Rotokauri North Sub-Catchment ICMP

Stormwater and MUSIC Modelling Report

Technical Appendix to Sub-Catchment Integrated Catchment Management Plan

PREPARED FOR:

Green Seed Consultants Ltd

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CLIENT: Green Seed Consultants Ltd

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Revision	Date	Originator	Checker	Approver	Description
DRAFT	11/18	BJR	AJSH	AJSH	Draft for client review
1	12/18	BJR	AJSH	AJSH	Draft for HCC
2	2/19	BJR	AJSH	AJSH	Addressed HCC comments from draft; added sensitivity analysis for WRC
3	3/19	BJR	AJSH	AJSH	Addressed WRC and Morphum comments

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APPENDICES

1.0 INTRODUCTION

McKenzie & Co. Consultants (McK) have been engaged by Green Seed Consultants Ltd (GSCL) to prepare a stormwater modelling report to assess pre-development stormwater flows for the Rotokauri North Sub-Catchment Integrated Catchment Management Plan (ICMP). This report has been prepared alongside a Private Plan Change (PPC) to rezone 133 ha (within the ICMP area) for medium density housing and a neighbourhood centre.

The full extent of modelling (including that in this report) covers the extent of land identified in Figure 1, based on existing topographical catchments. However, the ICMP covers approximately 203 hectares as shown in Figure 1 below, and is only based on land falling inside the HCC Territorial Authority Boundary.

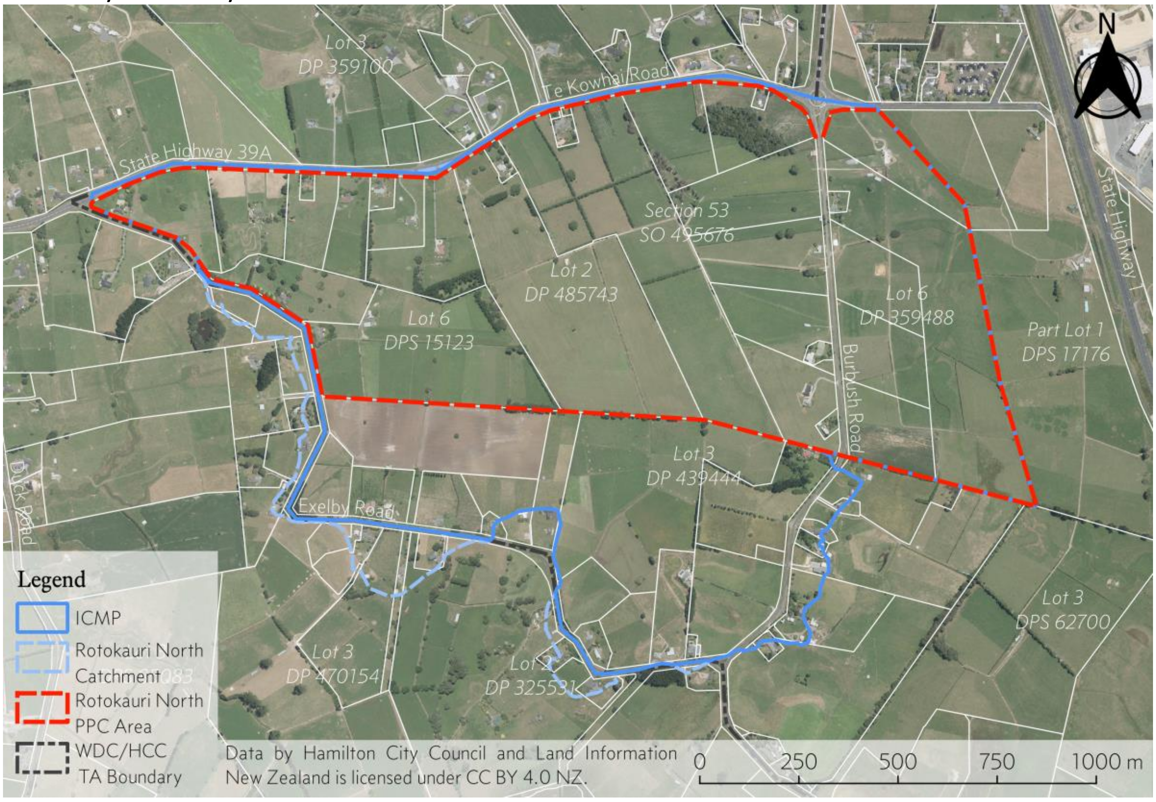

Figure 1: ICMP Area and Rotokauri North Catchment

This report outlines the methodology and results of stormwater analysis including MUSIC modelling for the Plan Change area. The design within this report is to a feasibility level to support the Private Plan Change application.

2.0 SITE DESCRIPTION

The site is located at the edge of Hamilton City's urban limit toward the northwest corner of the city. The site is bounded to the north by State Highway 39 (Te Kowhai Road), and generally on the west and south by Exelby Road. The Waikato Expressway lies to the east and Burbush Road passes through (North – South) the middle of the site – see Figure 2.

The site is comprised of farmland pastures, with a small number of farmhouses/residential dwellings, and farm utility buildings present.

The landform is generally very flat with around 2 m fall across the site. Burbush Road is elevated some 10 m above the site to the south. The total elevation range across the ICMP catchment is from RL 27m to RL 47m.

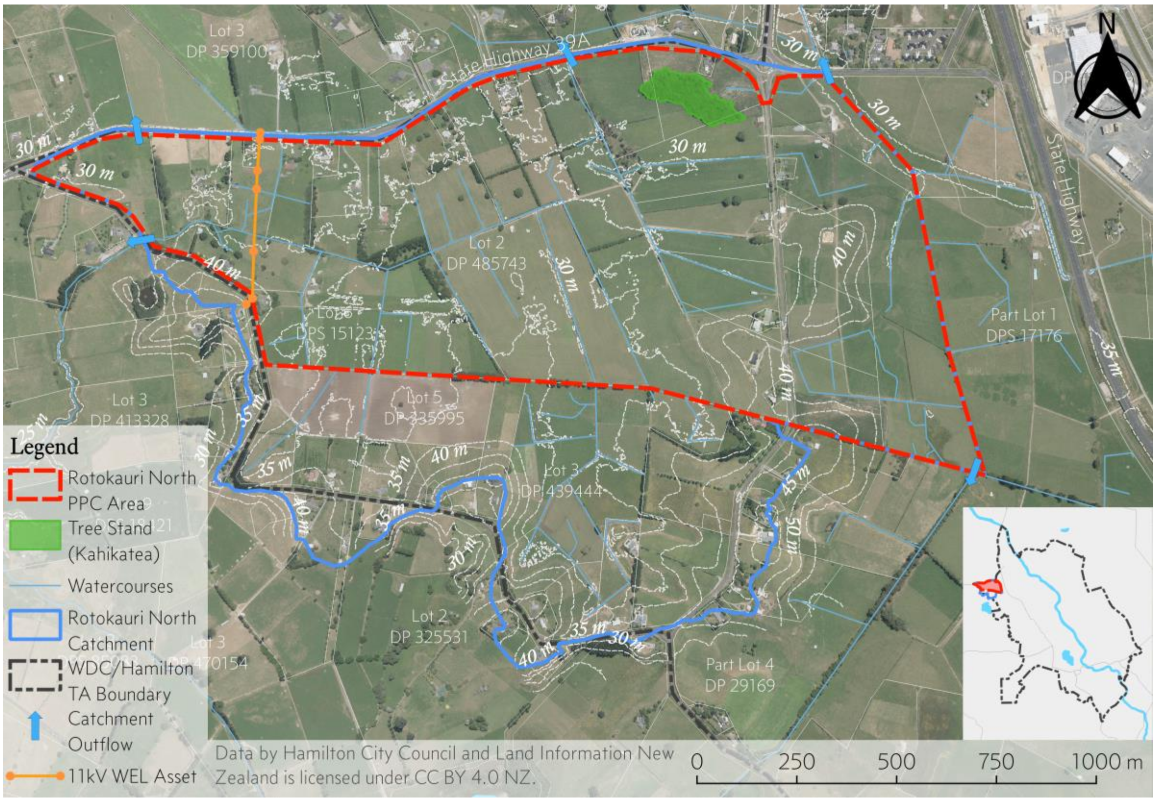

Figure 2 Site Location

3.0 STORMWATER BACKGROUND

3.1 ICMP Objectives

The Subcatchment ICMP objectives have been summarised in the following tables (Table 1 and Table 2). For detailed objective descriptions please refer to Section 2 of the ICMP.

Table 1: Strategic Objectives (All ICMPs)

Reference Number	Strategic Objective
SO1	Protect freshwater systems - Maintain, protect and enhance freshwater ecosystems and natural drainage systems.
SO2	Protect terrestrial systems - Maintain, protect and enhance indigenous biodiversity values and functions.
SO3	Kaitiakitanga - Give effect to the relationship of tangata whenua as kaitiaki of receiving water bodies and including the relationship of Waikato-Tainui with the Waikato River.
SO4	Stormwater Management - Stormwater management related to land use and development shall encourage and enable low impact design and incorporate best practicable mitigation measures to minimise actual and potential adverse effects
SO5	Wastewater Management - Wastewater management shall incorporate best practicable options
SO6	Potable Water Management - Water supply is planned and provided for in a way that meets existing and future requirements
SO7	Three Waters Management - Three waters networks are planned, managed and operated in an integrated manner to meet existing and future development requirements

The following strategic objectives are specific to the Rotokauri North Subcatchment ICMP. As the site falls within both the Mangaheka and Rotokauri ICMPs the strategic objectives of both of these catchments have been considered and are incorporated below.

Table 2: Strategic Objectives (Applicable to this ICMP)

Reference Number	Strategic Objective
CS1	Alignment with the Rotokauri North Structure Plan - manage stormwater in a manner that minimises the effects of development on downstream receiving waters.
CS2	Provide flood protection and downstream level of service.
CS3	Protecting water quality - Require the stormwater network to incorporate a treatment train approach to improve water quality of onsite watercourses.

3.2 Existing Catchment Overview

The Rotokauri North area falls at the intersection of the Ohote, Te Otamanui, Mangaheka and Rotokauri South catchments. Modelling and reporting on these catchments were undertaken by external consultants for Hamilton City Council (HCC) previous to the consideration of the Rotokauri North Plan Change Area. Previous reports have been referenced in Section 13.0.

The majority of stormwater catchment discharge is via the Ohote catchment, which runs predominantly east-west through Rotokauri North. The Ohote catchment ultimately discharges to the Waipa River approximately six kilometres downstream. The catchment drains through a culvert located at Exelby Road, which is also the western boundary of the Rotokauri North catchment.

The Te Otamanui catchment within Rotokauri North (portions south of Te Kowhai Road) also falls within the HCC territorial authority boundary. The remainder of the Te Otamanui catchment (downstream of the Rotokauri North Plan Change area) is within Waikato District Council's jurisdiction. Two culverts under Te Kowhai Road convey flow from the southern to northern portions of the Te Otamanui catchment. The Te Otamanui catchment discharges north westerly to the Waipa River approximately eight kilometres to the west northwest of Rotokauri North.

The Mangaheka catchment flows from south to north along the eastern edge of Rotokauri North. The upper portion of the Mangaheka catchment within HCC jurisdiction falls within Rotokauri North. The catchment eventually discharges to the Waipa River approximately 2.5 kilometres south of Ngaruawahia. This catchment has an approved Integrated Catchment Management Plan (ICMP) (Adams, 2018a), for which the stormwater management requirements have been confirmed.

The Rotokauri South sub-catchment has a higher level of detail within the approved Integrated Catchment Management Plan (Hart, 2017). As such, the stormwater management requirements have been confirmed for that portion of the Rotokauri North area. The portion within the Rotokauri North area covers the upper reach of the Rotokauri South sub-catchment. The catchment flows south westerly to Rotokauri Lake approximately 1.5 kilometres away.

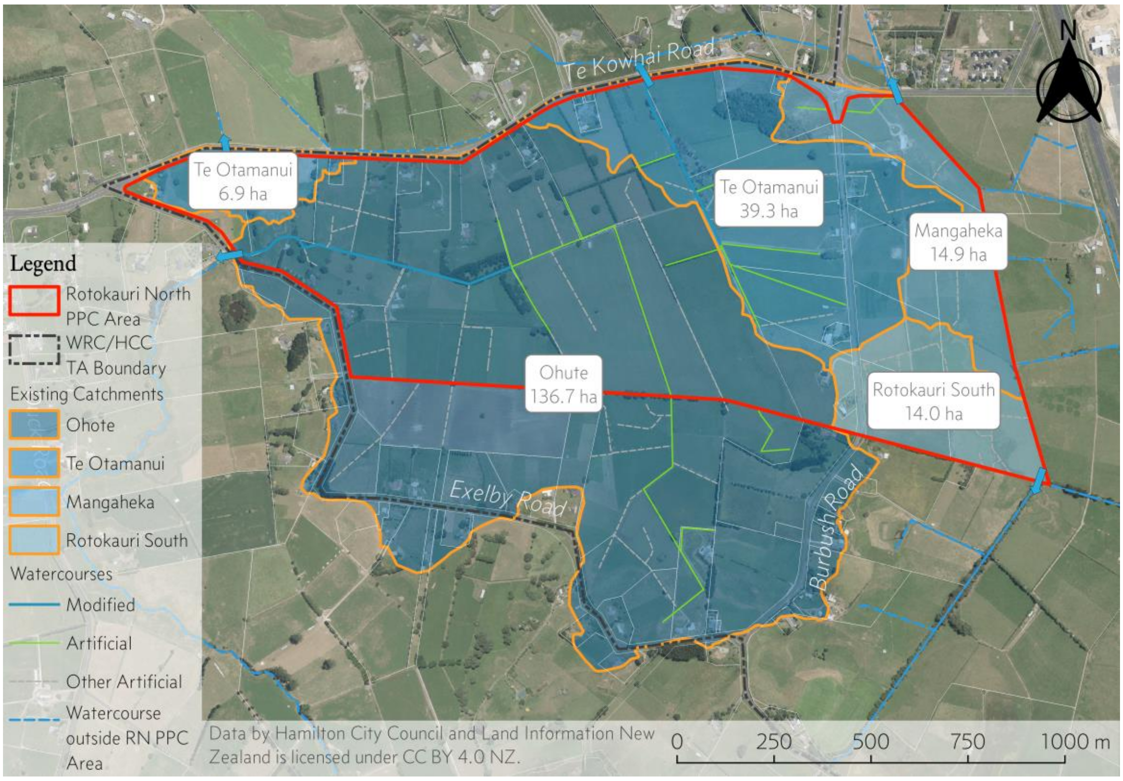

Figure 3: Current Catchment Boundaries

Refer to Appendix A – Catchment Extent Plans for larger figure.

3.3 Proposed Catchment Overview

The Rotokauri North Plan Change area will have catchment boundaries amended to suit the proposed master plan development and topography. The amendment will direct the western Te Otamanui 6.9 ha catchment area into the Ohote catchment, thereby increasing the overall size of that catchment. The eastern portion of Te Otamanui catchment has a revised boundary primarily with Ohote.

The Mangaheka and Rotokauri North catchments have only minor adjustments.

Amendments and adjustments to the catchment boundaries would be expected to occur based on changes to topography through earthworks and stormwater conveyance systems following road networks.

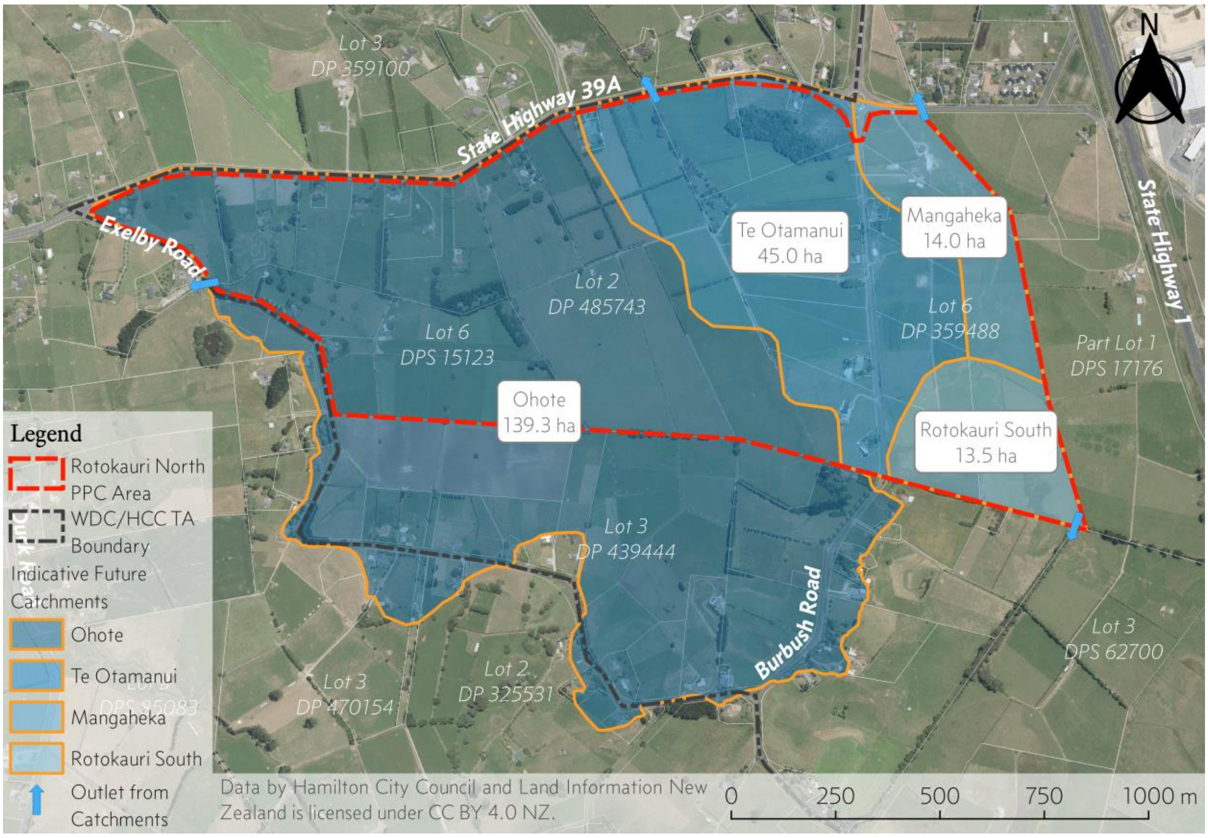

Figure 4: Proposed Catchment Boundaries

Refer to Appendix A – Catchment Extent Plans for a larger figure.

The changes to the contributing catchment areas have been summarised as per the following table (Table 3).

Table 3: Existing and Proposed Catchment Areas

Catchment Reference	Existing Area (ha)	Proposed Area (ha)	Comments
Ohote	136.7	139.3	Catchment area was the area upstream of Exelby Road culvert
Te Otamanui West	6.9	0.0	Area to be redirected to Ohote catchment
Te Otamanui East	39.3	45.0	Boundary adjusted with Ohote catchment
Mangaheka	14.9	14.0	Minor adjustment with Te Otamanui and Rotokauri North catchments
Rotokauri South	14.0	13.5	Minor adjustment with the Mangaheka catchment
TOTAL	211.8	211.8	

3.4 Consents

Stormwater discharge consents will form part of the future Qualifying Development (under HASHAA) and resource consent applications (under RMA).

3.5 Ecological Assessment

Two ecological reports were completed for the Rotokauri North Plan Change area:

1. Rotokauri North Sub-Catchment, Receiving Environment and Rapid Erosion Assessment (Morphum, 2018 Draft); and
2. Rotokauri North Development Area: Technical review of stream classifications (Miller, 2018 Draft)

A key stormwater management opportunity for the Plan Change area will be the ecological enhancement of the receiving environments as per the reports above.

3.6 Geotechnical and Hydrogeology

A geotechnical desktop assessment has been documented within:

1. Rotokauri North SHA, Geotechnical Assessment Report (Alder, 2018).

The key risk identified within the report was the moderate to high risk of liquefaction at the site. It is expected that this risk can be mitigated for residential development, subject to further detailed investigation and analysis.

Hydrogeological assessment has been documented in:

2. RNDA ICMP: Desktop Review of Hydrogeological Conditions Influencing Stormwater Design (Nutsford, 2018).

The report noted two specific soil types across the Plan Change area:

- Sandy CLAY – low hydraulic conductivity, typical layer thickness of 0.5m.
- SAND – moderate to high hydraulic conductivity, anisotropic, typical layer thickness of 3.75m.

Groundwater levels ranged across the site from 0.1 m to 1.5 m below ground level and were noted to be much shallower than those recorded for the adjacent Rotokauri South area.

Using the water table method on limited monitoring results estimated that rainfall recharge was ~100%, indicating a very direct connection between ground water levels and rainfall.

3.7 Existing Hydrology and Hydraulics

The existing hydrology of the site, and the related hydraulics have been documented in the following reports and correspondence:

1. Rotokauri North Private Plan Change, Catchment Modelling (Rudsits, 2019b)
2. Ohote Catchment 2D Modelling Sensitivity (Rudsits, 2018a)
3. Rotokauri North Catchment Stormwater Modelling, Ohote Stream Capacity Assessment Model Build Report (Vajlikova, 2018)
4. Rotokauri ICMP – Major Drainage Options (AECOM, 2016)

The modelling analysis and reports have estimated the Existing Development (ED) flows relevant to the Plan Change area. The peak flow predictions were for the locations at the interface of development area and receiving environments. The peak flow predictions were for the whole of the contributing catchment, including areas outside of the Plan Change area.

Peak flow predictions were based on 24-hour 50%, 10% and 1% Average Exceedance Probability design rainfall events excluding climate change factors.

Due to the differences in modelling software and input datasets used by AECOM and McKenzie & Co. it was recommended that the peak value of 0.7m^3/s be adopted as per the previous Rotokauri ICMP for the 1% AEP design rainfall event. The final value to be used for ED flows can be further refined in the future during Resource Consenting, subject to additional information being gathered (topography) and runoff analyses agreed between all relevant parties (GSCL, HCC, WRC).

Table 4: Peak ED Flows

Location	50% AEP (m^3/s)	10% AEP (m^3/s)	1% AEP (m^3/s)
Exelby Road Culvert (Ohote)	0.33[1]	0.50[1]	0.70
Te Otamanui - Te Kowhai Road (West)	0.10	0.11	0.12
Te Otamanui - Te Kowhai Road (East)	0.85	1.50	1.81
Mangaheka	1.49	2.38	3.21
Rotokauri South	0.46	0.18	1.77

1. The AECOM modelling was acknowledged as providing a catchment level assessment primarily for assessing flooding for 1% AEP. The model was not configured as a detailed planning tool for the 50% and 10% AEP flows, as per correspondence between AECOM and HCC[1].

Additionally, as per comments in Section 3.3, the Te Kowhai Road (West) catchment will be directed towards the Exelby Road culvert. The flow values for the Exelby Road culvert will form the limiting ED flows for this catchment regardless of any redirection.

[1] Email Chris Hardy (AECOM) to Jackie Colliar (HCC), 19 November 2018, "Rotokauri North Hydrology".

3.8 *Upstream Catchments*

Catchments outside the Plan Change area but included within subcatchment ICMP boundary area were analysed as part of the catchment modelling. These areas (O-G and O-H, refer to Figure 5) will contribute to flows within the Ohote catchment.

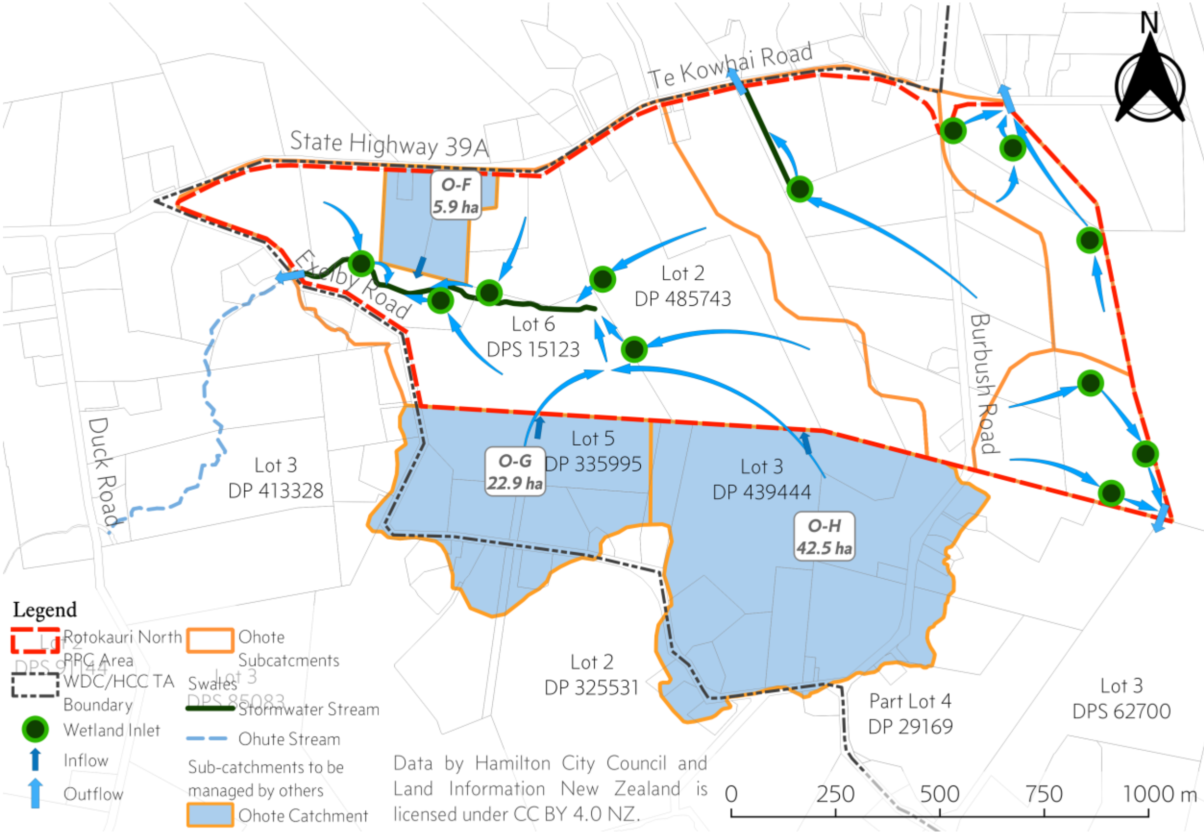

Figure 5: Upstream Ohote Catchments

These upstream catchment areas (identified as 'O-G' and 'O-H) 'have been assumed to provide water quality treatment and detention within their catchments. The Plan Change area has allowed for the stormwater flows from these areas to be conveyed through to the green corridor by dedicated conveyance channels. Dedicated conveyance channels were proposed as the stormwater from the upstream catchments can be considered 'clean' when it discharges to the green corridor.

