
6	31.19
7	8.51
8	2.10
9	9.90
10	16.18
11	22.91
12	14.43
13	6.18
14	14.43
15	3.35
16	14.87
17	32.95
18	8.48
19	12.98
20	8.03
21	3.18
22	20.20
23	2.58
24	36.32
25	16.48
26	6.20

LEGEND:

- SITE BOUNDARY
- EXISTING LOT BOUNDARIES
- EXISTING CONTOURS
- CATCHMENT BOUNDARIES
- 8 CATCHMENT LABELS
- CATCHMENT LABELS

NOTES:

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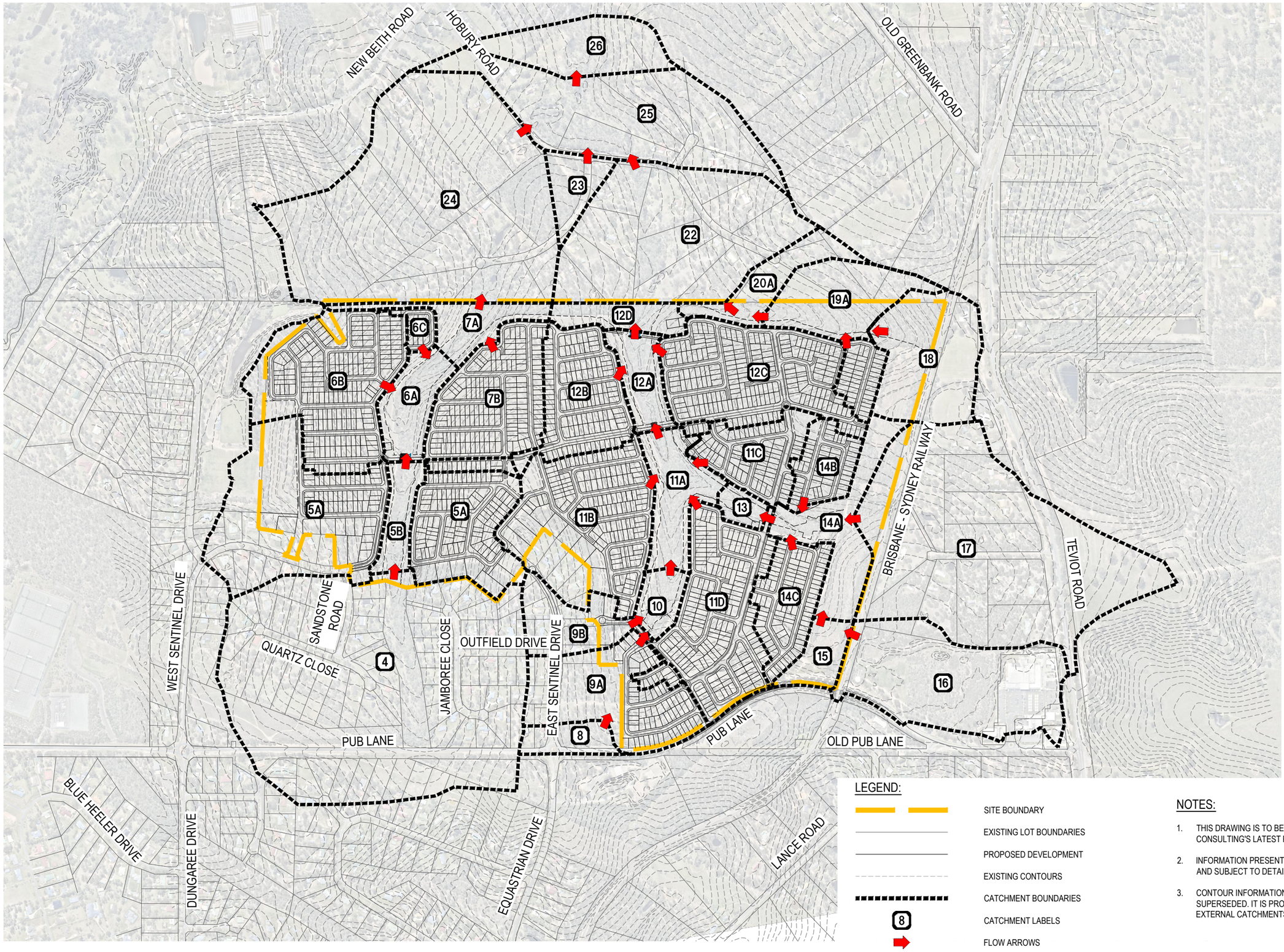
DRAWING TITLE: CONCEPT STORMWATER MANAGEMENT STRATEGY EXISTING CATCHMENT PLAN