If the upstream catchment flows were combined with the local swale/conveyance channels, this would result in the receiving wetland being considerably larger to treat the increased catchment area. This was not considered acceptable as the Plan Change area would need to have additional land allocated for stormwater management from catchments external to the Plan Change area.

The flow estimates for these upstream catchments were based on the McK modelling results, as they were more conservative than the AEOCM modelling results.

Table 5: Upstream Ohote Catchment Peak Flows

Location	50% AEP (m^3/s)	10% AEP (m^3/s)	1% AEP (m^3/s)	80% of 1% AEP (m^3/s)
Area 'O-G'	0.23	0.43	0.78	0.62
Area 'O-H'	0.68	0.79	0.87	0.70

The dedicated conveyance channels were sized for the 10% AEP peak flows, with flows in excess to managed through overland flow paths along/within road reserves. The 1% AEP peak flow to be accommodated within the Plan Change areas was based on 80% of peak flow for the 1% AEP storm event as per HCC requirements.

4.0 WATER QUALITY REQUIREMENTS

The post development water quality requirements have been summarised as per Table 6.

Table 6: Water Quality Requirements

Water Quality Parameter	Limit	Comment
Suspended Solids	Increase in concentration <10% of existing	WRC Regional Plan Section 3.2.4.6
	Concentration shall not exceed 100 g/m³	WRC Regional Plan Section 3.2.4.6
	75% removal of post development load	Waikato Local Authority Shared Services Regional Infrastructure Technical Specifications (Waikato Local Authority, 2018) (Waikato LASS RITS)
Temperature	No more than 3°C change in water temperature AND not greater than 23°C	Waikato LASS RITS (Waikato Local Authority, 2018)
Turbidity	No greater than 25 NTU in the stormwater discharge in a water quality storm (1/3rd of a 2-year 24-hour storm).	Waikato LASS RITS (Waikato Local Authority, 2018)
Dissolved Oxygen	Greater than 80% of saturation concentration - however if the If the concentration of dissolved oxygen in the receiving environment is below 80 percent saturation concentration, any discharge into the water shall not lower it further.	Waikato LASS RITS (Waikato Local Authority, 2018)
Ammoniacal Nitrogen	<0.88 g/m³	Waikato LASS RITS (Waikato Local Authority, 2018)
	<0.03 mg/L (<0.03 g/m³) annual mean	National Policy Statement - Freshwater Management, Attribute State 'A' (Ministry for the Environment, 2017)
	<1.30 mg/L (<1.30 g/m³) annual mean	National Policy Statement - Freshwater Management, Attribute State 'D' (Ministry for the Environment, 2017)
Total Nitrogen	Maximum practical removal possible	Waikato LASS RITS (Waikato Local Authority, 2018)
Total Phosphorus	Maximum practical removal possible	Waikato LASS RITS (Waikato Local Authority, 2018)

Water Quality Parameter	Limit	Comment
Total Metals	Maximum practical removal possible	Waikato LASS RITS (Waikato Local Authority, 2018)
Colour/Visual Clarity	No conspicuous change in colour or clarity (1/3rd of a 2-year 24-hour storm).	Waikato LASS RITS (Waikato Local Authority, 2018)
Hydrocarbons	No visible sheen	Waikato LASS RITS (Waikato Local Authority, 2018)
Gross Pollutants	No gross pollutants	Waikato LASS RITS (Waikato Local Authority, 2018)
Other Contaminants	Removal in accordance with the RITS.	Waikato LASS RITS (Waikato Local Authority, 2018)

The analysis and reporting within this document were related to design rainfall events. It is recommended that an annualised time series be completed as part of a future application for stormwater discharge consent. That would allow assessment of annual performance of the water quality devices for consideration and comparison with the National Policy Statement – Freshwater Management.

5.0 STORMWATER STRATEGY

The stormwater management strategy for Rotokauri North will implement the objectives of the Rotokauri North Sub-catchment ICMP and will meet the Hamilton City Council (HCC) requirements for a Greenfields development which follow Water Sensitive Design considerations. This includes the following:

- Quality;
- Retention and Detention;
- Conveyance for 10-year$_{cc}$ and 100-year$_{cc}$ rainfall events; and
- Application of Water Sensitive urban design for road reserves.

The flow effects will also be mitigated by applying at source stormwater management.

5.1 Conveyance

The limited topographic change across the Plan Change area limited the use of a piped gravity network, therefore swales and conveyance channels were preferred. Swales would be planted with high growing vegetation to reduce flow velocities to aid water quality outcomes. The conveyance channels would primarily be used for moving flow through the network, with water quality outcomes a secondary benefit.

The conveyance of the 10-year$_{cc}$ rainfall event will be via a swale network which will discharge into wetlands and detention basins (via high-flow bypass) prior to the outlet of each catchment to the receiving environment. Details of the proposed primary network for the development are provided in Appendix B.

The conveyance system in the Plan Change area was based on upper sub-catchment reaches using the road/carriageway for conveyance of stormwater flows, for maximum catchment area of 1.5 ha. The carriageways used for conveyance are expected to generally be local roads with a fixed 6.0m width. The maximum flow depth of 100mm was based on conveying the 10% AEP$_{cc}$ within the carriageway.

Conventional vegetated swales would be used for catchments up to 4.0 ha. Conveyance channels are proposed for conveyance within subcatchments with contributing areas exceeding 4.0 ha. The swales and channels within the Ohote catchment will discharge to the green corridor where wetlands and a naturalised stream section (green corridor) are located.

Table 7: Swale/Channel Designs (10% AEP_{cc})

Swale/Channel Reference	Max. Upstream Catchment Size (ha)	Base width (m)	Top Width (m)	Side Slopes
A (Swale)	<4.0	0.6	3.75	1:3
B (Channel)	4.6	0.85	4	1:3
C (Channel)	6.4	1	4.5	1:3
D (Channel)	17.3	3	7.5	1:3
E (Channel)	25.7	3.8	9	1:3

Manning's n Values

RITS (Waikato Local Authority, 2018) recommends a Manning's *n* values of 0.25 for design of planted swales, which was adopted for the Type 'A' swales above. However, the larger swales and conveyance channels within the Plan Change area are primarily for conveyance. These swales and conveyance channels are expected to comprise cobbled bases and grassed sides, with planting proposed above the 10% AEP_{cc} water level. Subsequently the hydraulic analyses have used an equivalent Manning 'n' value of 0.05 for design of those swales.

Should planted treatment swales be adopted during future detailed design for swales other than Type 'A', the RITS value of 0.25 should be adopted.

Planting to be used as part of the swales/channels shall be selected from RITS Table 4-35 based on hydraulic and landscaping requirements.

5.2 Quality

The proposed development will include Single Housing, Duplex Housing and Terrace housing urban typologies. These residential typologies are considered to be a comparatively low contaminant producing activity. The majority of roads are designed to have water sensitive design elements included, such as swales.

The development proposes to apply at-source (on site/on lot) treatment systems for the Single and Duplex Housing. The remaining lot typologies and roads are expected to achieve water quality outcomes via communal systems. Several practical treatment options have been considered for the Plan Change area, which include the following options, and can be applied in a treatment train approach that includes but is not limited to:

- Minimisation of impervious surfaces as far as practically possible;
- Inert or low contaminant generating cladding material for buildings;
- Proprietary treatment devices;
- Bioretention devices;
- Detention basins;
- Swales;
- Wetlands; and
- Permeable paving in shared spaces, car parking bays and driveways.

The proposed catchment has relatively shallow surface gradient zones which can accommodate at-source treatment within the residential lots, shared spaces, and road reserves.

Wetland Design

Wetlands were proposed for the treatment of stormwater flows downstream of the conveyance system. The wetlands have been designed for the water quality volume (WQV) as calculated using Auckland Council TP10 (Auckland Regional Council, 2003) design information, in addition to providing extended detention volume (EDV) as per RITS. Rainfall design depth values used were based on local (Waikato) values, excluding adjustments for initial abstraction, were:

- WQV = 23.6mm (Auckland Regional Council, 2003 Chapter 3)
- EDV = 28.3mm (Auckland Regional Council, 2003 Chapter 5), adjusted for local conditions including additional 20% for unstable receiving environment.

When the extended detention volume within the wetland is reached, the flows will bypass at the forebay. This ensures higher flows bypass the wetland with minimal effect on wetland operating levels.

The wetlands are expected to be designed based on an assumption of banded wetlands with the following levels relative to Normal Water Level (NWL):

- PSZ Macrophyte zone 0m - 0.2m deep from NWL
- PSZ Macrophyte zone 0.2m - 0.35m deep from NWL
- PSZ Inlet Pool 0.35m - 1.5m deep from NWL
- PSZ Outlet Pool 0.35m -2.0m deep from NWL

Wetland area has been taken as the area at Normal Water Level with EDV water depth set at 0.5m.

Discharge from the wetlands to the receiving green corridors will be through flow limiting orifice so as to maximise treatment and detention time.

Design specifics of the wetlands are as per the following summary table (Table 8), with detailed information included in Appendix C – Wetland Design.

Table 8: Wetland Designs

Subcatchment Reference	WQV (m^3)	EDV (m^3)	Inlet Pond / Forebay (m^3)	Wetland Area (m^2)	Max Release Rate (m^3/s)
Ohote A	1640	3230	370	4860	0.08
Ohote B	1730	3410	390	5130	0.08
Ohote D	800	1570	180	2360	0.04
Ohote E	670	1330	160	1990	0.03
Te Otamanui	3280	6480	740	9750	0.15
Mangaheka A	160	300	40	410	0.01
Mangaheka B	390	760	90	1050	0.03
Mangaheka C	460	910	110	1260	0.03
Rotokauri South A	210	410	50	560	0.01
Rotokauri South B	80	160	20	210	0.01
Rotokauri South C	80	160	20	220	0.01
TOTAL	9500	18 720	2170	27 800	-

Consideration of wetland liner requirements has not been undertaken as long-term hydrogeological monitoring and analysis has not been completed. Plant selection and planting plans have not been considered. These two items are considered matters for design at Resource Consent stage.

The WQV values above include 33% additional volume allowance for vegetation and planting.

5.3 Treatment

The Rotokauri North catchment will consist of predominantly residential land use, which is generally a comparatively low contaminant producing activity. Road runoff would be collected by road swales and related water sensitive devices.

The overarching principle of the development is to consider treatment of runoff. Several practical at source treatment options have been considered for this catchment, which include the following:

- Rainwater tanks
- Permeable paving in shared spaces, car parking bays and driveways; and
- Swales
- Wetlands
- Detention basins.

5.4 Retention, reuse and detention

Stormwater management options for retention, reuse and detention must achieve the ICMP objectives by utilising a combination of at-source retention and detention with centralised detention facility for areas that cannot apply at-source solutions.

The application of retention and reuse within residential lot is limited by space available onsite. Residential lots will provide onsite retention through the provision of retention tanks, permeable pavement and sheet flow to an equivalent pervious area. Detention from Single lots and Duplex lots will be detained by detention tank and released over 24 hours. The detention volume from affordable, terraced and duplex lots will be directed off site to downstream detention devices, which will hold and release the detention volume over 24 hours, this being a measure to manage affordability of said lot types within the Plan Change area.

No retention requirements for road reserves are required. Detention shall be managed within road corridor swales and downstream detention devices.

An analysis of the application of the best practical option with respect to retention and detention has been undertaken with the outcomes documented within the Rotokauri North Sub--catchment ICMP.

6.0 RUNOFF MODEL COMPARISON

Previous runoff analysis for the project by others was undertaken using Auckland Council TP108 methodology. Additionally the Waikato Regional Council "Waikato stormwater runoff modelling guideline' (SRM) (Shaver, Wood, & Grant, 2018) would also be an applicable methodology for estimating runoff.

The swale network analysis was modelled using MUSIC, with some amendments to replicate local conditions. The results from of the MUSIC modelling were compared with the estimated runoff using TP108 and WRC SRM.

A sample sub-catchment from within the overall MUSIC model was interrogated to determine the peak flows predicted for the 1% AEP_{cc} design rainfall event. The MUSIC model was initially configured with variables such as effective storage as per WRC Stormwater Modelling methodology. Further the primary links were configured with no routing values, as the differential for flow transferring between modelled elements such as roofs and rainwater tanks was considered to be minimal. Rainfall threshold was set as 0 mm/day so as to provide volume conservation.

Effective storage calculation was based on Group B soils with CN = 69. The effective storage calculation was applied with this CN value to the pervious area within the MUSIC catchment. It is noted that the TP108 and SRM calculation uses the effective CN value of the whole catchment, i.e., factored based on impervious and pervious CN values. For a sample sub-catchment draining to the Ohote A wetland as used within Rotokauri North MUSIC model:

- MUSIC Effective Storage = 114mm
- TP108/SRM = 24.67mm

A TP108 analysis was undertaken on sample sub-catchment of Ohote A wetland to determine the peak flows for the same rainfall event. The differences in the analysis of TP108 vs MUSIC predicted flows are summarised in the following table (Table 9). This analysis was also undertaken using stormwater runoff calculations as per SRM for the sample sub-catchment. The sample sub-catchment was analysed for four reaches each with decreasing contributing catchment area.

For the rainfall depth, HIRDS V4 DCP6.0 was adopted as per previous project modelling, rather than the values within WRC methodology.

The WRC methodology involved greater consideration for time of concentration calculations in comparison to TP108.

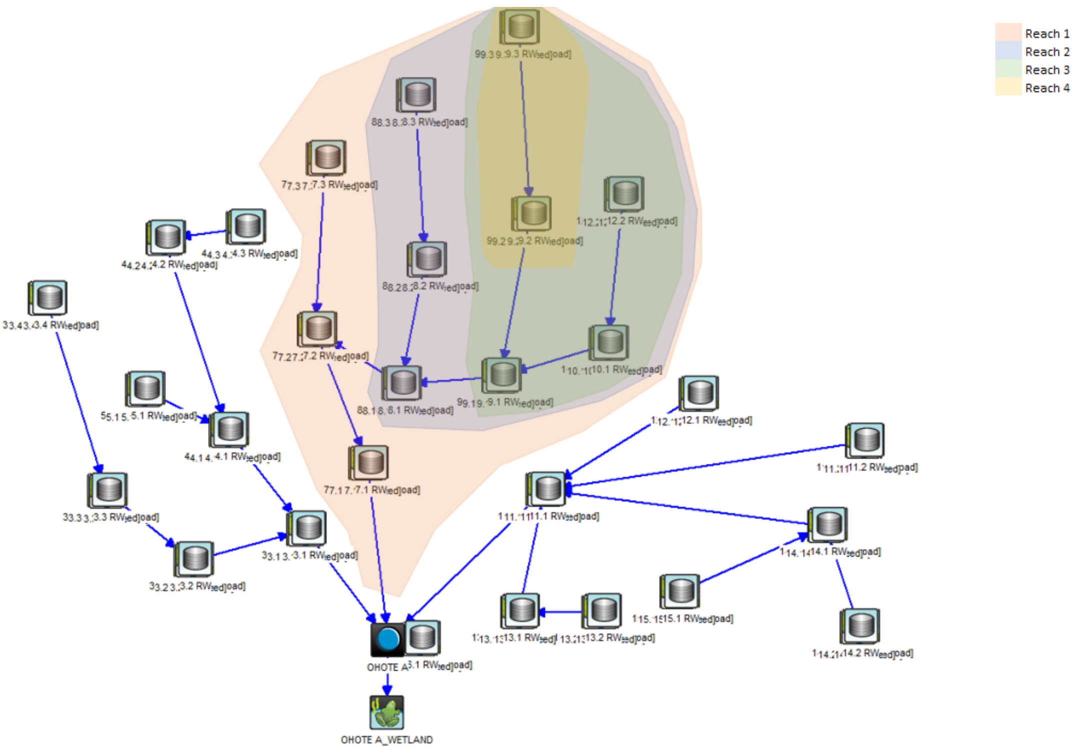

Figure 6: Ohote A Subcatchment Reaches

The results and differences have been noted in the following tables (Table 9 and Table 10).

Table 9: MUSIC vs TP108 vs WRC Peak Flows

Item	Whole of Ohote A	Reach 1	Reach 2	Reach 3	Reach 4
Catchment Size (ha)	18.33	6.89	5.09	1.65	0.75
Catchment Size (km^2)	0.183	0.069	0.051	0.016	0.007
Catchment Imp Area (km^2)	0.137	0.052	0.038	0.012	0.006
Catchment Length (m)	680	680	464	252	73
Effective Curve Number	90.6	90.68	90.7	90.6	91.15
TP108 Flow (m^3/s)	3.32	1.25	1.04	0.39	0.20
WRC Flow (m^3/s)	2.60	0.98	0.82	0.30	0.17
MUSIC Flow (Base)(m^3/s)	6.04	2.06	1.74	0.81	0.36
% Diff. (TP108)	182%	165%	168%	153%	179%
% Diff. (WRC)	232%	211%	213%	198%	210%

The MUSIC model overestimated peak flow compared to TP108 and WRC methodologies. It is noted that TP108 estimated higher peak flows than WRC due to the differences in calculation of time of concentration.

Due to the overestimation of the MUSIC peak flows, the following amendments were made to the MUSIC model to reflect the runoff factors as per TP108:

- Change 1 - Effective storage for all catchments set to 25mm, with field storage set to 20mm.
- Change 2 – Rainfall threshold set to 1.26 mm, based on effective curve number of 90.7 as per TP108.
- Change 3 – All primary links configured with routing value of 10 minutes (as per TP108 minimum time of concentration.
- Change 4 – All of the above changes.
- Change 5 - All primary links configured with routing value of 17 minutes (as per WRC minimum time of concentration for sheet flow on the example sub-catchment.

These sensitivity results have been presented in the table below (Table 10).

Based on the results above, amending the primary link routing values was the largest contributor to change in the predicted peak flows.

Table 10: MUSIC vs TP108 vs WRC Sensitivity Analysis

Item	Whole of Ohote A	Reach 1	Reach 2	Reach 3	Reach 4
TP108 Flow (m^3/s)	3.32	1.25	1.04	0.39	0.20
WRC Flow (m^3/s)	2.60	0.98	0.82	0.30	0.17
MUSIC Flow (Base)(m^3/s)	6.04	2.06	1.74	0.81	0.36
Difference	182%	165%	168%	206%	179%
Change 1 – Effective Storage					
MUSIC Flow (m^3/s)	6.81	2.3	1.95	0.66	0.39
% Dif (TP108)	205%	184%	188%	168%	194%
% Dif (WRC)	262%	235%	239%	218%	227%
Change 2 – Rainfall Threshold					
MUSIC Flow (m^3/s)	6.06	2.06	1.74	0.6	0.36
% Dif (TP108)	182%	165%	168%	153%	179%
% Dif (WRC)	233%	211%	213%	198%	210%
Change 3 – Primary Links Routing (TP108)					
MUSIC Flow (m^3/s)	3.22	1.19	1.10	0.44	0.28
% Dif (TP108)	97%	95%	106%	111%	139%
% Dif (WRC)	124%	122%	134%	144%	163%
Change 4 - All Changes					
MUSIC Flow (m^3/s)	3.6	1.31	1.22	0.47	0.31
% Dif (TP108)	108%	105%	118%	120%	152%
% Dif (WRC)	138%	134%	149%	155%	178%
Change 5 – Primary Links Routing (WRC)					
MUSIC Flow (m^3/s)	2.5	0.87	0.84	0.38	0.27
% Dif (TP108)	75%	69%	81%	97%	132%
% Dif (WRC)	96%	88%	103%	125%	155%

The Change 3 sensitivity scenario was adopted for sizing of the swale network, wetland sizing and detention basin sizing. This scenario was considered suitable based on following:

- Minor under estimation compared with TP108 flows for larger catchments, but over estimation when compared with WRC methodology.
- Over estimation compared with TP108 and WRC for smaller catchments.

Based on the predictions typically being over estimated in comparison to TP108 and WRC, the predictions can be considered conservative. As such they were considered suitable for the purpose of stormwater infrastructure sizing at the current level of design.

7.0 MUSIC METHODOLOGY

With the range of different water sensitive measures across the development, a MUSIC (eWater, 2012) (Model for Urban Stormwater Improvement Conceptualisation) model was developed. MUSIC (eWater, 2012) offered the advantage of modelling both the on-lot measures, the swale and channel conveyance system, wetlands and ponds. It provided hydraulic and water quality predictions for the Plan Change area of the Rotokauri North sub-catchment ICMP.

The model was configured with 12 catchments, modelling the locations where swales and conveyance channels would be connected with green corridors or wetlands. The 12 catchments were named after the overall catchment for which they contribute:

- Ohote – A, B, D, E.
- Te Otamanui
- Mangaheka – A, B, C.
- Rotokauri South – A, B, C.

7.1 Model Resolution

With the large number of lots proposed within the development, modelling each lot individually was not considered appropriate. Grouped catchments were developed based on the number of probable lots that would discharge to stormwater infrastructure.

Lots

The impervious and pervious areas of the lots were separated into two catchments:

- Roof area = Single lot housing roofs have been assumed to discharge to rain water tanks. Imperviousness was assumed at 100%, draining to rain water tank node.
- Remain Area = This catchment area covered the impervious area of single lots, excluding roof area, and the area of all other lots (duplex, terrace). The percentage pervious/impervious was based on addition of roof areas, not serviced by rain water tanks, plus an allowance for outdoor paving, driveways. entranceways etc. This area was configured to discharge to the swale node.
- Based on 50% of the resultant lot area (Lot area less roof area) draining to an infiltration device such as well liner or soakage pit. Imperviousness was estimated at 54 %
- Front of Lot = Based on 50% of the resultant lot area (Lot area less roof area) draining to the conveyance swale. Imperviousness was estimated at 54 %

Road carriageway

The road carriageway was modelled as a specific catchment with 100% impervious surface draining to the swale node.

Berm

The berm was modelled as a catchment area with variable impervious/pervious split based on area of the road reserve less the road carriageway area.

Schematically the arrangement for a grouped catchment has been presented in Figure 7.

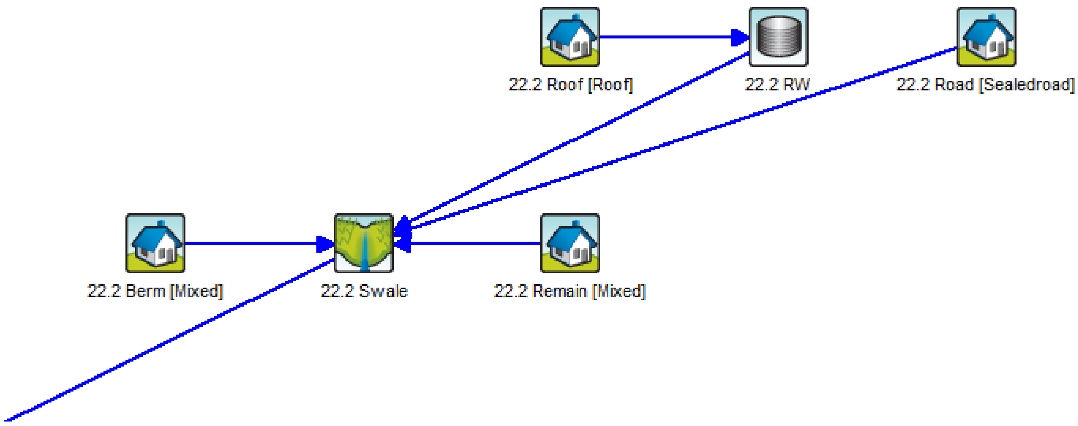

Figure 7: Schematic Lot Arrangement

Typical lot parameters have been summarised in Table 11 below for the different lot/housing typologies. These parameters are based on generalised lot information, derived from a maximum of 80% impervious surfacing. Individual lot areas and roof sizes will vary across the development, however the average values presented below are considered appropriate for the catchment wide modelling.

Table 11: Average Lot Runoff Sources

Lot Typology	Single	Small Lots	Duplex (parent lot)	Terrace
General Lot Dimensions (m)	14 x 28	10 x 28	12.5 x 28	6 x 28
Lot Area (m^2)	392	280	350	168
Roof Area (m^2)	196	140	175	92
Other Impervious Area (m^2)	118	84	105	50
Impervious (%)	80	80	80	85
Pervious Area (m^2)	78	56	70	34
Pervious (%)	20	20	20	20

Two additional potential subcatchments types were identified – Neighbourhood Parks and Neighbourhood Centre. These subcatchments types were modelled as combinations of the lot typologies in Table 11 above. While the individual flows from these sub-catchment types may differ, at a conceptual level they were not considered to be sufficiently different to necessitate specific parameters.

7.2 Rainfall Runoff Parameters

Default MUSIC (eWater, 2012) rainfall runoff parameters have been included within Appendix D. The parameters amended for this modelling were as per the following adjustments:

Rainfall Threshold

All catchments have rainfall threshold of 0.0mm/day.

Soil Storage Capacity

The Waikato Regional Council (WRC) Stormwater Runoff Modelling (SRM) Guideline (2018)was used to determine the soil storage capacity. For impervious areas a Curve Number (CN) of 69 was assumed based on Table 5-2 of the WRC SRM (2018). The CN value was based on assumption of "Open Space, Fair Condition (grass cover 50%-75%), Group B soils". The resultant soil storage capacity was 114 mm based on Equation 5-2 WRC SRM (2018), as applied to the pervious surfaces only.

Field Capacity

Based on high level comments within the BECA hydrogeological report (Nutsford, 2018), the soils within the development area were predicted to have low permeabilities. The field capacity value was adjusted to 91mm corresponding to 80% of the Soil Storage Capacity.

Potential Evapotranspiration

The value for daily potential evapotranspiration (PET) was based on NIWA's (Chappell, 2014) "The Climate and Weather of Waikato 2nd Edition". Table 21 for the report has mean yearly PET of 807 mm at Hamilton, Ruakura.

The daily PET values were derived by averaging the Mean value in Table 21 by number of days in each month.

Design Rainfall

The modelling was based on two separate analyses:

- Analysis 1 — nested design rainfall events over a 24-hour simulation period as per the normalised 24-hour pattern in Table 4-1 of WRC SRM (2018). The rainfall event depths were as per HIRDS V4 (NIWA, 2017), including climate change scenario RCP6.0 (2081-2100). This climate change scenario had the best correlation with the HIRD V3 rainfall allowing for climate change increase as per in Table 4-3 of WRC SRM (2018). Refer Table 12 and Figure 8.
- Analysis 2 — Long term rainfall record from 1 January 2006 to 31 December 2010, based on 5-minute increments. This rainfall record was supplied by Morphum Environmental to ensure modelling is comparable to other Hamilton City Council stormwater quality improvement projects.

Table 12: Analysis 1 - Design Rainfall Depths

Design Rainfall AEP (%)	HIRDS V3 Depth (mm)	HIRDS V3 Depth + Climate Change (mm)	HIRDS V4 RCP6.0
50%	64.5	70.5	70.7
10%	92.6	104.9	109.0
1%	145.3	169.7	169.0

The design rainfall hyetographs as per the following have been included within Appendix E – Design Rainfall Hyetographs.

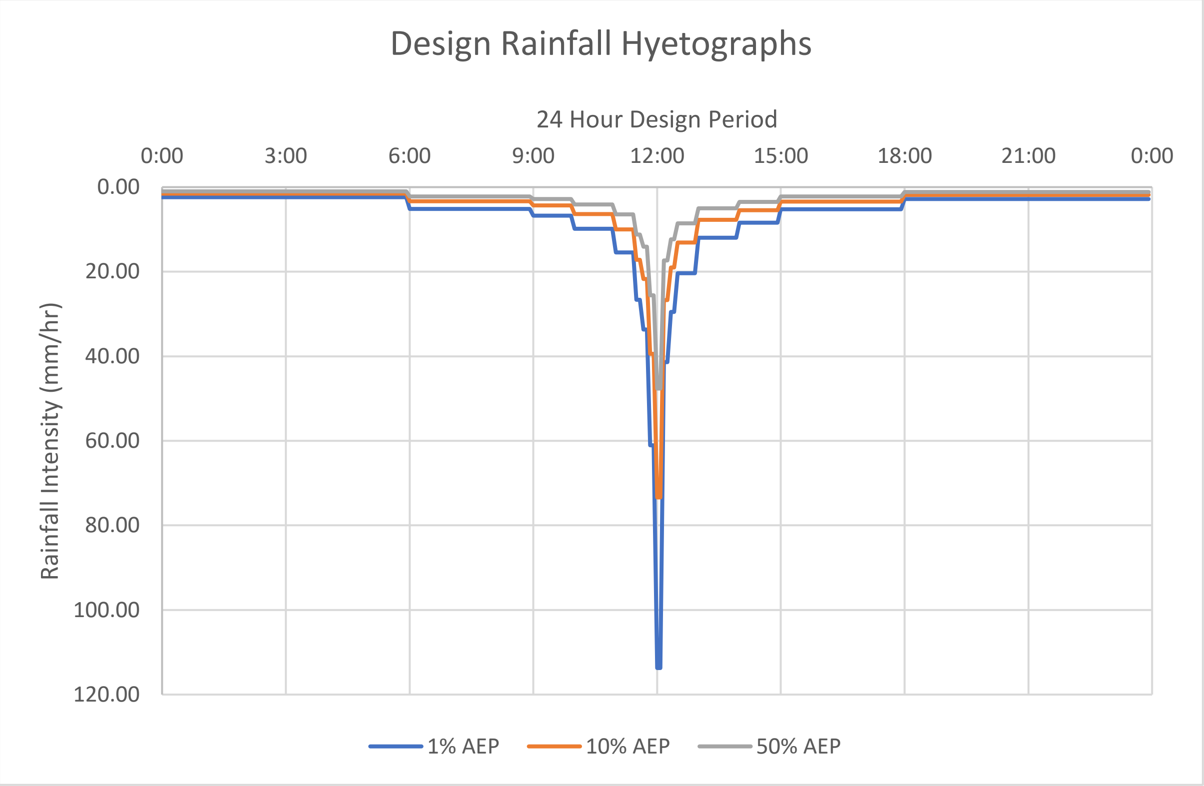

Figure 8: Analysis 1 - Design Rainfall Hyetographs (Including Climate Change)

Long term rainfall record from historical data was based on the hyetograph in Figure 9 below.

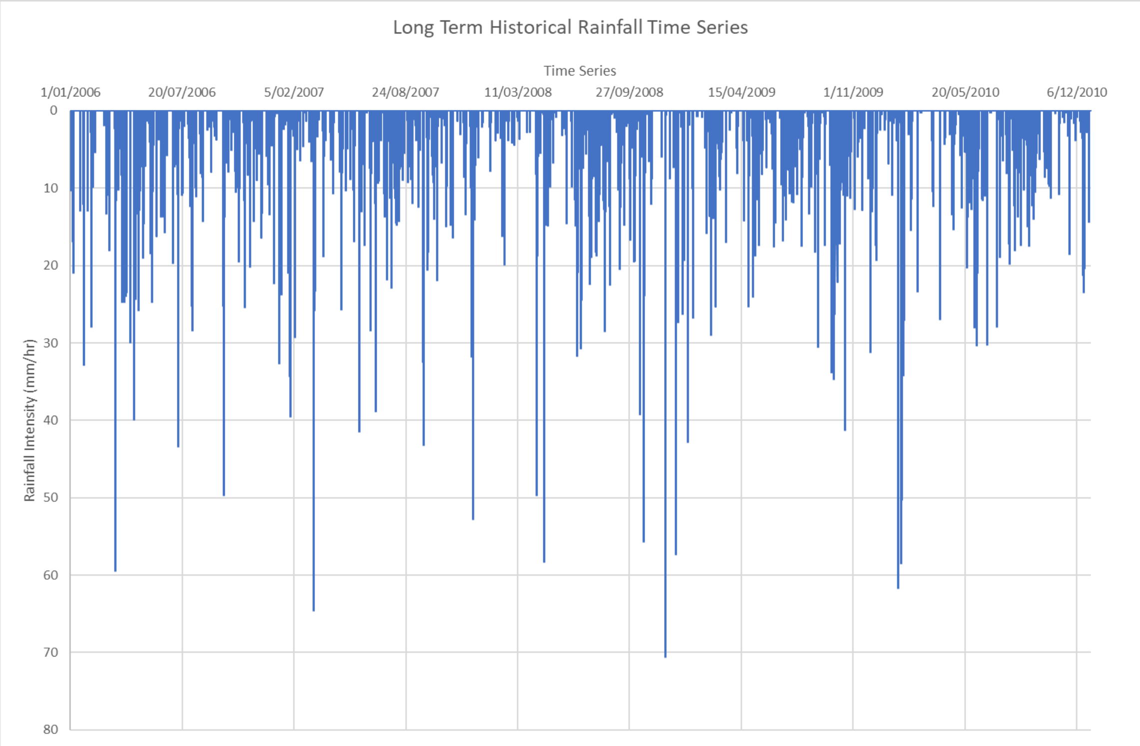

Figure 9: Analysis 2 – Long Term Historical Rainfall Hyetographs (Source: Morphum Environmental)

7.3 Swale Parameters

Bed Slope

All swales were modelled with Bed Slope of 0.4% based on the conceptual road design. While specific future road design may have steeper slopes, adopting a standardised value was considered suitable for the conceptual modelling.

Carriageway Swales

Parts of the Plan Change area were designed to use the road/carriageway for conveyance of stormwater flows. The carriageways used for conveyance were local roads with a fixed 6.0m wide carriageway.

As the carriageway cannot be modelled as a channel within MUSIC it was modelled as swale with equivalent area to the carriageway with assumed maximum depth of 100mm. A further limitation was vegetation height value within MUISC which cannot be reduced below 0.005m. Therefore, the carriageways modelled as swales had a Manning N of 0.052, higher than typically asphaltic concrete value of 0.016.

Based on typical slope of 0.4% and cross-sectional area of 0.3m^2, the maximum flow through modelled swale was 48 l/s, compared with an asphalt road of 157 l/s.

The water quality parameters for carriageway swales were all set zero, i.e., no treatment benefits.

Vegetated Swales

Vegetation height was adjusted for vegetated swales so as to achieve Manning's *n* as per Section 5.1.

Water quality parameters were unchanged from the default values within MUSIC. These should be verified during future modelling for consistency with rates achieved by similar HCC devices.

7.4 Rain Water Tanks

Volume Below Overflow Pipe

Modelling was based on providing $5.0m^3$ to the single lots. Detention and retention storage for the other lots would be provided within the communal downstream devices (ponds, wet lands etc).

Surface Area

Tanks were assumed to have a diameter of 2.2m and corresponding area of $3.8m^2$.

Depth above overflow

The maximum depth above the overflow was set at 2.0m, a height considered sufficient to force overflow through the overflow orifice rather than predicting tank overflow using weir estimation.

Overflow Pipe Diameter

All overflow pipes were modelled as 100mm diameter.

Reuse – Daily Demand

Set to 0.225 kL/day based on assumptions within HCC Three Waters Practice Notes (Hamilton City Council, 2016c, 2016b, 2016a).

Water quality parameters were unchanged from the default values within MUSIC (eWater, 2012). These should be verified in future modelling for consistency with rates achieved by similar HCC devices.

Primary Drainage Links

All primary drainage links within the MUSIC model were configured using a 10-minute translation, as per analysis in Section 6.0.

7.5 Contaminant Loading Rates

The contaminant loading rates for roof, residential and road surfaces were updated to match the values within Table 12-5 of Waikato Stormwater Management Guidelines TR2018/01 (Shaver, 2018) – see Table 13. Annual rainfall of 1,300mm was used to calculate the average mg/l loading rate for Total Suspended Solids (TSS), Total Nitrogen (TN) and Total Phosphorus (TP). The conversion from kg/ha/year within Table 12-5, to mg/l was based on unit area (hectare) assumption.

All roofs were assumed to be either galvanised steel or zinc/aluminium coated; roads supporting 5,000-20,000 vehicles per day category; and remaining subcatchments as paved residential areas.

No distinction was made between base or storm flows within the modelling. Therefore, these modelling values were comparable to the converted WRC SMG values. The *log* values were calculated for each contaminant loading rate for inclusion within MUSIC.

The default values within MUSIC (eWater, 2012) have been included within Table 13 for reference. Note that the values presented are the *log* values.

The performance of the treatment train to reduce contaminant values should be verified during future modelling for consistency with rates achieved by similar HCC devices.

Table 13: Contaminant Loading Rates

Values	Roof	Roads	Residential
WRC SGM Values (kg/ha/year)[1.]			
TSS	54.2	574.2	346.7
TN	16.3	21.7	15.2
TP	1.2	2.1	6.0
Rainfall (l/ha/year)	13,000,000		
Contaminant Loading Rates (mg/l)			
TSS	4.2	44.2	26.7
TN	1.3	1.7	1.2
TP	0.09	0.4	0.5
Contaminant Loading Rates (*log* mg/l)			
TSS	0.62	1.65	1.43
TN	0.1	0.22	0.07
TP	-1.04	-0.41	-0.34
MUSIC Default Contaminant Loading Rates (*log* mg/l) Base Flow / Storm Flow			
TSS	1.1 / 1.3	1.2 / 2.43	1.1 / 2.2
TN	0.32 / 0.30	0.22 / 0.30	0.07 / 0.15
TP	-0.82 / -0.89	-0.85 / -0.30	-0.82 / -0.45

1. Adjusted from Table 12-5 (Shaver, 2018) values with assumed 1,300mm rainfall.

7.6 Wetlands

Wetlands were initially sized based on application of Auckland Regional Council TP10 (2003). The wetland designs have been documented in section 5.2. The relevant information for use within MUSIC (eWater, 2012) is summarised in Table 14.

Note, Te Otamanui has a single wetland servicing the western (Te Otamanui A) and eastern catchments (Te Otamanui B).

Contaminate treatment parameters were as per the MUSIC (eWater, 2012) default values. It is recommended that these treatment values be verified during future detailed wetland design with performance information from other similar HCC devices.

Table 14: Wetland Modelling Parameters

Subcatchment Reference	Inlet Pond Volume (m3)	Wetland Surface Area (m2)	Extended Detention Depth (m)	Permanent Pool Volume (m3)	Outlet Pipe Diameter (mm)	Overflow Weir Width (m)
Ohote A	370	4860	0.5	1640	260	3
Ohote B	390	5130	0.5	1730	280	3
Ohote D	180	2360	0.5	800	80	3
Ohote E	160	1990	0.5	670	180	3
Te Otamanui	740	9750	0.5	3280	170	3
Mangaheka A	40	410	0.5	160	160	3
Mangaheka B	90	1050	0.5	390	80	3
Mangaheka C	110	1260	0.5	460	100	3
Rotokauri North A	50	560	0.5	210	120	3
Rotokauri North B	20	210	0.5	80	90	3
Rotokauri North C	20	220	0.5	80	50	3

7.7 Initial Detention Basins

The requirements for buffering flows to meet the ED peak flow requirements was achieved by providing detention within the green corridors and areas immediately adjacent to the wetlands for the Ohote, Te Otamanui and Mangaheka catchments. Outflow from the detention basins would be achieved through use of hydraulic controls such as slotted weirs.

The sizing for the detention basins was based on initial HEC-HMS modelling results, to complement and verify the results of the MUSIC model. The HEC-HMS model used the MUSIC hydrograph output (before wetland) as the key boundary condition. For the Ohote catchment the upstream catchments were included as per Section 3.8.

The total required detention volumes to achieve the 1% AEP_{cc} peak flow values as per Table 4 based on HEC-HMS have been summarised below.

Table 15: Detention Volumes

Subcatchment Reference	1% AEP_{cc} Detention Volume (m^3)
Ohote	85,100
Te Otamanui	23,000
Mangaheka	8,400
Rotokauri South	Further modelling required

Within MUSIC, the detention basins have been modelled as “detention” nodes with maximum depth in the Ohote basin of 1.81m and 2.0m in all others. The area used within MUSIC was based on volume required divided by the maximum depth.

Custom outflow relationships were defined within MUSIC, based on separate analysis for slotted weirs to control the downstream discharge for the 1%, 10% and 50% AEP_{cc} peak flows.

Specific to the Ohote Catchment the discharges was limited to $0.7m^3/s$ as per the existing Rotokauri ICMP. Further, the maximum depth of 1.81m was based on the elevation/storage relationship developed as a preliminary design topography for the basin. The elevation/topography was based on the available land area for the detention basin and maximum water level that would affect upstream infrastructure.

For the HEC-HMS model each stream catchment was modelled with the wetlands, detention storage and discharge reach configured as follows:

- Wetland – storage basin with inflow limited to the volume of the wetland.
- Detention storage – storage basin with outflow limited to a maximum as per Table 18.
- Bypass – Bypass junction modelled such that flow initially directed to the wetland, and when the wetland design volume was reached, all flow then directed to detention storage.

For MUSIC the volumes will be iteratively adjusted such that maximum outflow from the detention basin will match the limiting catchment discharge.

8.0 CATCHMENT RESULT AND STATISTICS

The model results have been summarised from Table 16 through to Table 25 and Figure 10 through to Figure 15. The sub-catchment references were the locations where the stormwater conveyance network discharges to wetlands and green corridors.

8.1 Hydraulics

The catchment analysis was undertaken based on 24-hour design rainfall as per Section 7.2. The results for the 1% AEP_{cc} have been included for completeness. However, the MUSIC model was not configured specifically to model this hydraulic scenario, as the numerical engine assumes flow conservation. Therefore, any flows exceeding swale or channel capacity are assumed to pass through without attenuation to the downstream node. In practical application 1% AEP_{cc} flows would be expected to be conveyed through both the swale/conveyance channels and road reserves with a variable cross-sectional channel with different Manning's values. It would be expected that the peak flow rates would be lower due to the effect of the variable cross-sectional area and range of Manning's values.

Hydraulic analysis based on Long Term Historical Rainfall was limited to the maximum flow predicted over the 5-year time series.

The predicted peak flows from wetlands are based on summation of flow through orifice and overflow spillway.

Table 16: MUSIC Hydraulics Summary

Subcatchment Reference	WQV Peak Flow before Wetland (L/s)	WQV Peak Flow after Wetland (L/s)	50% AEP_{cc} Peak Flow before Wetland (m^3/s)	50% AEP_{cc} Peak Flow after Wetland (m^3/s)	10% AEP_{cc} Peak Flow before Wetland (m^3/s)	10% AEP_{cc} Peak Flow after Wetland (m^3/s)	1% AEP_{cc} Peak Flow before Wetland (m^3/s)	1% AEP_{cc} Peak Flow after Wetland (m^3/s)	Long Term Rainfall Peak Flow before Wetland (m^3/s)	Long Term Rainfall Peak Flow after Wetland (m^3/s)
Ohote A	71	17	0.83	0.24	1.56	1.05	3.59	3.14	0.61	0.40
Ohote B	86	21	0.74	0.25	1.35	0.98	3.10	2.75	0.58	0.39
Ohote D	47	6	0.34	0.09	0.68	0.40	1.46	1.22	0.26	0.20
Ohote E	39	6	0.35	0.11	0.70	0.59	1.60	1.54	0.25	0.19
Te Otamanui	185	18	1.14	0.48	2.13	1.62	5.15	4.19	0.98	0.77
Mangaheka A	17	4	0.13	0.09	0.24	0.23	0.53	0.53	0.097	0.065
Mangaheka B	33	6	0.31	0.15	0.57	0.49	1.37	1.26	0.26	0.16
Mangaheka C	27	7	0.26	0.14	0.48	0.46	1.18	1.14	0.21	0.14
Rotokauri South A	10	3	0.08	0.03	0.17	0.16	0.44	0.44	0.063	0.054
Rotokauri South B	4	1	0.05	0.02	0.09	0.09	0.25	0.25	0.047	0.025
Rotokauri South C	2	<1	0.05	0.02	0.10	0.10	0.22	0.22	0.035	0.032

Hydrographs for the design rainfall events for each wetland have been included in Appendix F – Wetland Hydrographs.

8.2 Detention Volume

A HEC-HMS model was created to complement and verify the results of the MUSIC model. The HEC-HMS model used the MUSIC hydrograph output (before wetland) as the key boundary condition.

The required 1% AEP_{cc} detention volume was based on the predicted maximum volume within the detention storage nodes as modelled in HEC-HMS.

Within MUSIC, the detention basin area was iteratively adjusted such that the detention basin was not predicted to overflow. The two sets of predictions have been summarised in Table 17 below.

Table 17: Detention Basin Volumes

Catchment Reference	Ohote	Te Otamanui	Mangaheka
1% AEP_{cc} MUSIC Volume (m^3)	79,900	24,300	8,720
1% AEP_{cc} HEC-HMS Volume (m^3)	85,100	23,000	8,400

The detention volumes between the two software packages were comparable and considered to be representative of the volumes need to achieve the development discharge requirements.

The final required area and depth of flow to achieve the detention volume would be determined through detailed design of hydraulic structures, final surface levels, landscaping and urban design.

With reference to Section 11.0, the detention volume for the Ohote catchment could be lowered subject to further analysis of the downstream system.

8.3 Post Development Discharge

The allowable development area discharge is based on the ED values and required adjustments as per HCC and WRC requirements. The ED flows have been summarised previously in Section 3.7.

Upstream catchments have been included in the cumulative values as per the flows in Section 3.8. Note that the Mangaheka values are the peak values for the total catchment which includes majority of catchment being external to the ICMP area.

Table 18: Limiting Catchment Discharges

Flow Scenario	Ohote (Exelby Road Culvert) (m^3/s)	Te Otamanui (Te Kowhai Road East) (m^3/s)	Mangaheka (m^3/s)	Rotokauri South (m^3/s)
50% AEP ED / 50% AEP_{cc} Post	0.33	0.85	1.19	0.46
10% AEP ED / 10% AEP_{cc} Post	0.50	1.50	1.90	0.91
80% of 1% AEP ED / 1% AEP_{cc} Post	0.70	1.45	2.57	1.51

Predicted peak flows from the MUSIC modelled detention basins are summarised in the following table (Table 19). Generally, the peak flows can be considered to meet the limiting discharge values. Minor differences were due to numerical rounding and considered to be within modelling confidence levels.

Table 19: Predicted Peak Discharges

Flow Scenario	Ohote (m^3/s)	Te Otamanui (m^3/s)	Mangaheka (m^3/s)[1.]	Rotokauri South (m^3/s)
50% AEP_{cc} Post	0.27	0.16	1.25	Refer below
10% AEP_{cc} Post	0.45	0.97	2.05	Refer below
1% AEP_{cc} Post	0.70	1.45	3.80	Refer below

1. The Mangaheka catchment discharge was inclusive of the external catchment inflows. The peak predicted flow from the ICMP area catchment for the 50%, 10% and 1% AEP_{cc} events was 0.03 m^3/s, 0.08 m^3/s and 0.57 m^3/s respectively. Therefore, any reduction in flows to meet the limiting sub-catchment discharge needs to incorporate upstream mitigation measures on the contributing external catchment. These have been covered in the Mangaheka ICMP (Adams, 2018b)

For the Rotokauri South catchment, the predicted peak discharges are the summation of the individual hydrographs from the wetlands. The requirement for additional detention volume will be need to be checked relative to the assumptions and proposed measures within the Rotokauri South sub-catchment ICMP.

8.4 Water Quality Performance

The performance of the development in regards to water quality has been assessed based on the effectiveness of the treatment options modelled within MUSIC. While a toolbox approach for on lot residential treatment is proposed within the sub-catchment ICMP, the results as modelled are considered to be representative of the effectiveness of the range of treatment options within the toolbox.

The water quality requirements were noted within Section 4.0. The water quality results have been presented for the Long-Term Rainfall event time series as modelled within MUSIC. The results have been presented for the following parameter as modelled:

- Total Suspended Solids (TSS)
- Total Phosphorus (TP)
- Total Nitrogen (TN)

The performance of the treatment train has been considered based on TSS, TN and TP generated at the nodal level, amount present immediately before wetlands, and after wetlands.

The measurement units by MUSIC were kg/year of TSS, TN and TP.

MUSIC – Pollutant Load Calculation Limitation

The calculations undertaken by MUSIC achieve a water balance at each node. However, pollutant load balancing is not undertaken. Instead outgoing pollutant loads from treatment nodes are calculated based on outflow rate and outflow pollutant concentrations. This can lead to the situation where calculated outgoing pollutant loads can exceed incoming pollutant loads.

While this was not observed in the results for this modelling, this comment has been included for reference purposes.