PROJECT No: 16-002518

DRAWING No.: SK10

REVISION: A

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CATCHMENT	AREA (ha)
4	46.26
5A	24.06
5B	2.52
6A	4.82
6B	13.77
6C	1.02
7A	3.49
7B	9.31
8	2.10
9A	9.76
9B	5.08
10	1.94
11A	5.12
11B	14.35
11C	5.23
11D	11.87
12A	3.44
12B	7.70
12C	12.63
12D	2.63
13	1.14
14A	6.43
14B	3.31
14C	5.16
15	2.38
16	14.87
17	32.95
18	9.23
19A	6.44
19B	2.11
20A	3.83
22	20.20
23	2.58
24	36.32
25	16.48
26	6.20

LEGEND:

- SITE BOUNDARY
- EXISTING LOT BOUNDARIES
- PROPOSED DEVELOPMENT
- EXISTING CONTOURS
- CATCHMENT BOUNDARIES
- 8 — CATCHMENT LABELS
- FLOW ARROWS

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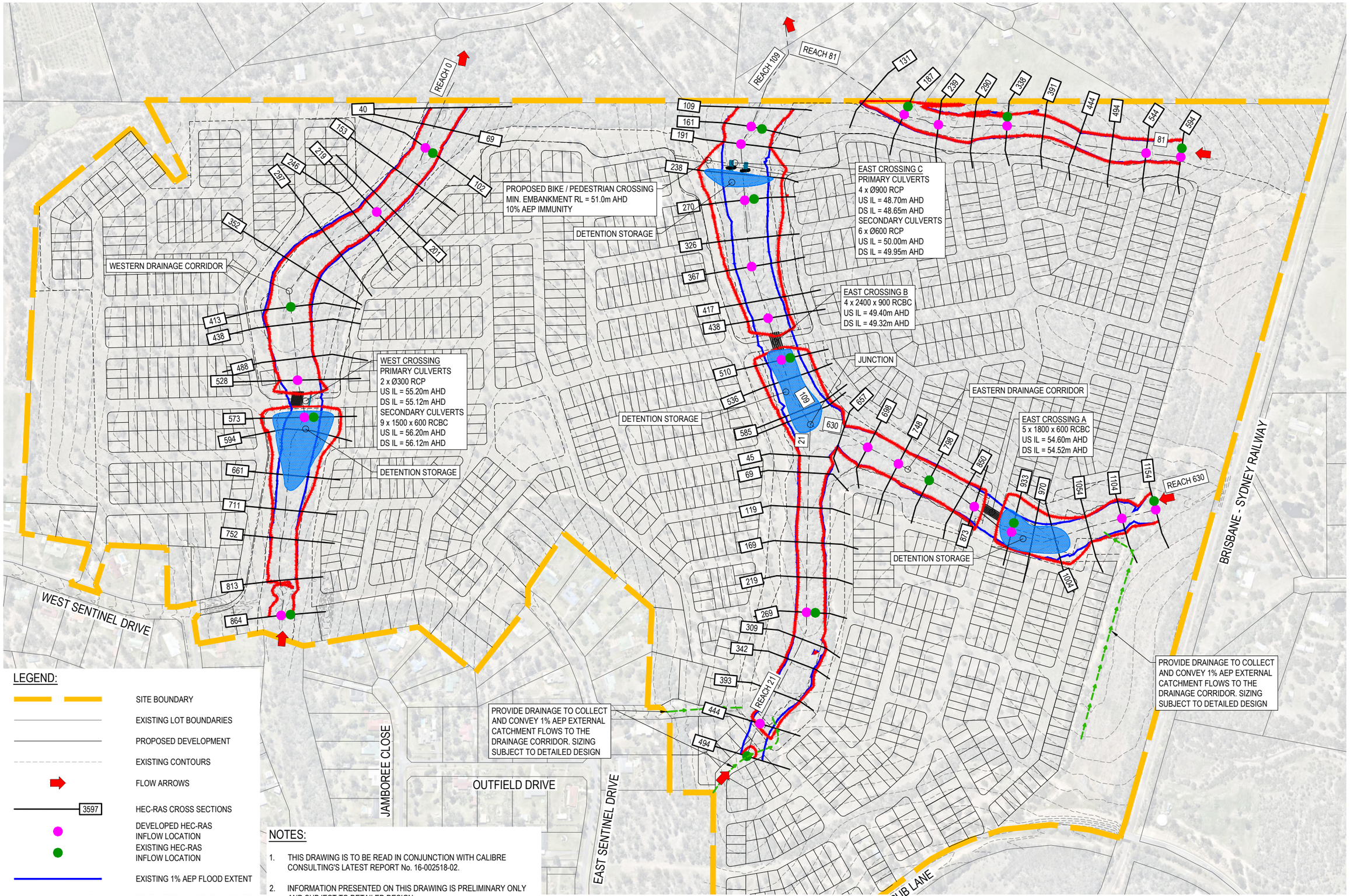
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- SITE BOUNDARY
- EXISTING LOT BOUNDARIES
- PROPOSED DEVELOPMENT
- EXISTING CONTOURS
- FLOW ARROWS
- 3597 HEC-RAS CROSS SECTIONS
- DEVELOPED HEC-RAS INFLOW LOCATION
- EXISTING HEC-RAS INFLOW LOCATION
- EXISTING 1% AEP FLOOD EXTENT
- DEVELOPED 1% AEP FLOOD EXTENT