Table 20: WQV Design Rainfall Water Quality Performance – TSS

Subcatchment Reference	Total Generated (All Contributing Nodes) (kg/year)	Before Wetland (kg/year)	% Reduction before wetland	After Wetland (kg/year)	% Reduction by wetland	Total % Reduction
Ohote A	13448	5900	56%	586	40%	96%
Ohote B	14445	7670	47%	724	48%	95%
Ohote D	5799	2880	50%	159	47%	97%
Ohote E	5043	2610	48%	174	48%	97%
Te Otamanui	30551	27700	9%	1800	85%	94%
Mangaheka A	1501	1470	2%	159	87%	89%
Mangaheka B	3765	3610	4%	336	87%	91%
Mangaheka C	4318	4150	4%	352	88%	92%
Rotokauri South A	2007	1940	3%	149	89%	93%
Rotokauri South B	856	841	2%	65.7	91%	92%
Rotokauri South C	536	465	13%	15.4	84%	97%
TOTAL	82269	59236	28%	4520	67%	95%

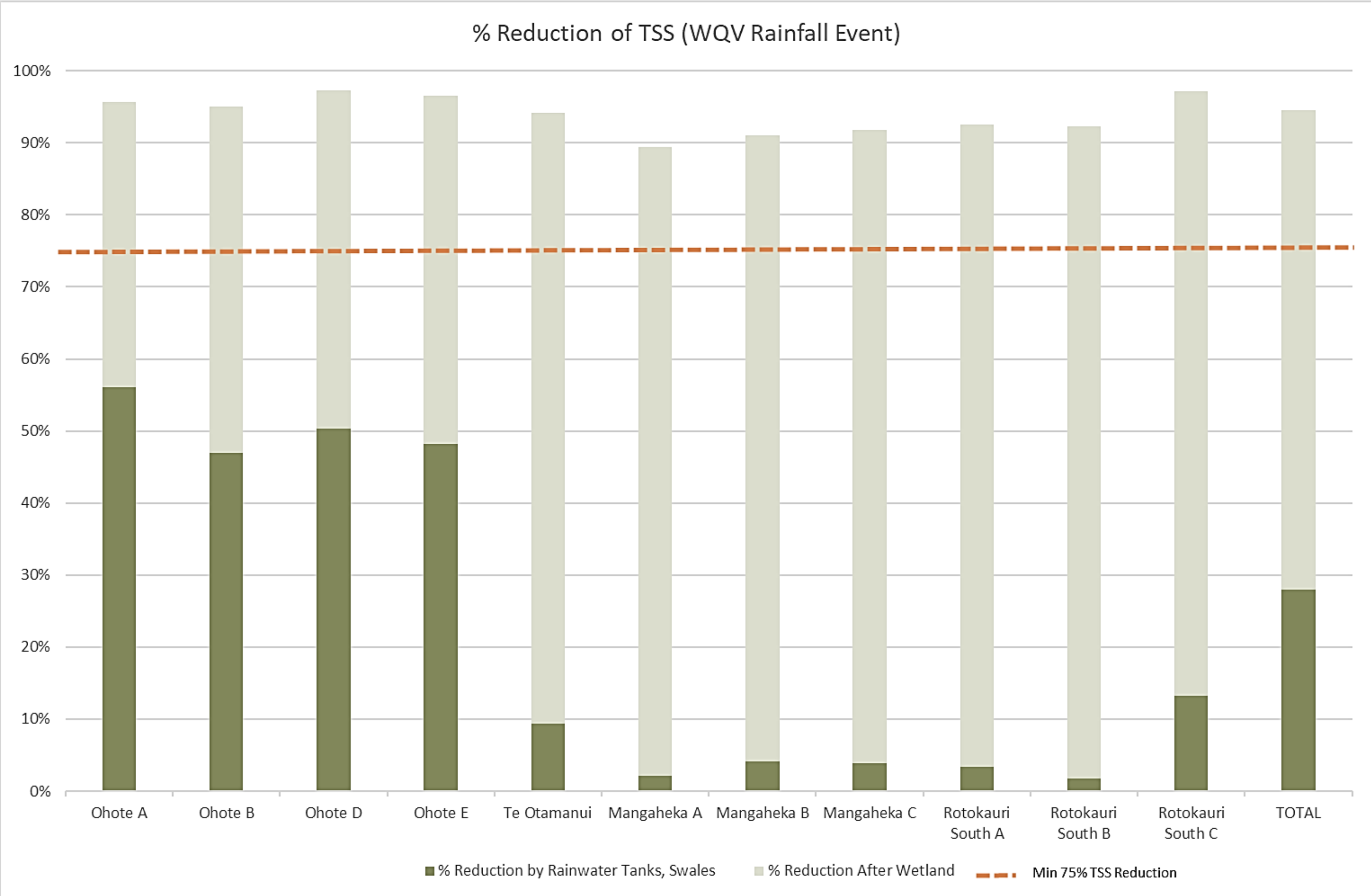

Figure 10: TSS Reduction – WQV Rainfall Event

Table 21: Long Term Rainfall Water Quality Performance – TSS

Subcatchment Reference	Total Generated (All Contributing Nodes) (kg/year)	Before Wetland (kg/year)	% Reduction before wetland	After Wetland (kg/year)	% Reduction by wetland	Total % Reduction
Ohote A	4029	2550	37%	1070	37%	73%
Ohote B	4235	2860	32%	1090	42%	74%
Ohote D	1723	1180	31%	465	42%	73%
Ohote E	1495	1060	29%	418	43%	72%
Te Otamanui	8933	8760	2%	2770	67%	69%
Mangaheka A	427	427	0%	116	73%	73%
Mangaheka B	1087	1087	0%	306	72%	72%
Mangaheka C	1251	1251	0%	327	74%	74%
Rotokauri South A	586	586	0%	141	76%	76%
Rotokauri South B	252	252	0%	53.2	79%	79%
Rotokauri South C	156	156	0%	49.8	68%	68%
TOTAL	24174	20170	17%	6806	55%	72%

Preliminary sensitivity modelling was undertaken for the wetlands predicted to not meet a long-term threshold of 75% TSS removal. Sensitivity results indicated wetland sizing to achieve 75% removal would require a substantial (100%+) increase in wetland surface area. The wetland sizing was retained as per the design completed using Auckland Council TP10 and for which the design rainfall event showed the overall treatment providing 75% removal.

The predicted TSS removal rates in for the long-term rainfall modelling in MUSIC were generally close to the required removal rate for the wetlands designed as per TP10. Considering assumptions and limitations involved in both designs as per TP10 and inputs to MUSIC, the wetlands were considered functional for the current level of investigation and design. Future wetland detailed design should consider updates to the MUSIC model based on additional field investigations and testing as completed.

Further the long-term rainfall record includes events which have a higher exceedance probability than the design rainfall event used for sizing as per TP10. Therefore, the pollutant loads included in the result tables include these larger intensity events, for which the treatment nodes have lower relative removal efficiency.

We note that the final detention basin proposed for each catchment, to ensure outflows from the catchment do not exceed 80% ED flows, will provide additional TSS polishing. Modelling and assessment of this component is ongoing.

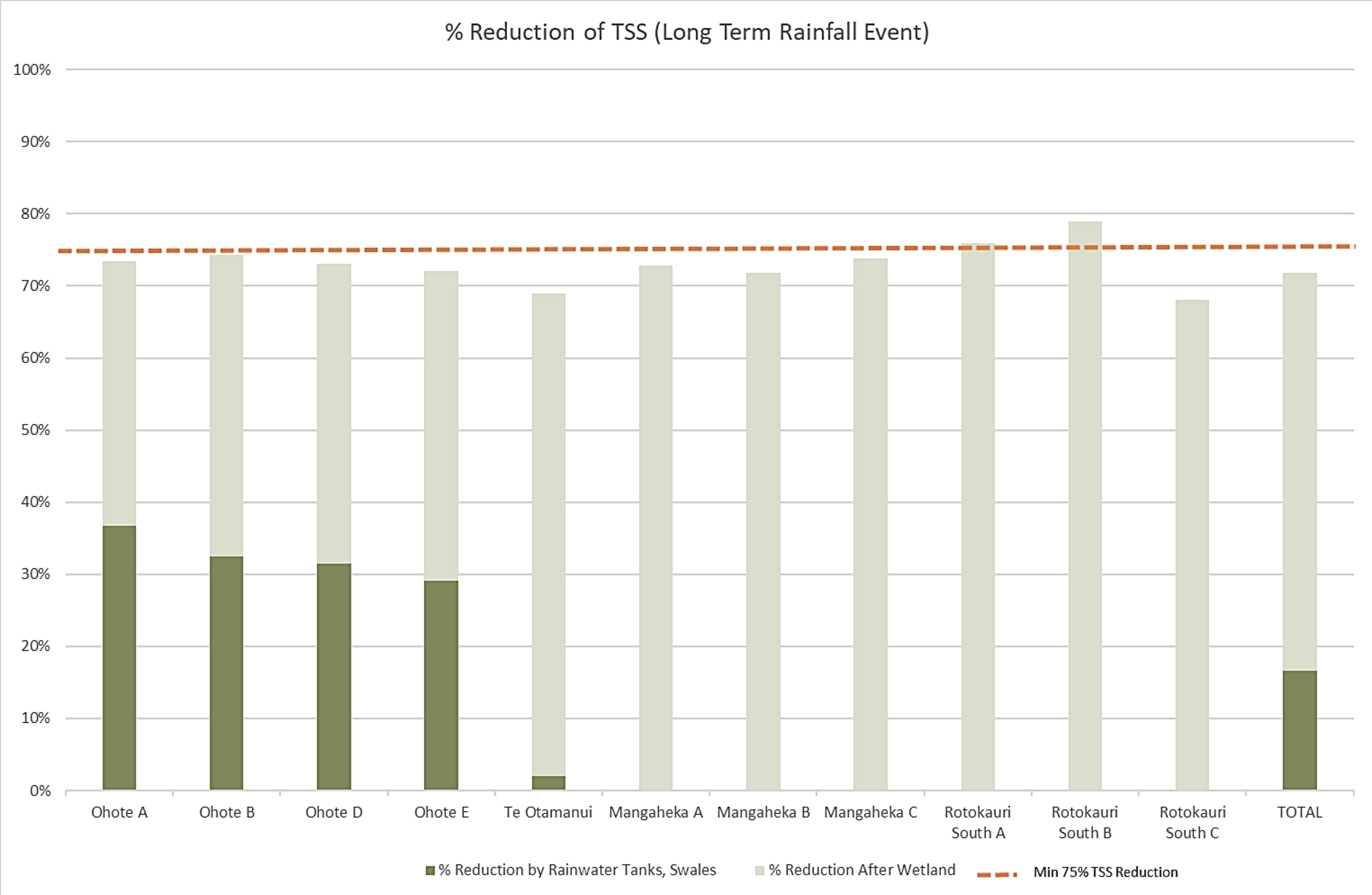

Figure 11: TSS Reduction - Long Term Rainfall

Table 22: WQV Design Rainfall Water Quality Performance - TP

Subcatchment Reference	Total Generated (All Contributing Nodes) (kg/year)	Before Wetland (kg/year)	% Reduction before wetland	After Wetland (kg/year)	% Reduction by wetland	Total % Reduction
Ohote A	200	57.2	71%	5.94	26%	97%
Ohote B	216	60.7	72%	7.34	25%	97%
Ohote D	89	32.6	64%	1.6	35%	98%
Ohote E	78	29.7	62%	1.8	36%	98%
Te Otamanui	465	407	13%	18.8	83%	96%
Mangaheka A	24	23.5	3%	2.1	89%	91%
Mangaheka B	58	55.1	6%	4.0	87%	93%
Mangaheka C	66	62.4	5%	4.1	88%	94%
Rotokauri South A	29	27.5	5%	1.7	89%	94%
Rotokauri South B	11	10.9	2%	0.7	92%	93%
Rotokauri South C	9	7.89	16%	0.2	82%	98%
TOTAL	1247	774	38%	48	58%	96%

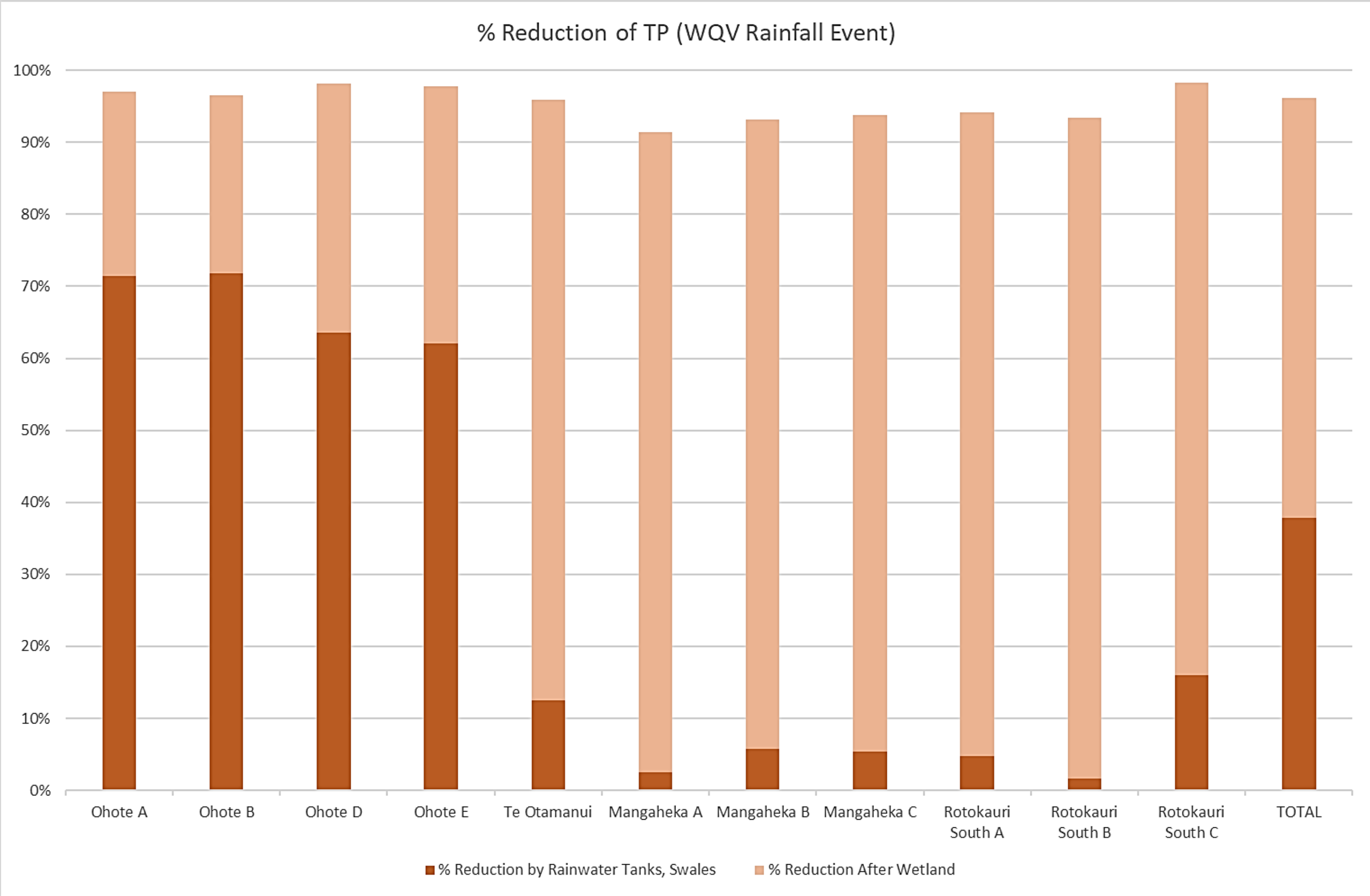

Figure 12: Total Phosphorus Reduction - WQV Design Rainfall

Table 23: Long Term Rainfall Water Quality Performance - TP

Subcatchment Reference	Total Generated (All Contributing Nodes) (kg/year)	Before Wetland (kg/year)	% Reduction before wetland	After Wetland (kg/year)	% Reduction by wetland	Total % Reduction
Ohote A	61	24	61%	11	21%	82%
Ohote B	64	23	64%	11	19%	83%
Ohote D	27	13	53%	5	29%	82%
Ohote E	23	11	52%	4	30%	82%
Te Otamanui	138	129	7%	31	71%	77%
Mangaheka A	7	7	0%	1	79%	80%
Mangaheka B	17	17	1%	4	78%	79%
Mangaheka C	19	19	1%	4	79%	80%
Rotokauri South A	9	9	1%	2	80%	81%
Rotokauri South B	3	3	0%	1	83%	82%
Rotokauri South C	3	3	2%	1	77%	79%
TOTAL	372	258	31%	74	49%	80%

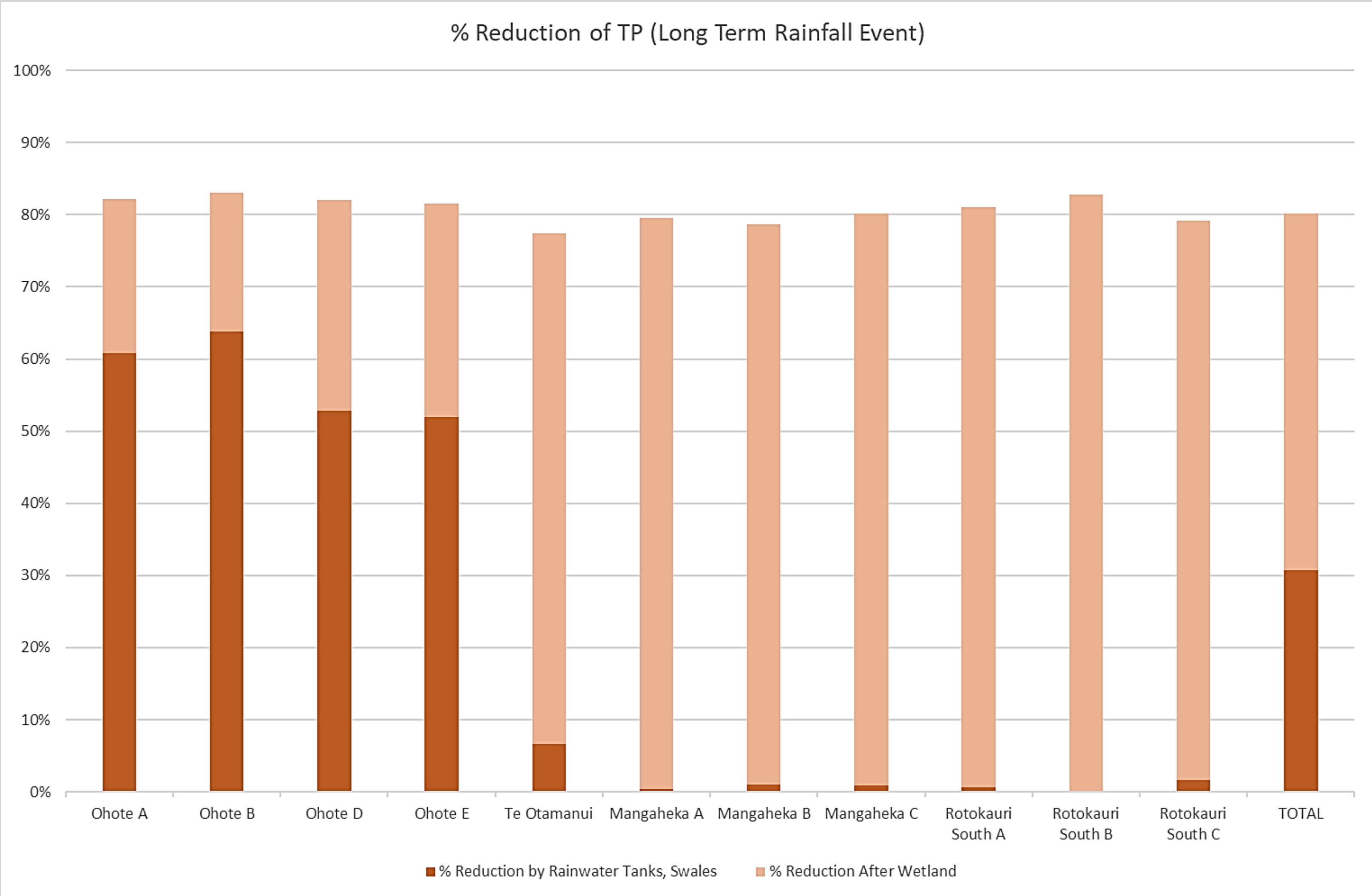

Figure 13: Total Phosphorus Reduction - Long Term Rainfall

Table 24: WQV Design Rainfall Water Quality Performance - TN

Subcatchment Reference	Total Generated (All Contributing Nodes) (kg/year)	Before Wetland (kg/year)	% Reduction before wetland	After Wetland (kg/year)	% Reduction by wetland	Total % Reduction
Ohote A	833	544	35%	108	52%	87%
Ohote B	832	597	28%	134	56%	84%
Ohote D	374	233	38%	28.5	55%	92%
Ohote E	327	204	38%	31.7	53%	90%
Te Otamanui	1595	1230	23%	325	57%	80%
Mangaheka A	71	63	12%	25.2	53%	65%
Mangaheka B	196	153	22%	57.6	49%	71%
Mangaheka C	220	175	20%	61.4	52%	72%
Rotokauri South A	97	80.3	17%	26.5	56%	73%
Rotokauri South B	35	34	2%	12	64%	65%
Rotokauri South C	39	20.3	47%	2.69	46%	93%
TOTAL	4618	3334	28%	813	55%	82%

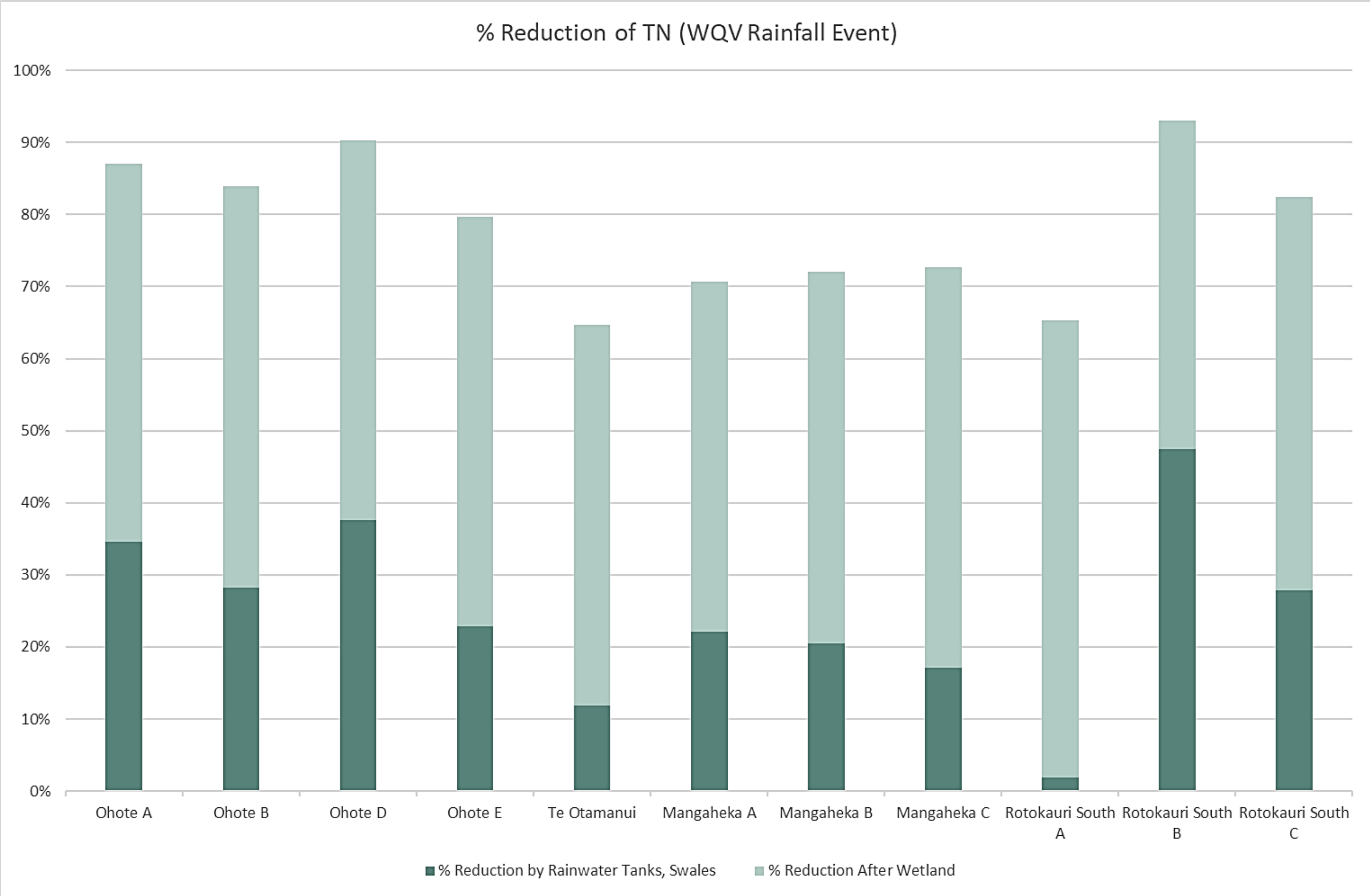

Figure 14: Total Nitrogen Reduction - WQV Design Rainfall

Table 25: Long Term Rainfall Water Quality Performance - TN

Subcatchment Reference	Total Generated (All Contributing Nodes) (kg/year)	Before Wetland (kg/year)	% Reduction before wetland	After Wetland (kg/year)	% Reduction by wetland	Total % Reduction
Ohote A	238	223	6%	180	18%	24%
Ohote B	236	226	4%	182	19%	23%
Ohote D	106	98	8%	79	18%	26%
Ohote E	92	85	8%	69	17%	25%
Te Otamanui	456	456	0%	358	22%	22%
Mangaheka A	20	20	0%	17	16%	16%
Mangaheka B	56	52	7%	45	13%	19%
Mangaheka C	63	63	0%	50	20%	20%
Rotokauri South A	28	28	0%	22	20%	20%
Rotokauri South B	10	10	0%	9	18%	18%
Rotokauri South C	11	9	15%	8	11%	26%
TOTAL	1316	1270	3%	1019	19%	23%

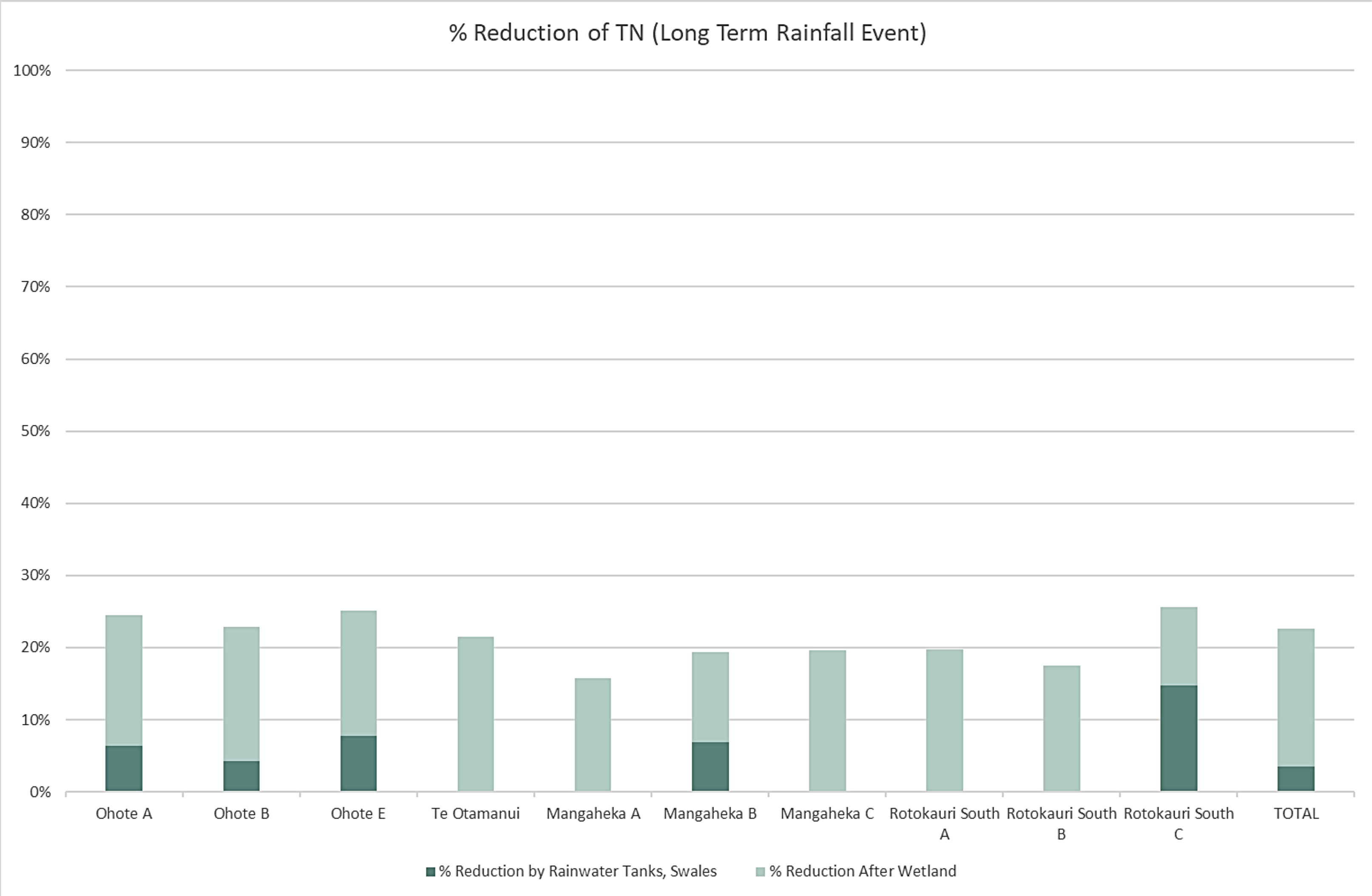

Figure 15: Total Nitrogen Reduction - Long Term Rainfall

Water Quality Results Commentary

Inspection of the water quality results indicates that the larger wetlands appear to be oversized with regards to their performance. Conversely the smaller wetlands, while meeting the quality parameters, appear to be undersized when compared with the performance of the larger wetlands.

The design rainfall event when applied to the MUSIC model shows that the wetland design, and upstream swales and rainwater tank provided positive water quality outcomes. The design rainfall event modelled using MUSIC confirms that the design of the wetlands in accordance with TP10 provides the required reduction in TSS, TP and TN. The long-term rainfall, which includes higher probability rainfall events than those used for TP10 wetland design, provides positive water quality outcomes albeit short of the required reduction quantities for TSS. The higher probability rainfall events within the long-term rainfall series when modelled would have higher pollutant loads (TSS, TP, TN) than those for which the wetlands were designed. As noted previously, preliminary increases in wetland sizes did not achieve overall reduction of TSS to greater than 75%. Due to the differences in modelling of design rainfall events compared with long term rainfall (including higher probability events), the wetlands are considered to be appropriately sized.

8.5 Soil Storage Capacity Sensitivity

The MUSIC model soil storage was based calculated based on Group B soils and Curve Number (CN) of 69. Model sensitivity was assessed by calculating the soil storage based on Group C soils Curve Number of 79. The resultant soil storage capacity was 68 mm based on Equation 5-2 WRC SRM (2018). The field capacity value was also adjusted to 54mm corresponding to 80% of the Soil Storage Capacity.

The Water Quality Volume event was simulated with the adjusted soil storage capacity, and peak flow results exported for the wetlands. The table (Table 26) below shows the peak inflows predicted for the base WQV results and the sensitivity results.

Table 26: Soil Storage Capacity Sensitivity Hydraulics Summary (WQV)

Subcatchment Reference	**Base**		**Sensitivity**	
	WQV Peak Flow before Wetland (L/s)	**WQV Peak Flow after Wetland (L/s)**	**WQV Peak Flow before Wetland (L/s)**	**WQV Peak Flow after Wetland (L/s)**
Ohote A	71	17	71	17
Ohote B	86	21	86	21
Ohote D	47	6	47	6
Ohote E	39	6	39	6
Te Otamanui	185	18	185	18
Mangaheka A	17	4	17	4
Mangaheka B	33	6	33	6
Mangaheka C	27	7	27	7
Rotokauri South A	10	3	10	3
Rotokauri South B	4	1	4	1
Rotokauri South C	2	<1	2	<1

The sensitivity results suggest no change to the predicted peak flows. Based on these model predictions the model results are considered insensitivity to changes to the soil group and related CN.

9.0 SWALE NETWORK HYDRAULICS

HEC-RAS was used to model the swale and conveyance channel network for the critical reaches, to demonstrate performance of the proposed swale and channel sizes. Two major upstream inputs to the swale conveyance from external catchments were included within the model.

HEC-RAS was used to develop a series of reaches with cross sectional dimensions as per the previous swale/channel design table. The invert levels for the network were based on the interim levels developed as part of the Qualifying Development (QD) subdivision design (on going).

9.1 Flow Scenarios

The 1% Average Exceedance Probability 24-hour design rainfall event including climate change allowance was modelled.

9.2 Model Configuration

The HEC-RAS model was configured as a one-dimensional network using steady flow analysis to determine the suitability of the swale and channel sizes, and required detention storage areas.

Flow conditions within each reach were based on aggregate of peak flows for the contributing upstream subcatchments.

Wetlands were configured with design water level as corresponding to the Extended Duration Level.

Two models were built, to consider the critical hydraulic path for, the Ohote A Wetland Catchment (Qualifying Development) and the Te Otamanui Wetland Catchment. The critical hydraulic path has been shaded in the figures below.

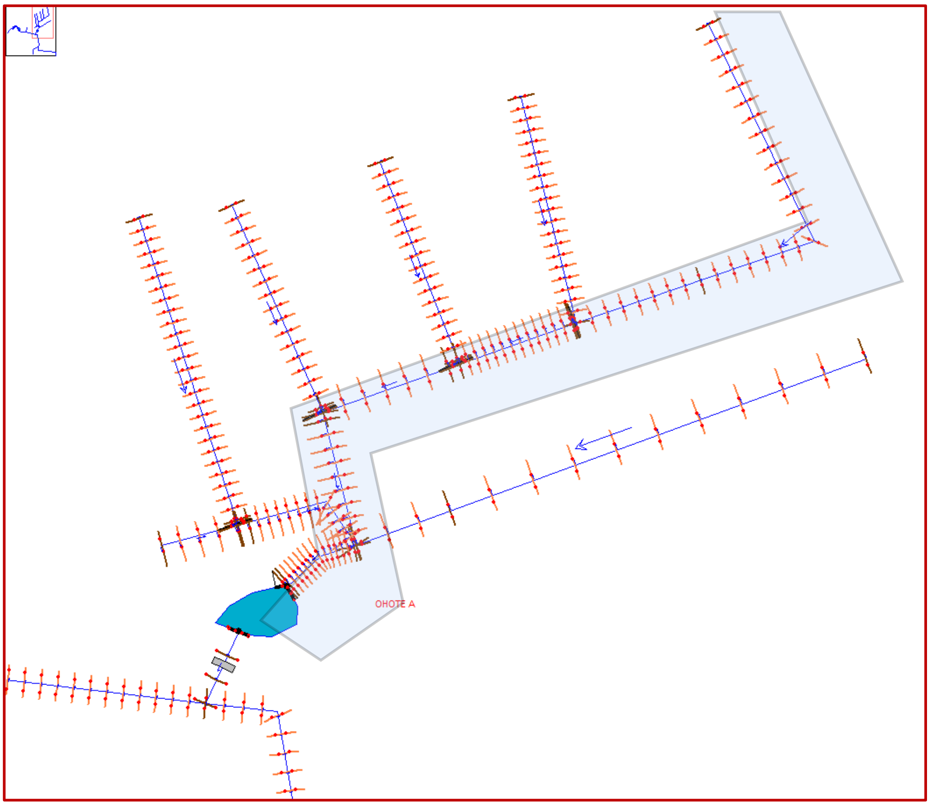

Figure 16: Ohote A Wetland Swale Network

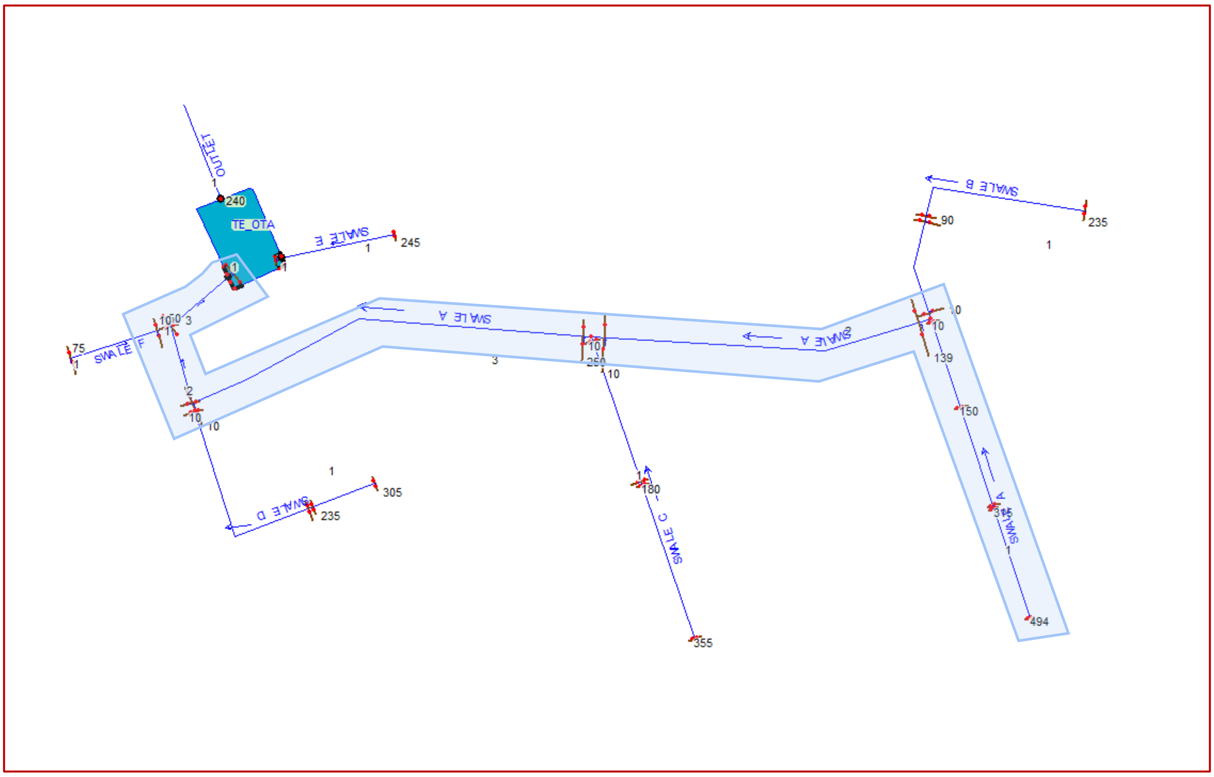

Figure 17: Te Otamanui Wetland Swale Network

Road Network

Parts of the Plan Change area were designed to use the road/carriageway for conveyance of stormwater flows. The road network used for stormwater conveyance of smaller catchments were modelled as standard dual cross fall roads, with the gutter invert matching the gutter invert of the downstream swale profile.

For model stability purposes a weir was added at the connection point of the road to the swale network. The weir profile matched the immediate upstream road profile so as to allow for numerical simulation engine stability where the flow would fall from road level into the lower swale network.

The carriageways used for conveyance were local roads with a fixed 6.0m wide carriageway.

Vegetated Swales

The vegetated swales were modelled with Manning 'n' of 0.06 (Flood plain, brush) for the 1%AEP_{cc} flows. This differs from the value of 0.25 as per RITS, however adopting that value was considered to be too conservative and likely to overestimate water depths for the 1%AEP_{cc} flows.

Conveyance Swales and Channels

These swales and channels were configured with base and sides having Manning's *n* of 0.03. The overbank areas corresponding to roadways were modelled with *n* of 0.015.

9.3 Inflow Hydrographs

Two sources were used for the inflow hydrographs for the reaches.

MUSIC modelling

A MUSIC model prepared previously predicted the inflow and outflow hydrographs for the range of water sensitive design features adopted within the Plan Change Area. MUSIC used the 24-hour design rainfall to predict the runoff from a range of catchment surfaces, and the conveyance of that runoff through the swale conveyance network.

Peak flows as predicted within the MUSIC model for the contributing subcatchments, were used as inputs for each HEC-RAS reach.

Two-dimensional catchment modelling

Previous catchment modelling of the Ohote Stream was used to determine the inflows from the two external catchments. The catchments were outside the Plan Change area but were included within catchment modelling. These areas (O-G and O-H, refer to) will contribute to flows within the Ohote catchment. Peak flows modelled for the flow scenarios were as per Table 5.

9.4 Wetlands and Detention Storage

Storage Areas within HEC-RAS were used to model the wetlands and detention areas for the ICMP area. The depth/volume relationship for the wetlands was based on the wetland design as per Section 5.2.

9.5 Ohote A Catchment Results

Inspection of the critical hydraulic path showed that the road carriageway and swale network was able to convey the 1%AEP_{cc} flows. The road carriageway flows were predicted to slightly overlap onto front berms, with a maximum predicted depth of flow being 131 mm (from water level to kerb invert). This meets the 150mm requirement of RITS (Waikato Local Authority, 2018, Section 3.3.14.1).

Maximum velocity predicted along the road carriageway was 0.72 m/s. The resultant pedestrian safety factor of 0.09m^2/s was less than 0.4 m^2/s as per Austroads Guide (Fanning, Richard, 2013).

The footpath was not predicted to have any inundation during the 1%AEP_{cc} rainfall.

The vegetated swale and conveyance channel sections were predicted to contain all the 1%AEP_{cc} flows within the swale/channel banks.

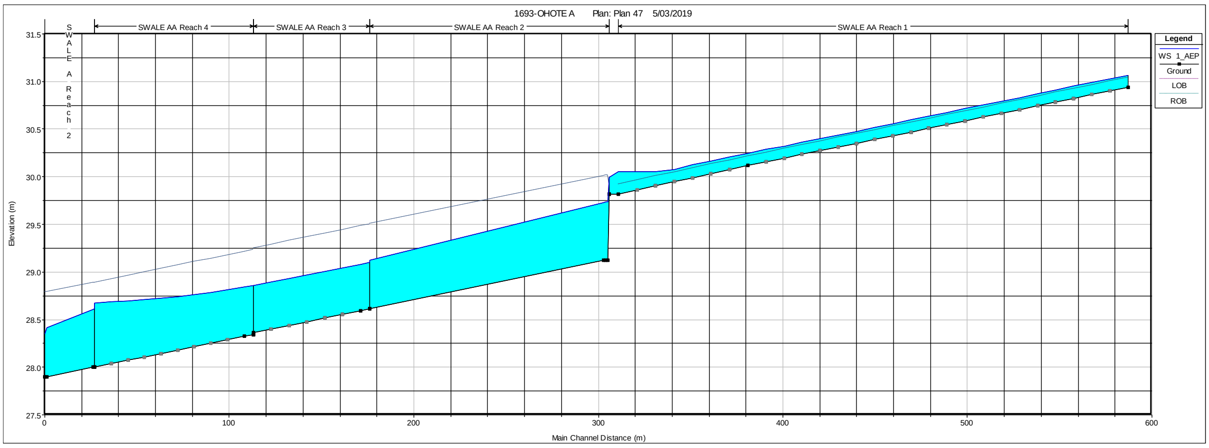

Figure 18: Ohote A Critical Hydraulic Path – 1%AEP_{cc} Results

The maximum velocity within the swales and channels was predicted to be 1.5 m/s, which was comparable with the RITS maximum of 1.5 m/s.

Refer to selected results as per Appendix G –Swale Hydraulic Results.

9.6 Te Otamanui Catchment Results

Inspection of the critical hydraulic path showed that the road carriageway and swale network was able to convey the 1%AEP_{cc} flows. The road carriageway flows were predicted to slightly overlap onto front berms, similar to the Ohote A results. The footpath was not predicted to have any inundation. The maximum predicted depth of flow 149 mm (from water level to kerb invert). This meets the 150mm requirement of RITS (Shaver, 2018, Section 3.3.14.1).

Maximum velocity predicted along the road carriageway was 0.79 m/s. The resultant pedestrian safety factor of 0.12 m^2/s was less than 0.4 m^2/s as per Austroads Guide Part 5A (Fanning, Richard, 2013).

The footpath was not predicted to have any inundation during the 1%AEP_{cc} rainfall.

The vegetated swale and conveyance channel sections were predicted to contain all the 1%AEP_{cc} flows within the swale/channel banks.

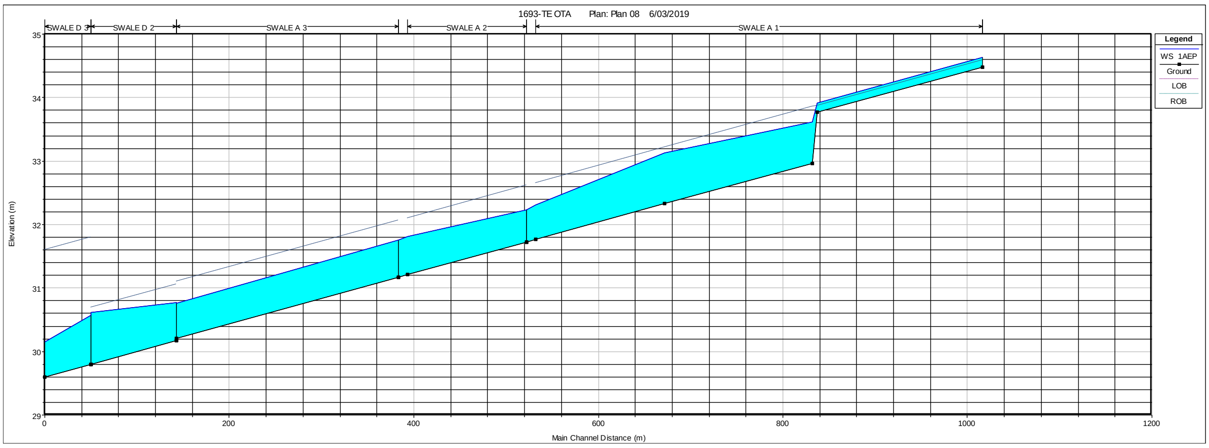

Figure 19: Te Otamanui Critical Hydraulic Path – 1%AEP_{cc} Results

The maximum velocity within the swale and channel network was predicted to be 1.83 m/s, which was greater than the RITS maximum of 1.5 m/s. Inspection of the location with the highest velocity showed that this was the junction of two swales discharging into a larger conveyance channel. The swale velocity upstream of the junction was <1.5 m/s.

Detailed design of the junctions will manage any higher velocities through design features such as additional planting, rip rap and engineered drop structures.

Refer to selected results as per Appendix G –Swale Hydraulic Results.

10.0 LOW IMPACT DESIGN (LID) ASSESSMENT

A high-level water impact (Low Impact Design) assessment as per WRC TR2018/01 (2018) and HCC's Water impact assessment (2016d) was undertaken as per the following table (Table 27).

Table 27: Low Impact Design Assessment

Implementation elements	Typical components	Maximum Individual score	Total score for each item
Source control maximised	Water re-use	0-4 depending on % of runoff capture	3
	Site disturbance reduced from a conventional development approach	0-3 depending on % of runoff capture	0
	Impervious surfaces reduced from a traditional approach	0-3 depending on % of runoff capture	1
	Use of building or site materials that do not contaminate	0 or 1 for residential 0-3 for commercial or industrial	1
	Existing streams and gullies located on site (including ephemeral) are protected and enhanced. The entire stream other than possible crossings shall be protected to qualify for points.	0 or 3	2
	Riparian corridors are protected, enhanced or created	0 or 3	3
	Protection and future preservation of existing native bush areas	0-2 depending on percentage of site area	2
LID stormwater device/practice used	Infiltration devices to reduce runoff volume	0-6 depending on % of runoff capture	1
	Revegetation of open space areas as bush	0-3 depending on % of site covered	0
	Bioretention	0-6 depending on % of runoff capture	1
	Swales and filter strips	0-3 depending on % of site covered	3
	Tree pits	0-6 depending on % of runoff capture	1
Traditional mitigation	Constructed wetlands	0-4 depending on % of runoff capture	4

Implementation elements	Typical components	Maximum Individual score	Total score for each item
	Wet ponds	0-1 depending on % of runoff capture	0
	Innovative devices	0-1 depending on % of runoff capture	0
	Detention ponds (normally dry)	0	1
Urban design	Stormwater management is designed to be an integral and well considered part of the urban design.	0-2	2
Total score			25

Based on the high-level assessment the Rotokauri North Plan Change area exceeds the minimum point value of 15 as required by WRC.

11.0 DOWNSTREAM OHOTE CATCHMENT OPTIONS

The Exelby Road culvert forms the discharge point for the Ohote catchment within the Plan Change area. As per Section 8.0 significant detention volume will be required to buffer peak flows to 80% ED. The following options have been identified for this discharge point so as to potentially lower the invert of Exelby Culvert to minimise earthwork volumes:

- Retain culvert as is;
- Upgrade culvert to allow for 80% of 1% AEP_{cc} ED flow to pass unattenuated;
- Upgrade culvert to allow for >100% of 1% AEP_{cc} ED flow.

Preliminary analysis indicates that retaining the existing culvert will require in the order of 85,100 m^3 of detention, where the flows are limited to the AECOM pre development maximum of 0.7m^3/s.

Increasing the culvert to allow 80% of the McK 1% AEP_{cc} ED flow modelling to pass unattenuated (1200mm Culvert, Q = 2.58m^3/s), reduces detention requirements to approximately 30,000 m^3.

Increasing the culvert further to allow >100% of McK 1% AEP_{cc} ED flow to pass unattenuated (1500mm Culvert, Q = 5.00m^3/s), reduces detention requirements to approximately 23,000 m^3.