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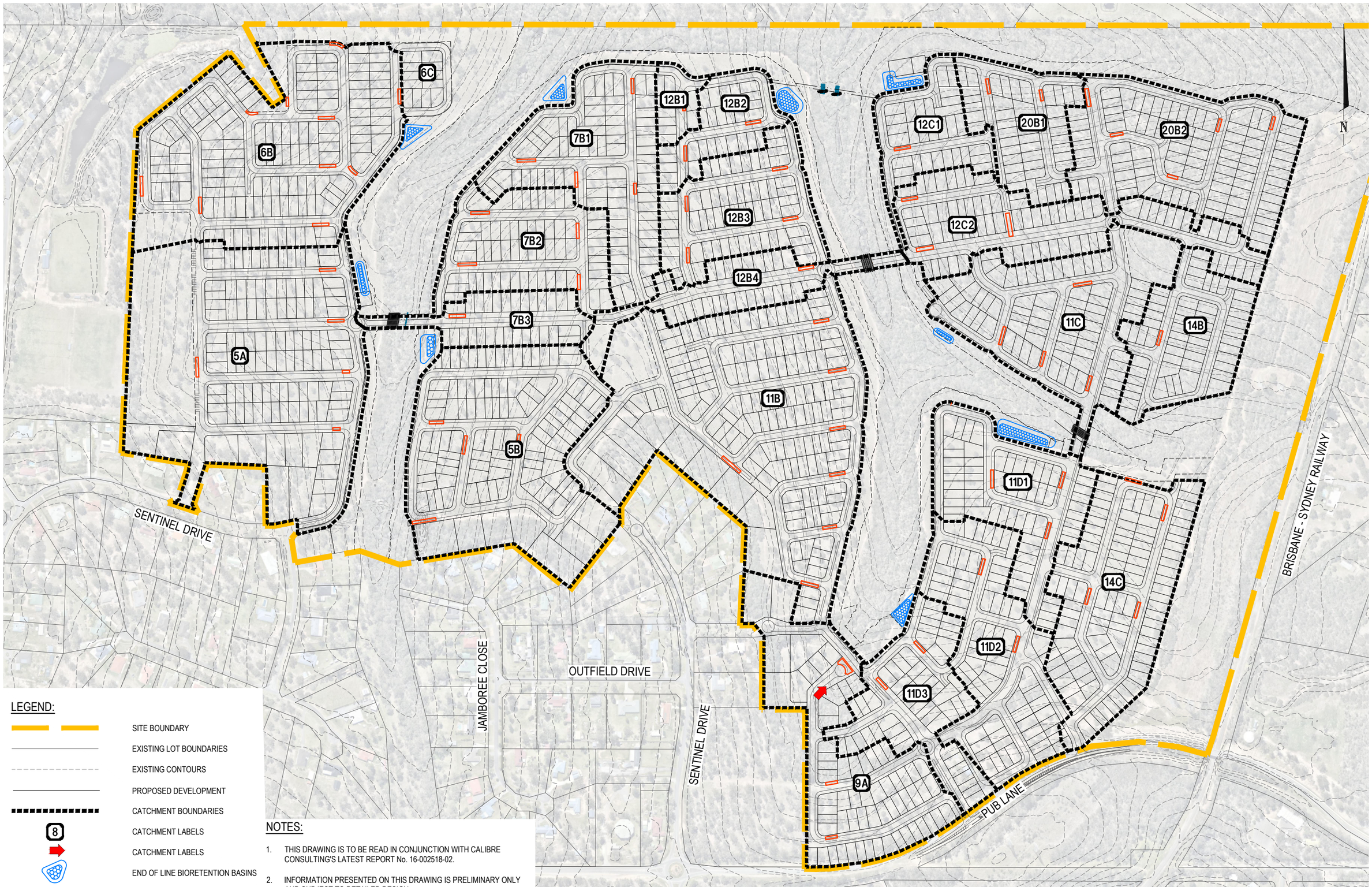
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- EXISTING LOT BOUNDARIES
- EXISTING CONTOURS
- PROPOSED DEVELOPMENT
- CATCHMENT BOUNDARIES
- 8 — CATCHMENT LABELS
- CATCHMENT LABELS
- END OF LINE BIORETENTION BASINS
- 'AT-SOURCE' BIOPODS

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