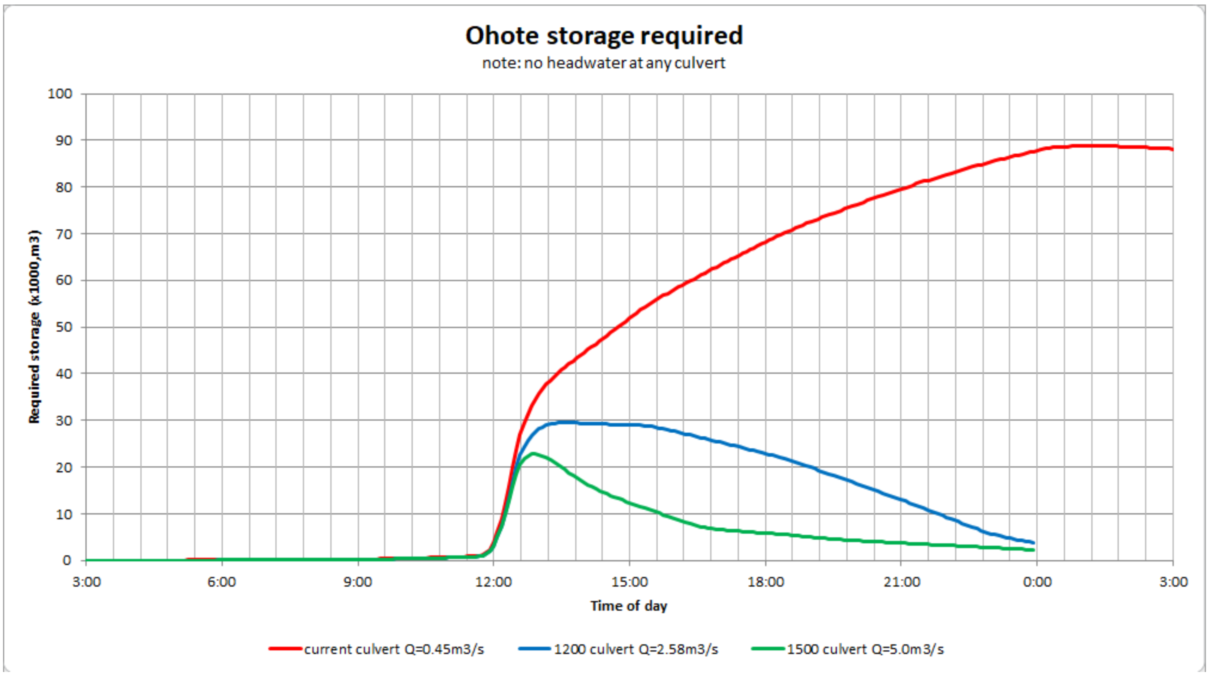

Figure 20: Ohote Storage Requirements

11.1 Downstream Ohote Modelling

Sensitivity modelling on the Ohote Stream downstream of the PPC and ICMP areas was undertaken using HEC-RAS. A one-dimensional model of the existing stream from Exelby Road to Duck Road was created, with stream cross sections derived from a digital elevation model from Lidar flown July 2018.

The following figures show the extent of the modelling, and digital elevation model used for generating cross sections.

The sensitivity modelling considered a range of increasing peak flows from the PPC and ICMP areas, nominally corresponding with different values for the 1%AEP_{cc} peak flow values.

Figure 21: Downstream Ohote Stream 1D Model (Aerial)

Refer to Appendix H –Ohote Stream Model Figure for larger figure.

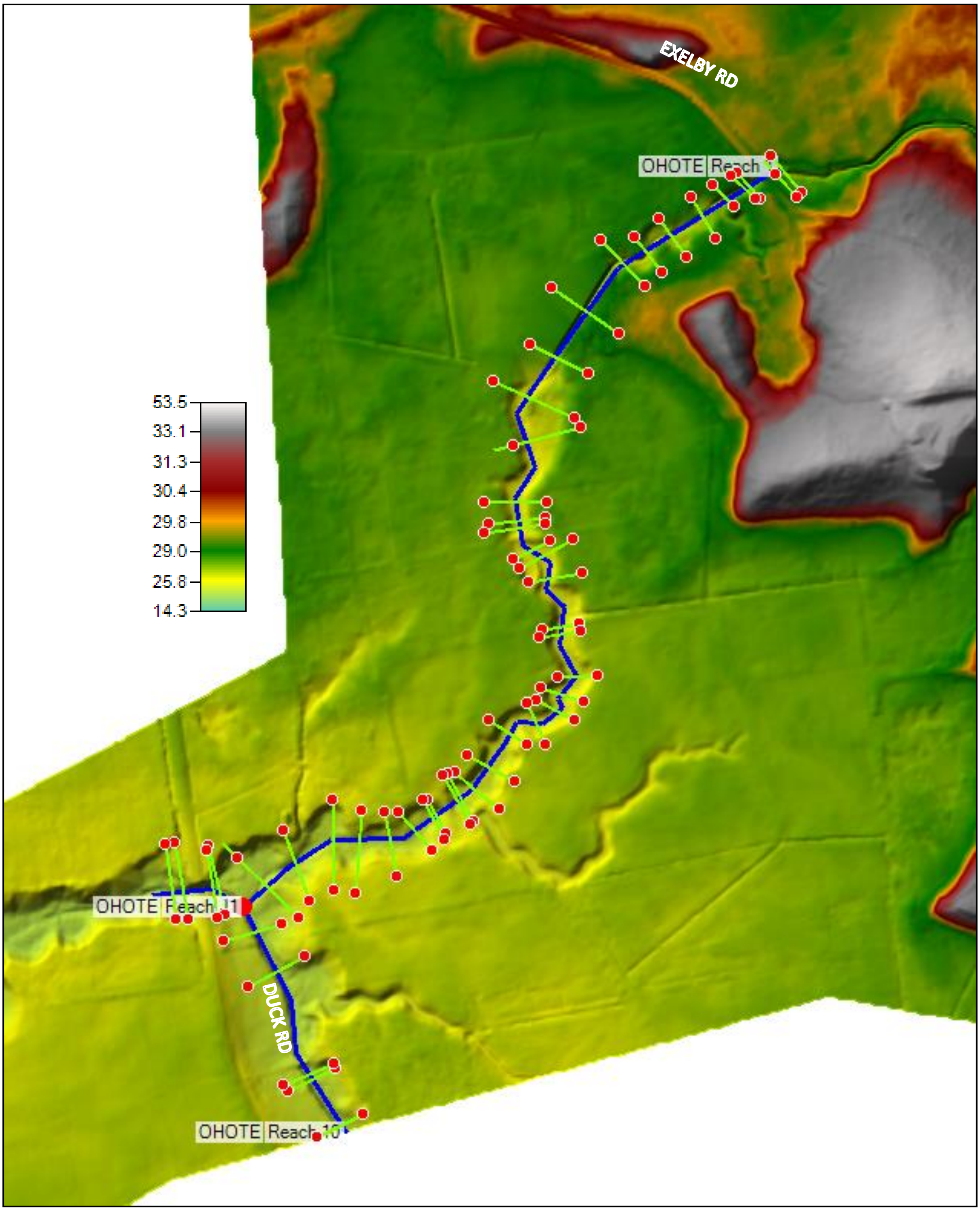

Figure 22: Downstream Ohote Stream 1D Model (Digital Elevation Model)

11.2 Digital Elevation Model Adjustment

A digital elevation model (DEM) was created within 12d software based on the LIDAR information, A small section of topography was manually adjusting such that a channel was added between Chainage 634m and 773m. This was due to a stand of trees and vegetation affecting the LIDAR measured heights. The stream was added with an assumed base width of 2.0m, and the longitudinal gradient based on matching the gradients of the upstream and downstream sections. The area of adjustment has been shown in the figure below.

The DEM was exported as raster image from 12d and used as the terrain association with HEC-RAS. Two-dimensional (2D) flow areas were defined for the stream catchments within the ICMP area.

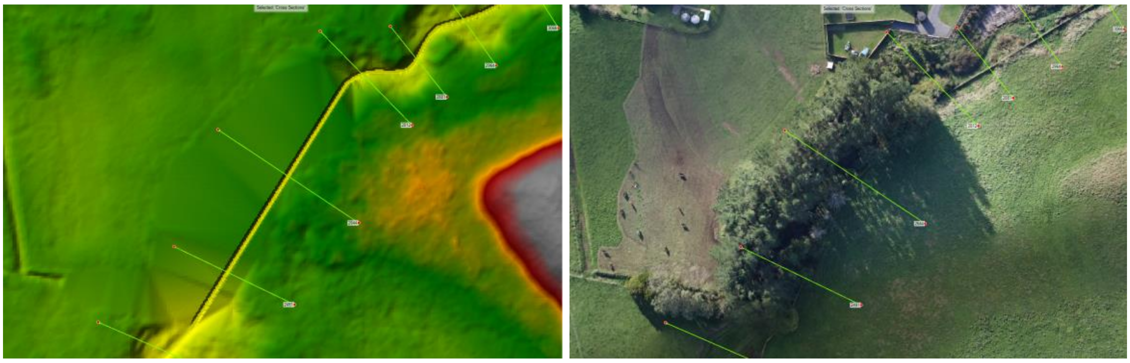

Figure 23: DEM Adjustment

Roughness values for all cross sections were Manning's n = 0.045 for all surfaces corresponding to weedy stream.

11.3 Inline Structures

Three inline structures were added to the model based on inspection of the aerial photography. The main structure modelled was the single lane Duck Road culvert, which was modelled with 5.6m span, 2.8m height and 5.5m width. Embankments either side of the bridge were modelled as per the figure below.

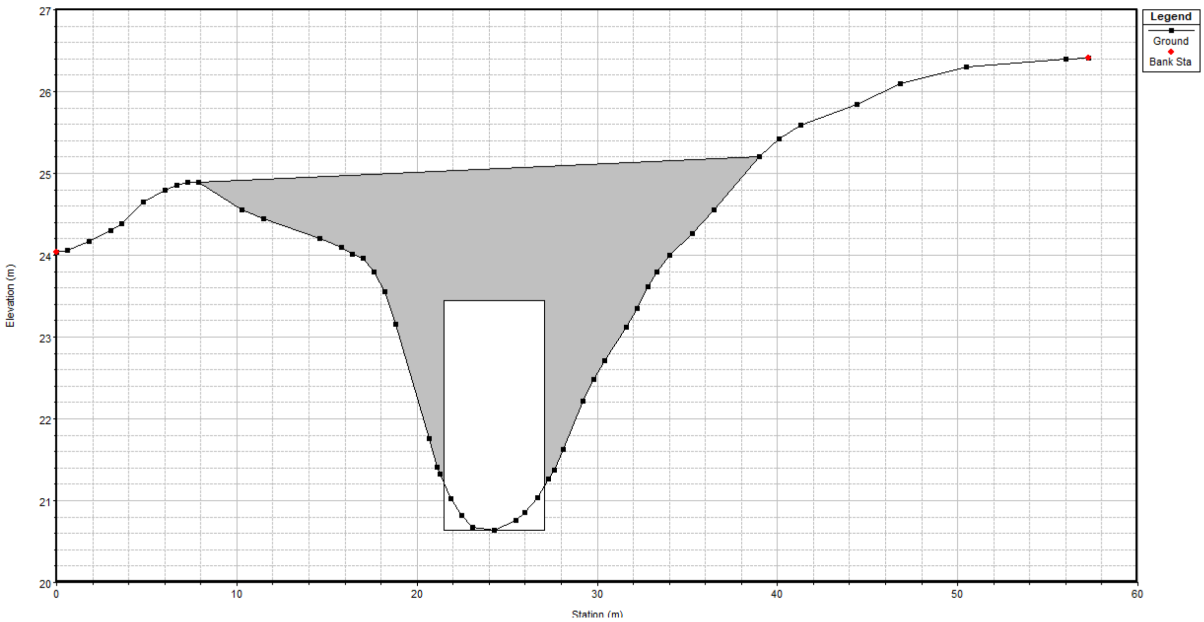

Figure 24: Duck Road Culvert

The other two inline structures were farm culverts added at Chainage 180m and 496m. The culverts were modelled with assumed diameters of 1.05m and 0.9m respectively, based on maximum distance between farm track and stream invert. The top surface of the culverts, typically corresponding with farm access tracks, was modelled as per DEM information.

11.4 Boundary Flow Conditions

The boundary flow conditions for steady state modelling were based on 2 flow rates modelled, one for the upper reach at Exelby Road, and the other at the southern reach. The southern reach modelled inflow from Lake Rotokauri to the Ohote Stream.

Southern Reach (Lake Rotokauri)

The 1% AEP flow from Lake Rotokauri was included, based on peak flow from the modelling in support of the Rotokauri South ICMP (Hart Environmental Ltd, 2017). The modelling report (AECOM, 2016) noted that the peak flow occurring at Duck Road was 6.3 m^3/s.

The contributing peak flow from the Lake Rotokauri catchment was based on pro rata application by contributing area. The contributing areas of catchments were as per Table 28 below.

Table 28: Pro Rata Flows

Name	Description	Area (ha)	% of Contributing Catchment	Pro Rata Peak Flow (m^3s)
Lake Rotokauri	Catchment upstream of Lake Rotokauri	486.3	40.5	2.55
Exelby Road	Catchment upstream of Exelby Road, corresponds to the ICMP area.	181.2	15.1	Refer Exelby Road Section below
Exelby - Duck Road and Lake Rotokauri (E-D - LK)	Contributing area between Exelby Road (ICMP area), Duck Road and downstream of Lake Rotokauri	534.4	44.4	2.80
Total	Total catchment upstream of Duck Road	1201.9	100	6.3

The Lake Rotokauri flow of 2.55 m^3s was modelled at the end of the southern reach. The E-D-LK flow was modelled as three lateral inflow hydrographs equally spaced along the main reach between Exelby Road and Duck Road.

The lateral inflows and locations were:

- Chainage 634m = 0.93m^3/s
- Chainage 410m = 0.93m^3/s
- Chainage 157m = 0.93m^3/s

Exelby Road

Three flow scenarios were considered for Exelby Road:

- Base = 2.7 m^3/s
- Intermediate = 3.7 m^3/s
- Upper = 5.5 m^3/s

These scenarios are to consider the affect of different flow rates on the Ohote Stream, specifically velocity, erosion potential, and sedimentation potential.

11.5 Hydraulic Performance Criteria

Hydraulic performance of the stream was assessed based on Waikato Regional Council Stormwater Modelling Guidelines (Shaver, 2018), and Auckland Regional Council 'Erosion Parameters for Cohesive Sediment in Auckland Streams' (Jowett & Elliot, 2009) with specific criteria noted below:

- Maximum permissible velocity = 1.14 m/s (alluvial silts)
- Critical shear stress = 33 N/m² (Assumed). We note that critical shear stress is a function of grain size/soil type and that soils within the stream corridor have not been specifically assessed.
- Froude <1.0

11.6 Existing Stream Results

For the base case flow of 2.7 m³/s from the ICMP area, the inline farm culverts were predicted to overtop during peak flow. This contributed to instances of velocities exceeding 1.14 m/s, shear stress exceeding 33 N/m² and Froude number exceeding 1.0.

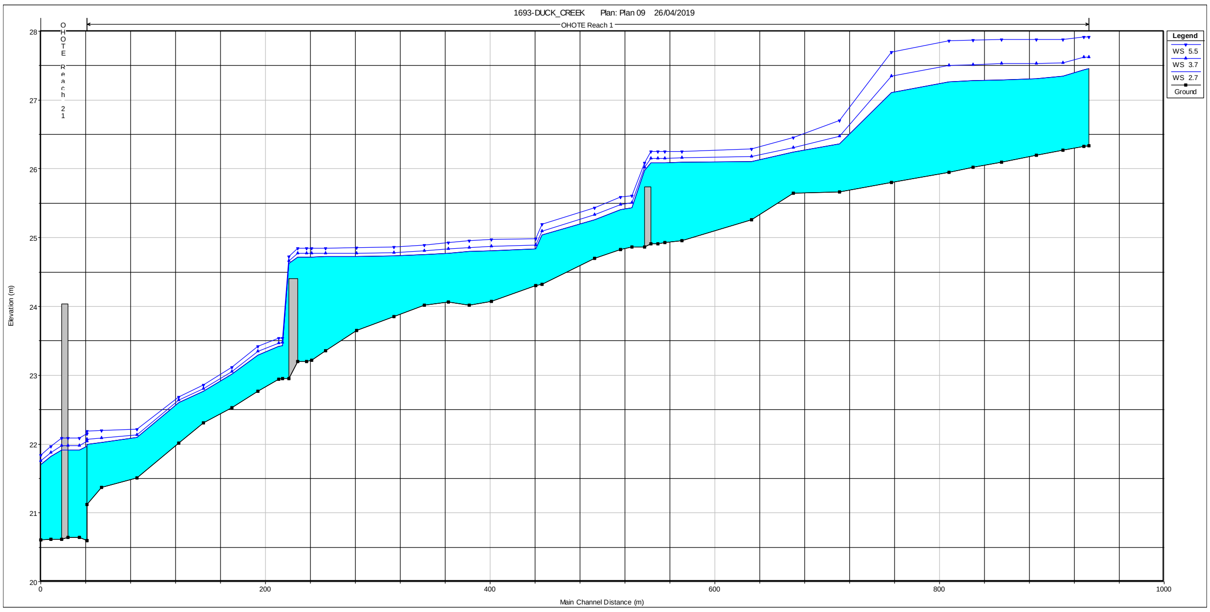

Figure 25: Existing Ohote Stream Water Profiles

The overtopping of the culverts was predicted to increase with increased flow from PPC area. Longitudinal sections showing hydraulic performance have been included within Appendix H.

The Duck Road bridge was not predicted to have any hydraulic deficiencies.

Table 29 below summarises the hydraulic performance criteria results for the Ohote Stream.

Table 29: Existing Downstream Ohote Stream Results

Results	Base (2.7 m³s)	Intermediate (3.7 m³s)	Upper (5.5 m³s)
Mean Velocity (m/s)	0.7	0.8	0.8
Median Velocity (m/s)	0.5	0.6	0.6
Maximum Velocity (m/s)	2.3	2.6	3.0
Minimum Velocity (m/s)	0.1	0.2	0.2
Mean Shear Stress (N/m²)	20	22	24
Median Shear Stress (N/m²)	8	8	10
Maximum Shear Stress (N/m²)	141	180	215
Mean Froude Number	0.34	0.35	0.35
Median Froude Number	0.29	0.28	0.28
Maximum Froude Number	1.00	1.01	1.01

The variability of the velocity, shear stress and Froude number along the alignment have been shown in the charts below, which have been included in detail in Appendix H.

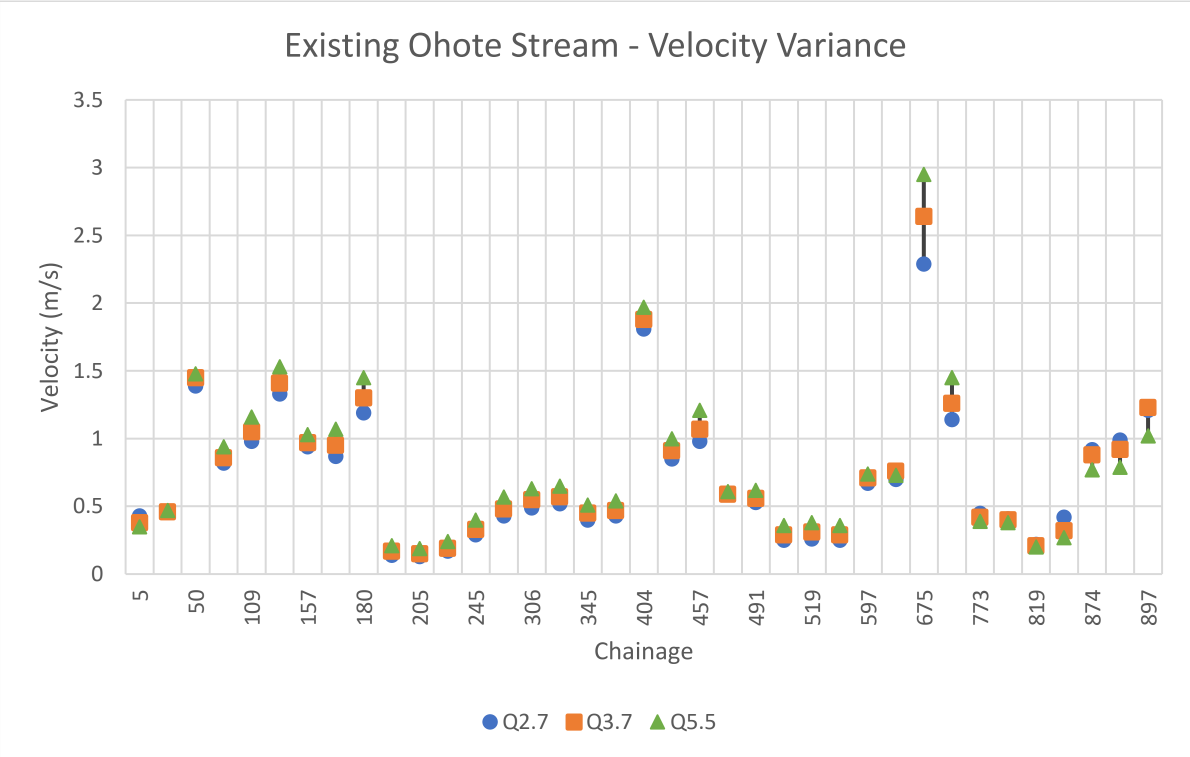

Figure 26: Existing Stream Velocity Variance

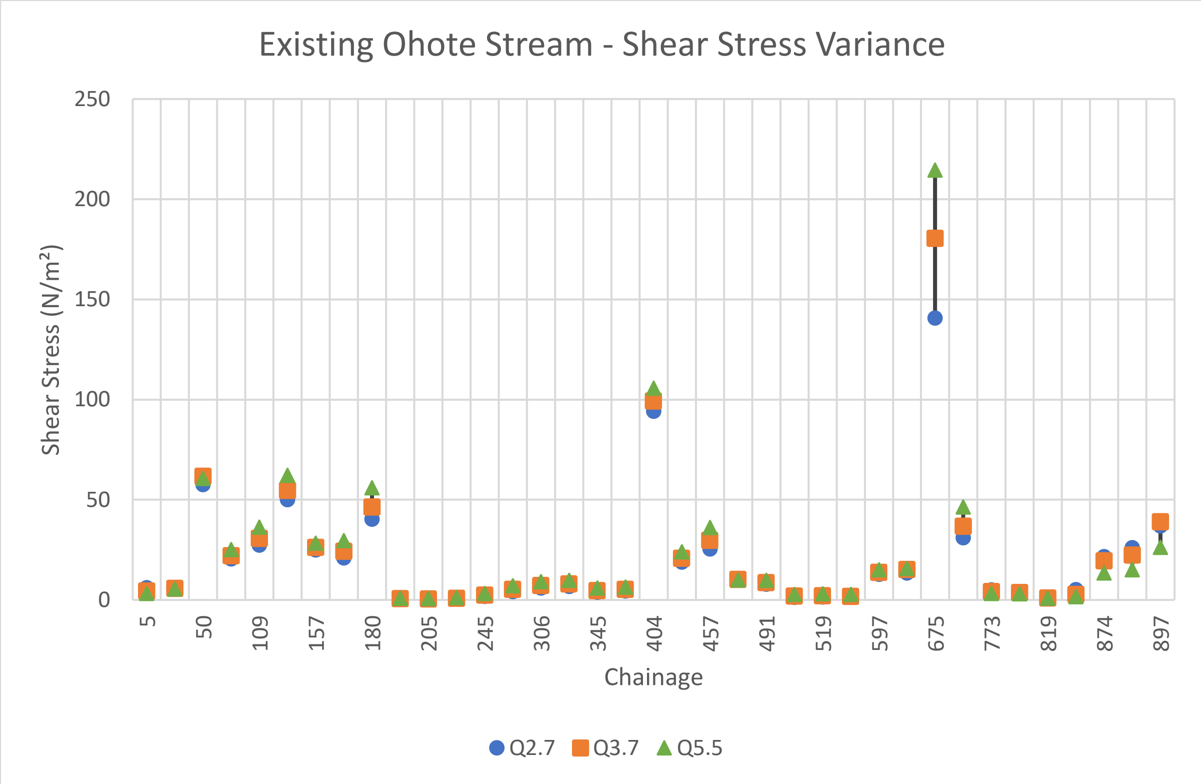

Figure 27: Existing Stream Shear Stress Variance

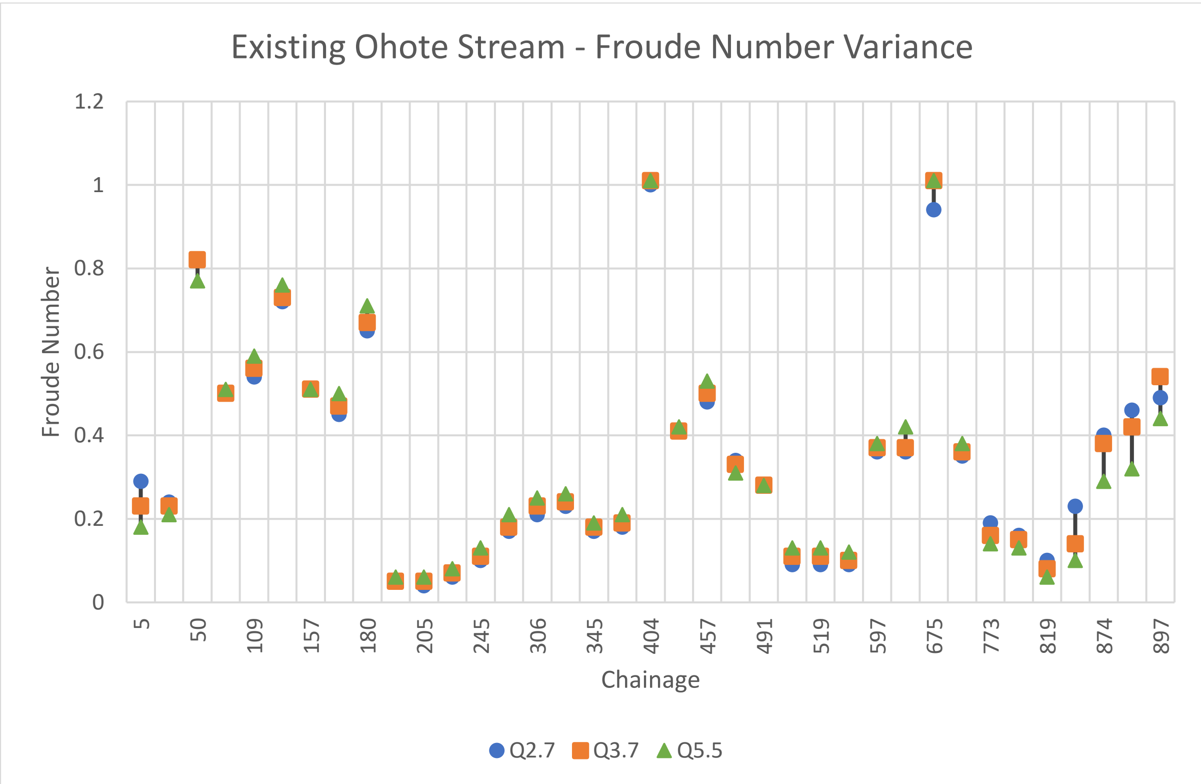

Figure 28: Existing Stream Froude Number Variance

Boxplots below, Figure 29, Figure 30, and Figure 31, give an indication of the distribution of the various parameters for each of the three flow rates. Given the median (thick black line) and the inter quartile range of each of the factors modelled are similar it is apparent that flows ranging between 2.7m^3/s and 5.5m^3/s produce similar metrics. The box plots do highlight a few outliers (stream locations with relatively high predictions): River Stations 456 (chainage 50), 1603 (chainage 404), and 2491 (chainage 675) – see Figure 32.

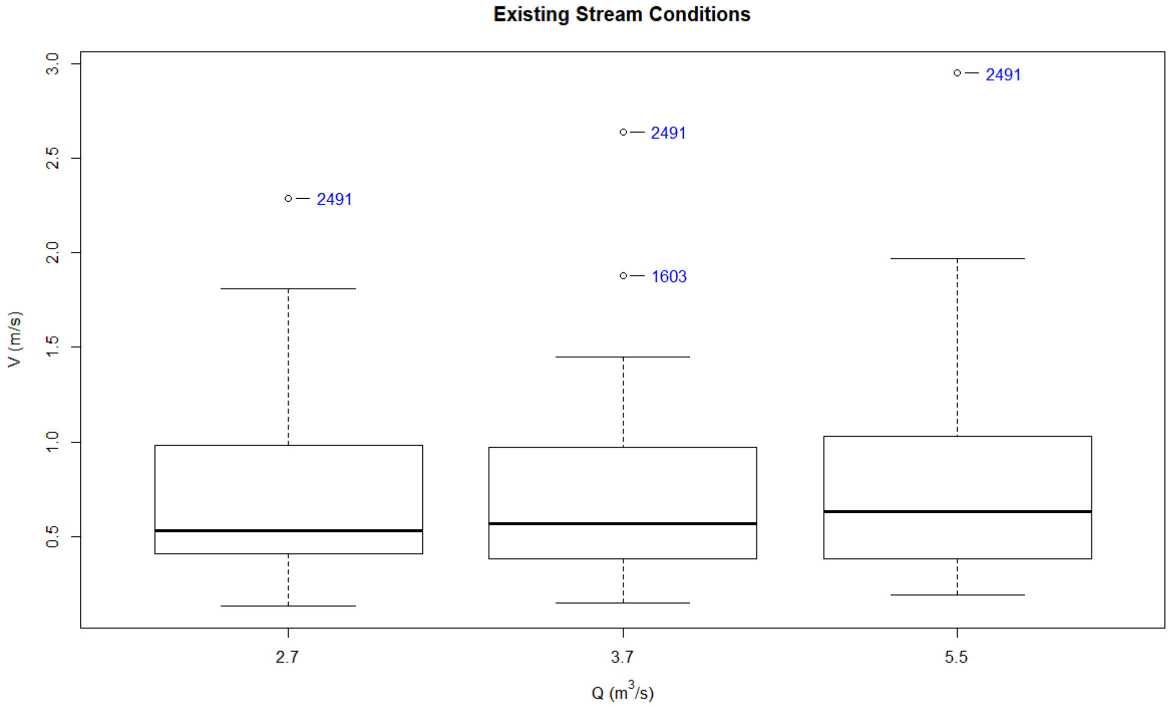

Figure 29: Exisitng Stream – Velocity Box Plot

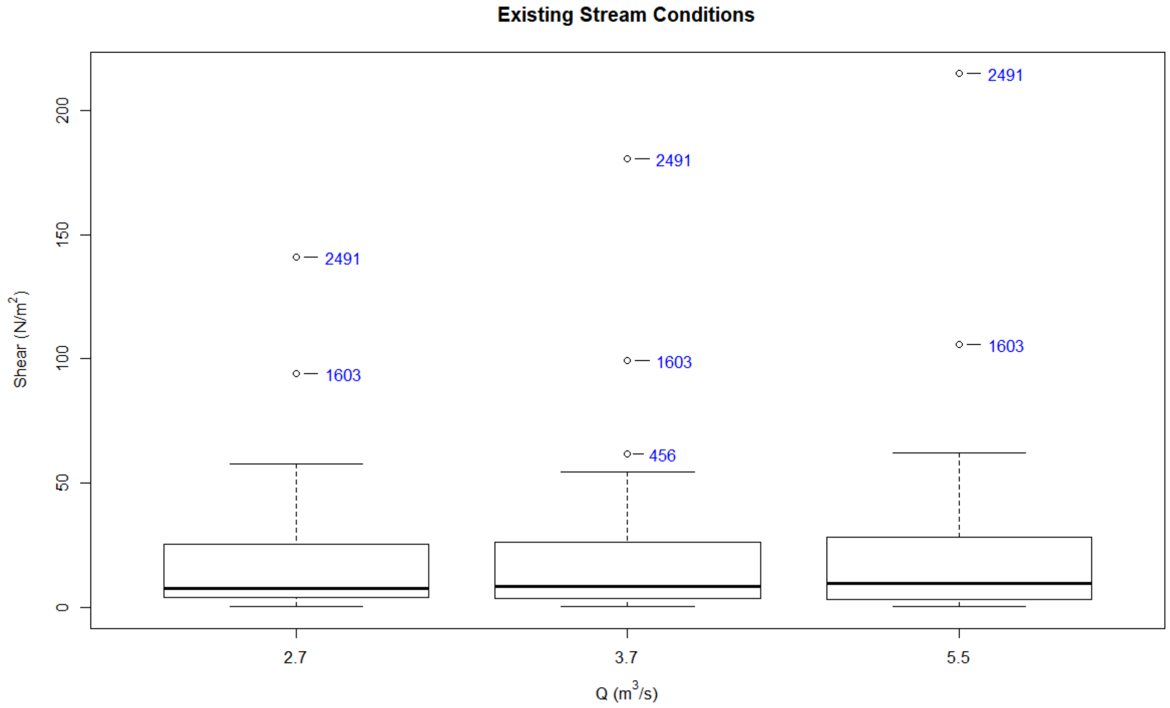

Figure 30: Existing Stream – Shear Stress Box Plot

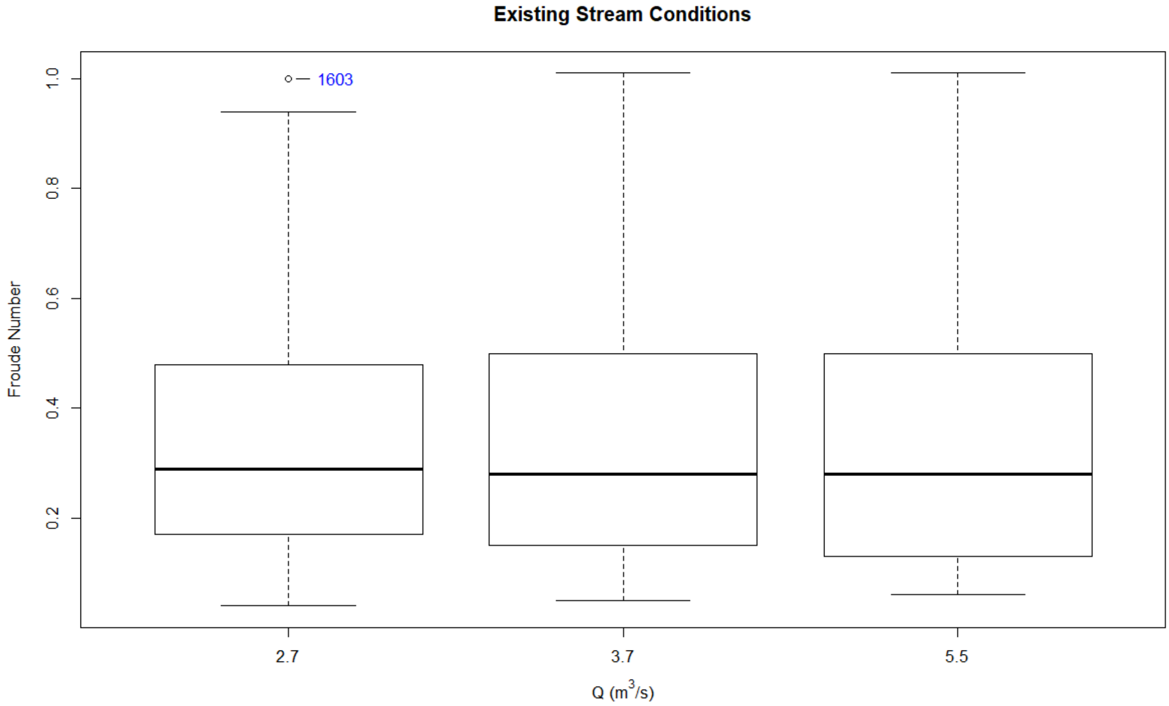

Figure 31: Existing Stream – Froude Number Box Plot

The major variance occurs at Chainage 675, which corresponded with the stream profile that was assumed due to the LIDAR being affected by vegetation. The stream profile should be revised with ground truth data from a topographical survey and remodelled. The other "hotspots" occur where the stream narrows and changes direction.

The hydraulic performance was compared with the information contained within the Morphum Environmental 'Rotokauri North Sub-Catchment – Receiving Environment and Rapid Erosion Assessment" report (Parmar, McArthur, Surrey, & Yeates, 2018). The report identified that the downstream section of Ohote Stream had minimal erosion hot spots. Refer to figure below, extracted from report. Their assessment is validated insofar as the median/average flow velocities along the stream are low, 0.5 to 0.8 m/s (less than 1.14 m/s); median/average Shear Stress are less than 33 N/m^2; and median/average Froude Numbers are less than 1.0.

Figure 32: Most Sensitive sections of Ohote Stream

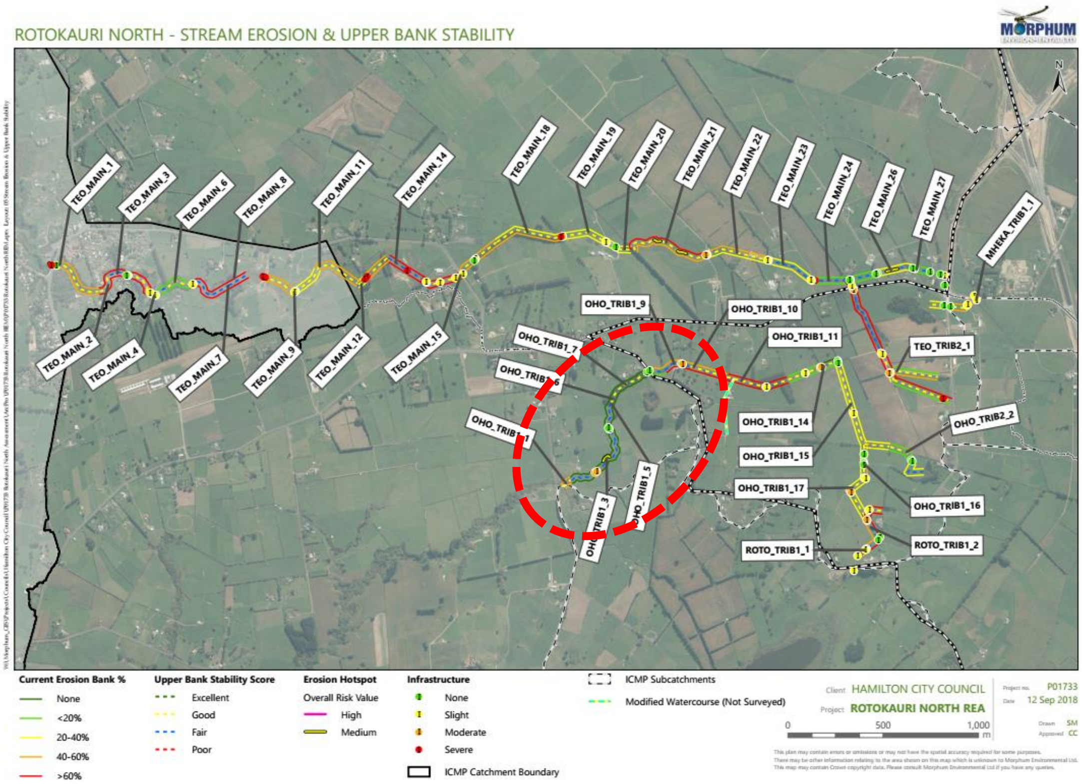

Figure 33: Stream Erosion and Upper Bank Stability (Source: Morphum Environmental)

Statistical Analysis

An Analysis of Variation (*Anova*) was undertaken to allow for comparison of the three flow scenarios. The *Anova* was completed for water level, velocity, shear stress and Froude number, with outputs of specific interest being:

- F-Ratio –measure of whether the different samples means are significantly different or not;
- n^2 value – proportion of variability between the data sets, calculated as sum of squares for between group variability divided by sum of squares for within group variability.

Critical F-Ratio ($F_{critical}$) was estimated based on alpha value of 0.05 (5%) i.e., if the F-Ratio was calculated to be within top 5% of sample data set distribution, then data sets can be considered significantly different. As the sample sizes for all data sets was the same, $F_{critical}$ was the same.

Anova results have been included within following table (Table 30).

Table 30: Anova Results

Variable	F-Ratio	$F_{critical}$	Sum of Squares (Between Group Variability)	Sum of Squares (Within Group Variability)	n^2
Water Level	0.179	3.080	1.074	325	0.33%
Velocity	0.259		0.145	30.15	0.48%
Shear Stress	0.149		347	12634	0.27%
Froude	0.001		0.000	6.88	0.00%

All estimated F-Ratio values were less than $F_{critical}$, indicating statistically the three flow scenarios were similar. Similarly, the low n^2 values indicate minimal difference in variability of the three flow scenarios.

As such, given the data and modelling, there is no significant difference with respect to erosion indicators for flow rates between $2.7m^3/s$ and $5.5m^3/s$. This suggests that differences in modelling approaches have little effect and that flow through the Exelby culvert could be increased to $5.5m^3/s$ with no additional effect on the downstream environment.

Sections of stream, for all three flow scenarios, did not meet the hydraulic design criteria. Therefore, it is expected that downstream works would be required where design criteria are cannot be met.

11.7 Downstream Works

The Morphum Environmental 'Rotokauri North Sub-Catchment – Receiving Environment and Rapid Erosion Assessment" report, Section 5.3, identified proposed downstream works for enhancement of the Ohote Stream. The hydraulic analysis of the existing stream profile indicated that there are areas where downstream works would be beneficial in achieving design criteria.

The following downstream works were modelled for the three flow scenarios based on enhancement recommendations and iterative amendment to meet the design criteria:

- Farm culverts all removed, future access across stream to be provided by oversized culverts or new stream fords;
- Planting along the whole stream to increase Manning 'n' to 0.06 (Planted floodplain).
- Greater density of planting between Chainages 0m and 180m to increase Manning 'n' to 0.1 (Dense brush).

- Cross section reshaping between Chainages 205m and 217m. Reshaping modelled as constant base width of 10m.
- Cross section reshaping between Chainages 365m and 410m. Reshaping modelled as constant base width of 8m.
- Cross section reshaping between Chainages 597m and 773m. Reshaping modelled as constant base width of 8m. Note that these works are through the area of tree vegetation and additional field survey should be undertaken to confirm stream invert levels before further design.
- Stream invert level amended at Chainage 634m to provide constant gradient.
- Cross section reshaping between Chainages 773m and 897m. Reshaping modelled as constant base width of 6m.

The proposed downstream works were consistent with the enhancement works proposed within Section 5.3 of Morphum Environmental 'Rotokauri North Sub-Catchment – Receiving Environment and Rapid Erosion Assessment" report.

11.8 Downstream Works Results

For the three flow scenarios, generally the downstream works mitigated the erosion potential for the three flow scenarios. The maximum velocity of 1.14 m/s was not exceeded for any flow scenarios, neither was the Froude number predicted to exceed 1.0.

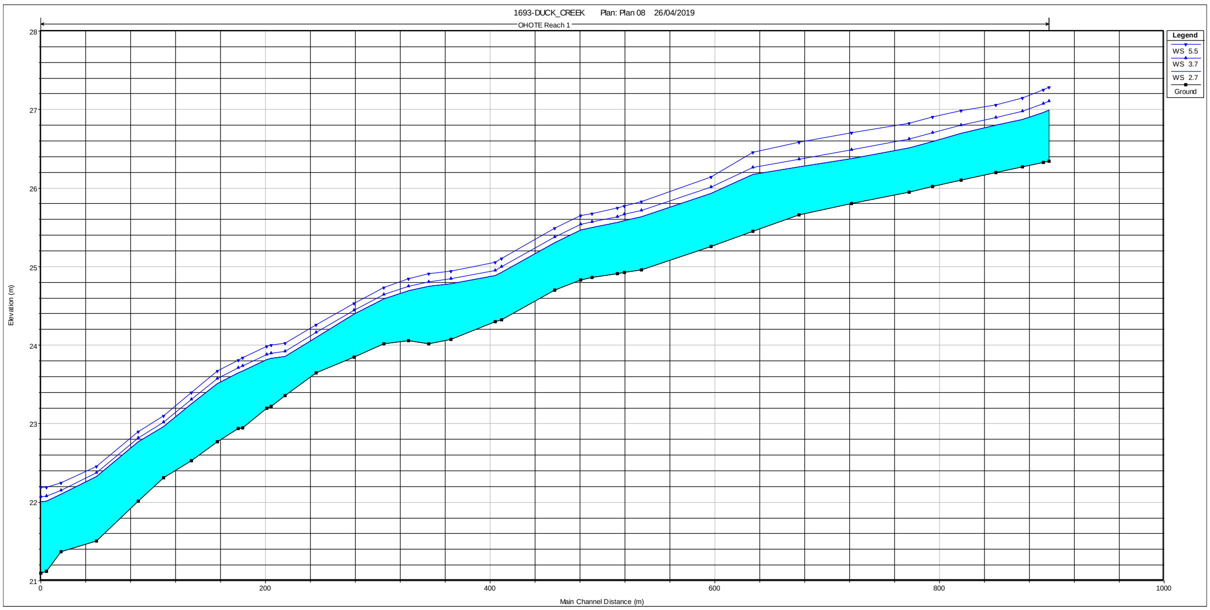

Figure 34: Ohote Stream Water Profiles After Downstream Works

Table 31: Downstream Works Ohote Stream Results

Results	**Base (2.7 m³s)**	**Intermediate (3.7 m³s)**	**Upper (5.5 m³s)**
Mean Velocity (m/s)	0.6	0.7	0.7
Median Velocity (m/s)	0.6	0.7	0.7
Maximum Velocity (m/s)	1.1	1.1	1.1
Minimum Velocity (m/s)	0.2	0.4	0.2
Mean Shear Stress (N/m²)	25	30	33
Median Shear Stress (N/m²)	21	25	26
Maximum Shear Stress (N/m²)	71	79	93
Mean Froude Number	0.29	0.31	0.31
Median Froude Number	0.28	0.28	0.29
Maximum Froude Number	0.59	0.59	0.57

In all instances, maximum values have been reduced substantially, and mean/median values are well within design specification.

The variability of the velocity, shear stress and Froude number along the alignment are shown in Figure 35 to Figure 40 below. Longitudinal sections showing hydraulic performance have been included within Appendix I.

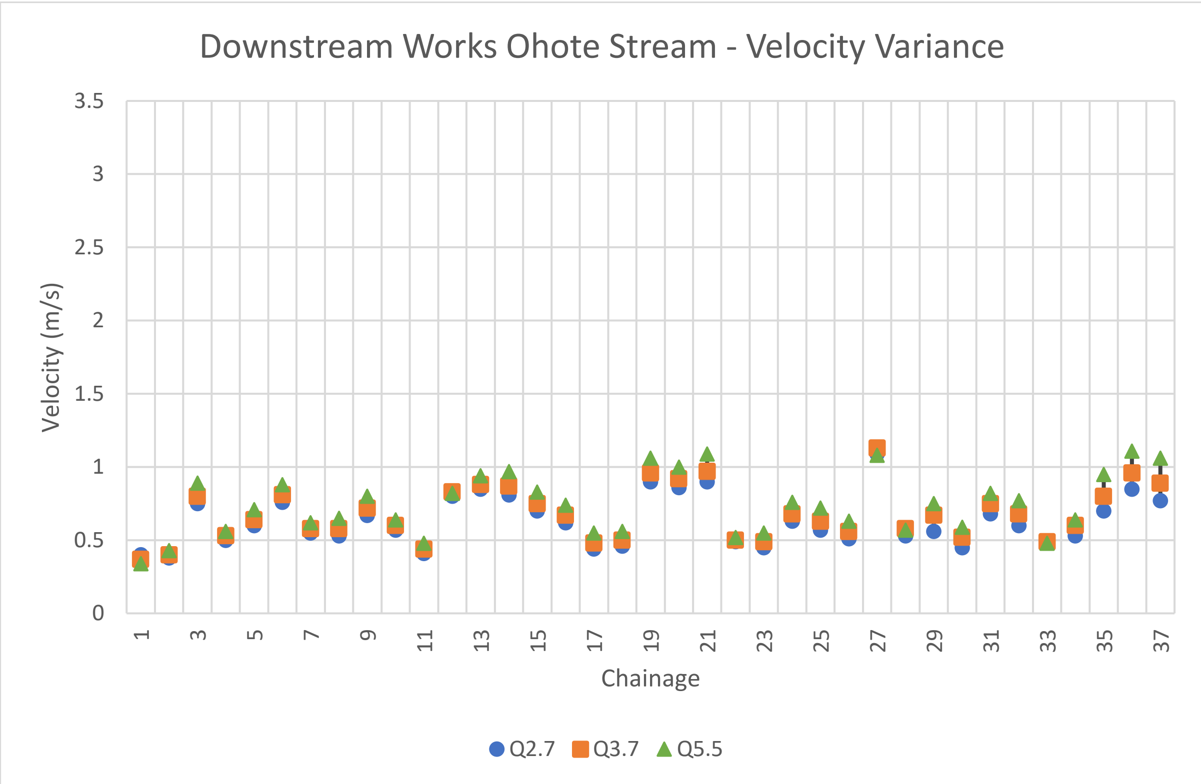

Figure 35: Downstream Works Stream Velocity Variance

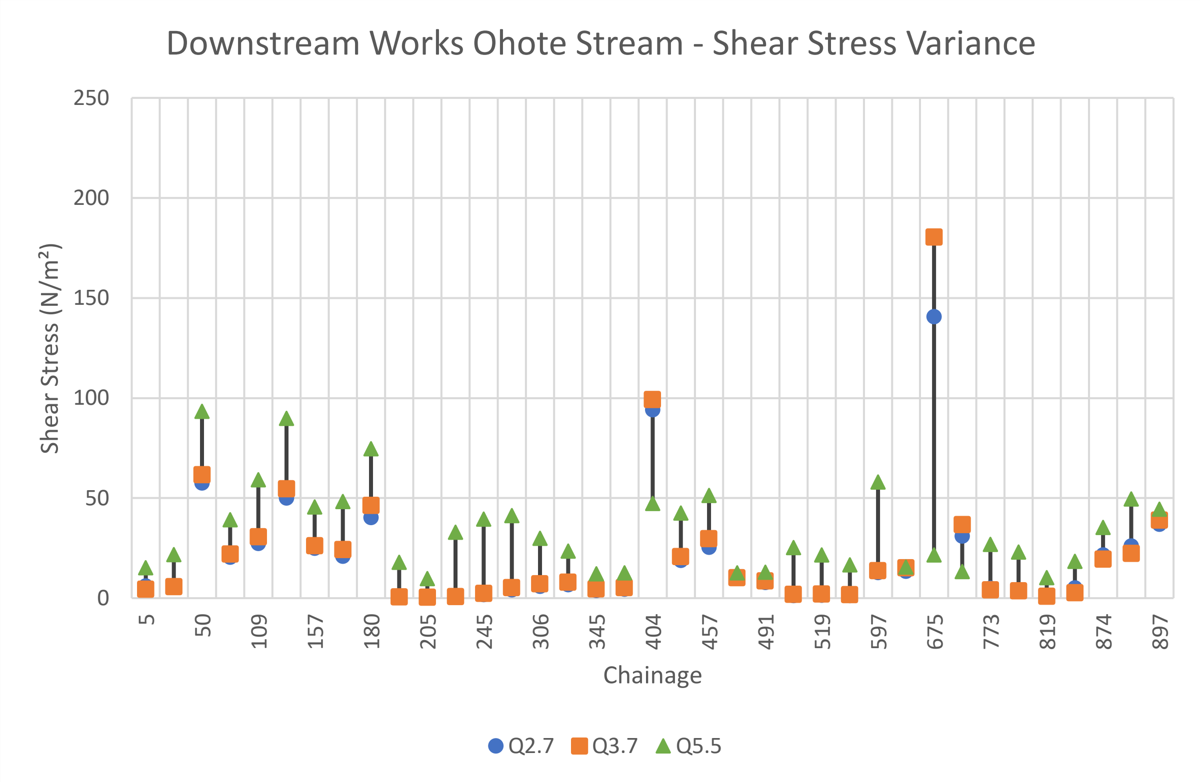

Figure 36: Downstream Works Stream Shear Stress Variance

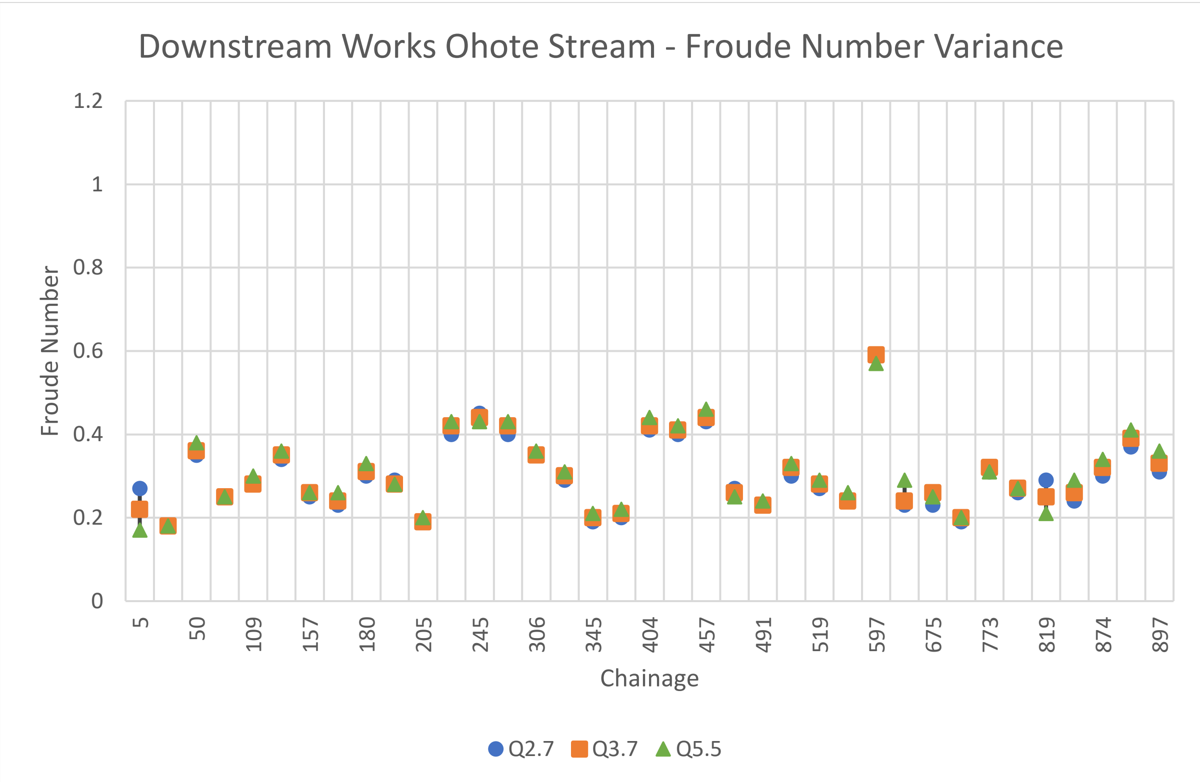

Figure 37: Downstream Works Stream Froude Number Variance

Figure 38, Figure 39 and Figure 40 show indicative distributions of each of the parameters if downstream works described above were undertaken. Figure 38 indicates that expected velocities will be consistent and less than recommended maximum velocities. Figure 39 indicates that average/median Shear forces are under the design threshold with River Stations 456 and 680 being outliers, although 680 is not an outlier at high flows. Froude Numbers are all low.

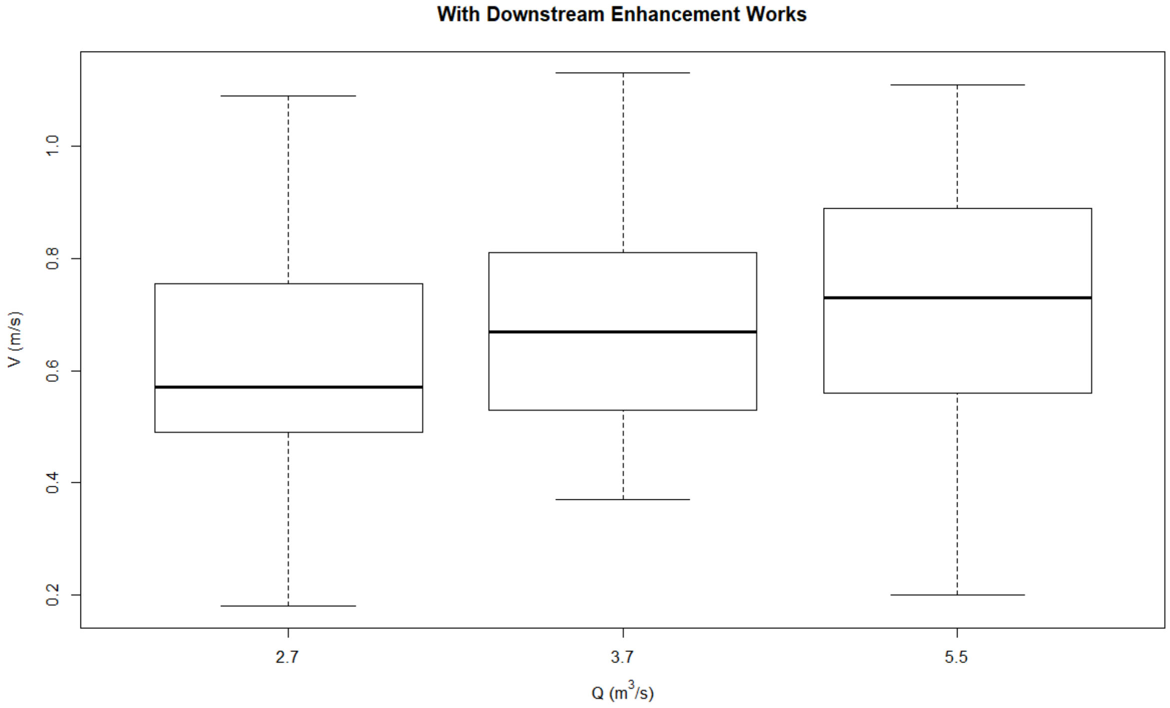

Figure 38: Downstream Works – Velocity Box Plot

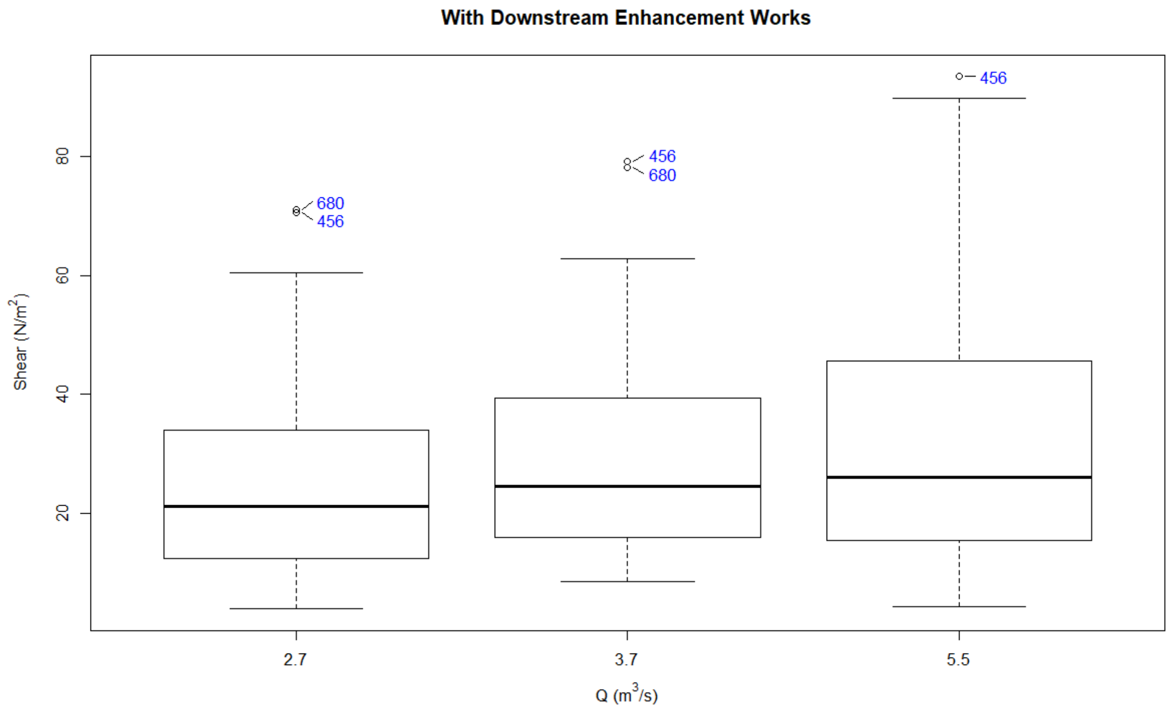

Figure 39: Downstream Works – Shear Stress Box Plot

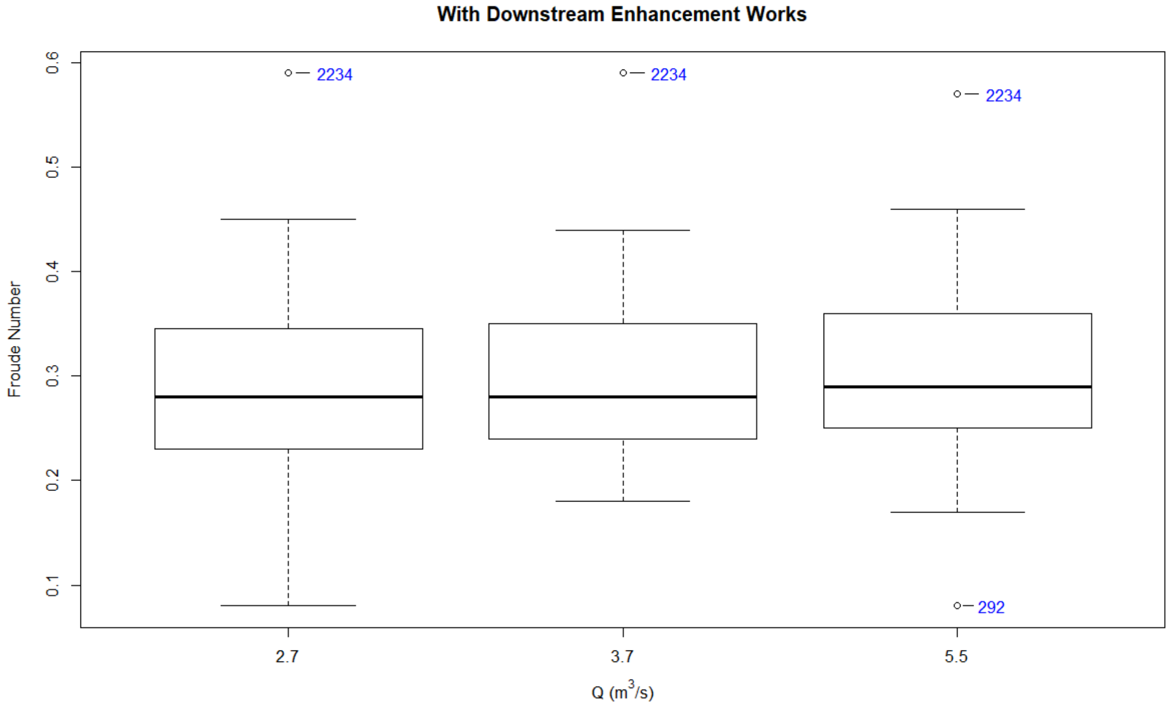

Figure 40: Downstream Works – Froude Number Box Plot

The main section not meeting hydraulic design criteria was between Chainage 50m and 180m, which exceeded the shear stress value of 33 N/m². This section of stream has a steeper gradient of 0.93% than elsewhere resulting in higher shear stresses.

With reference to Auckland Regional Council 'Erosion Parameters for Cohesive Sediment in Auckland Streams', critical shear stress values for streams are dependent on particle size distribution of the underlaying material. It is recommended that geotechnical sampling and testing, specifically particle size distribution (PSD) tests, be undertaken to inform any downstream stream works.

It is expected that a combination of PSD test results will allow for the shear stress hydraulic design criteria to be refined for actual site conditions. Stream design features can then be developed to be meet shear stress design criteria.

Statistical Analysis

An Analysis of Variation (*Anova*) was undertaken as per methodology in Section 9.6. Anova results have been included within following table (Table 32).

Table 32: Downstream Works Anova Results

Variable	F-Ratio	$F_{critical}$	Sum of Squares (Between Group Variability)	Sum of Squares (Within Group Variability)	n^2
Water Level	0.16	3.080	0.76	262	0.29%
Velocity	2.89		0.24	4.56	5.2%
Shear Stress	1.31		974	41307	2.4%
Froude	0.16		0.003	1.01	0.3%

All calculated F-Ratio values were less than $F_{critical}$, indicating statistically the three flow scenarios do not differ significantly.

Statistically, given the proposed downstream enhancement works on the Ohote Stream, flow rates over 2.7 m^3/s up to 5.5m^3/s discharged through the Exelby Road culvert (PPC and ICMP areas) would not be expected to increase the impact of stream erosion.

Summary

The hydraulic modelling and statistical analysis showed that the Exelby Road culvert could be lowered to reduce earthworks, when erosion mitigation measures were applied to downstream properties.

However, these downstream works would be within properties not within the PPC area and/or ICMP area. GSCL would be required to reach agreements with the property owners to undertake the works.

Notwithstanding potential access issues there were information gaps within the hydraulic modelling, specifically regarding topography in the area identified in Figure 23, for which additional investigation was recommended. The erosion potential, particularly critical shear stress, would require further quantification through stream bed testing to ascertain the grain size/soil type.

While there are hydraulic benefits to the PPC area and ICMP area from lowering the culvert and providing stream mitigation works, there are also a number of risks that need to be addressed (property owner consultation, topography survey, soil testing). Consultation, surveying and testing should be undertaken as part of future Resource Consenting to determine if the hydraulic benefits can be realised.

Until the risks above have been addressed the limiting discharge from the PPC area and ICMP area would be 0.7m^3/s as per the existing Rotokauri ICMP.

11.9 Recommendations

If additional discharge from the PPC/ICMP area above the Existing Development value (0.7m^3/s) were to be considered then the following are recommended:

- A detailed topographic survey of the Ohote Stream down stream of Exelby Road to confirm stream alignment, cross sectional shape, and grade.
- Grain size/soil testing to estimate critical shear stress for the Ohote Stream, i.e., what is the streams critical shear stress that activates erosion.
- Consultation with downstream property owners so as to determine likelihood of undertaking erosion mitigation measures for catchment wide benefit.

12.0 CONCLUSION

Stormwater within the Plan Change area and sub-catchment ICMP area will be managed through a water sensitive design philosophy and a suite of stormwater management measures that can be used to comply with Hamilton City Council and Waikato Regional Council retention, detention, and quality requirements within the public and private realms. The selection of a precise treatment train to meet these requirements will be determined at the subdivision consent stage.

The stormwater conveyance network and associated water quality devices were shown to manage the additional runoff from increased impervious surfaces while also marching the maximum Existing Development flows specifically for the 1%AEP_{cc} rainfall. With reference to the investigations and analyses undertaken in the Rotokauri North Private Plan Change: Catchment Modelling Report (Rudsits, 2019b), further work was recommended to refine the maximum Existing Development value.

Modelling of the Ohote stream downstream of Exelby Road has shown that given the data and model there is no significant change in erosion potential for flows between 2.7 m^3/s and 5.5 m^3/s. However, there were a number of risks identified with the modelling that should be addressed as part of future Resource Consenting investigations. Investigation of these risks should be undertaken to determine if there would be any adverse effects from increasing discharge rate above the Existing Development value.

13.0 REFERENCES

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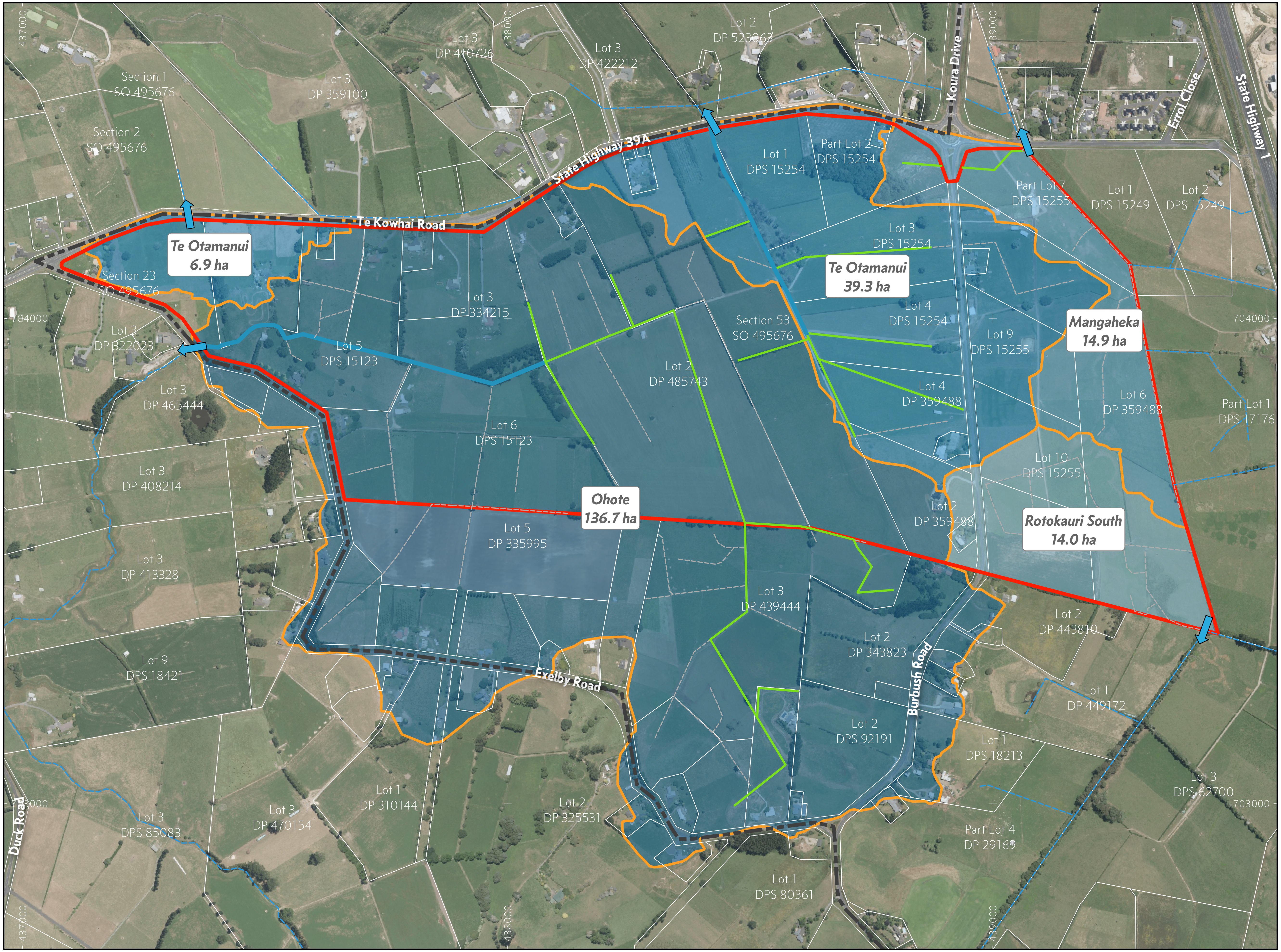
APPENDIX A – CATCHMENT EXTENT PLANS



Legend

- Rotokauri North PPC Area
- WDC/HCC TA Boundary

Existing Catchments

- Ohote
- Te Otamanui
- Mangaheka
- Rotokauri South

Watercourses

- Modified
- Artificial
- Other Artificial
- Watercourse outside RN PCC Area

Catchment In/Out Flows

- Outlet

Map Projection:
NZGD2000 / Mount Eden 2000 (EPSG: 2105)

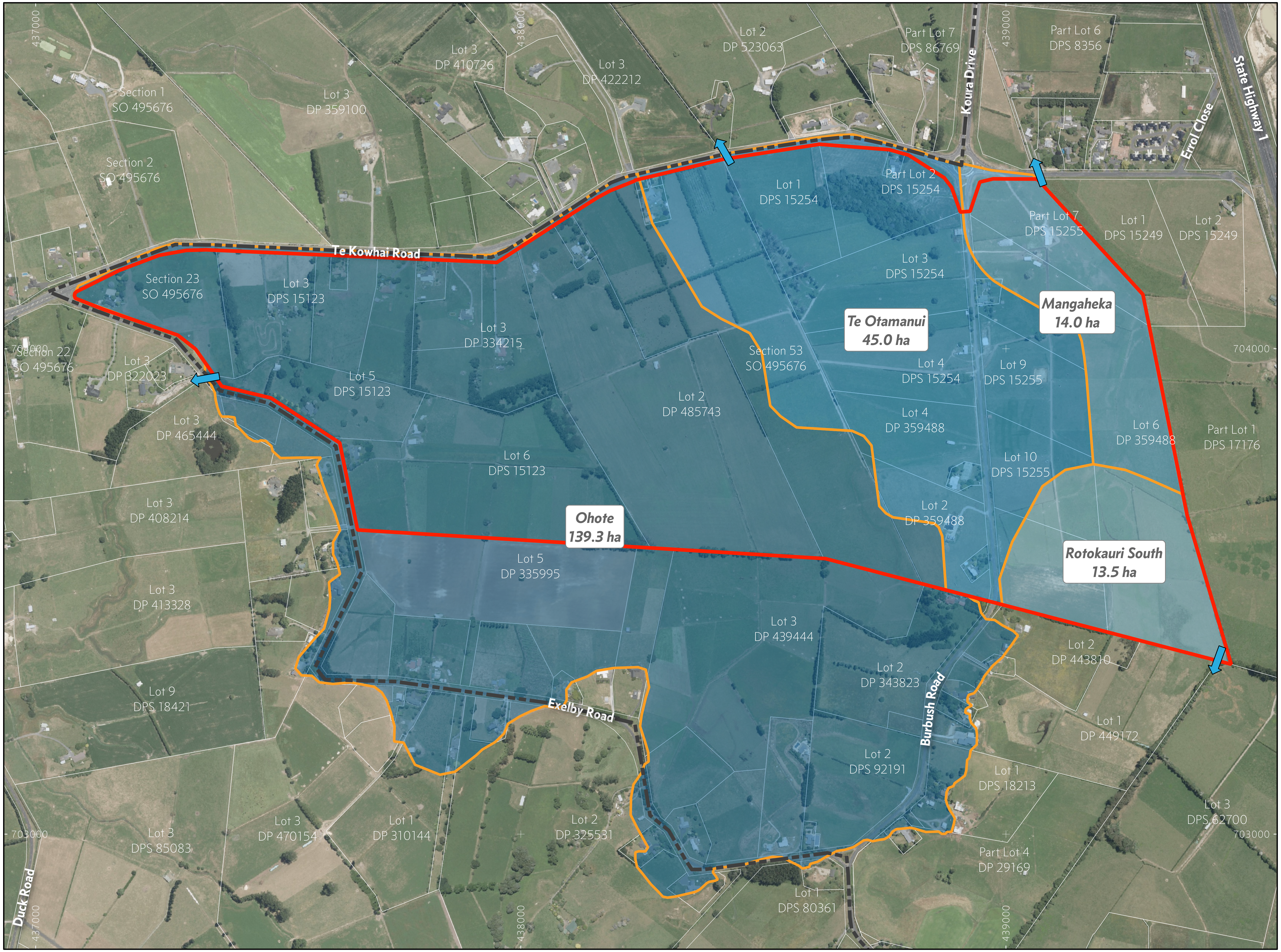
Drawn By:	AJSH	Date:	17/12/2018	Signed:	
Checked By:		Date:		Signed:	
Approved By:		Date:		Signed:	
Plot Date:	28/04/2019				

Project:
Rotokauri North
Private Plan Change (PPC)
Green Seed Consultants Limited

Title:
Existing Catchment Boundaries and Watercourses

McKenzie&Co Consultants Ltd

Issue Status:	For Information
Project Number:	1693-0
Drawing Number:	030
Revision:	F
A3 Scale:	1:7500



Legend

- Rotokauri North PPC
- WDC/HCC TA Boundary

Indicative Future Catchments

- Ohote
- Te Otamanui
- Mangaheka
- Rotokauri South

Catchment In/Out Flows

- Outlet

Data License:
Data by Hamilton City Council and Land Information New Zealand is licensed under CC BY 4.0 NZ.

Map Projection:
NZGD2000 / Mount Eden 2000 (EPSG: 2105)

Drawn By:	AJSH	Date:	12/02/2019	Signed:	
Checked By:		Date:		Signed:	
Approved By:		Date:		Signed:	
Plot Date:	28/04/2019				

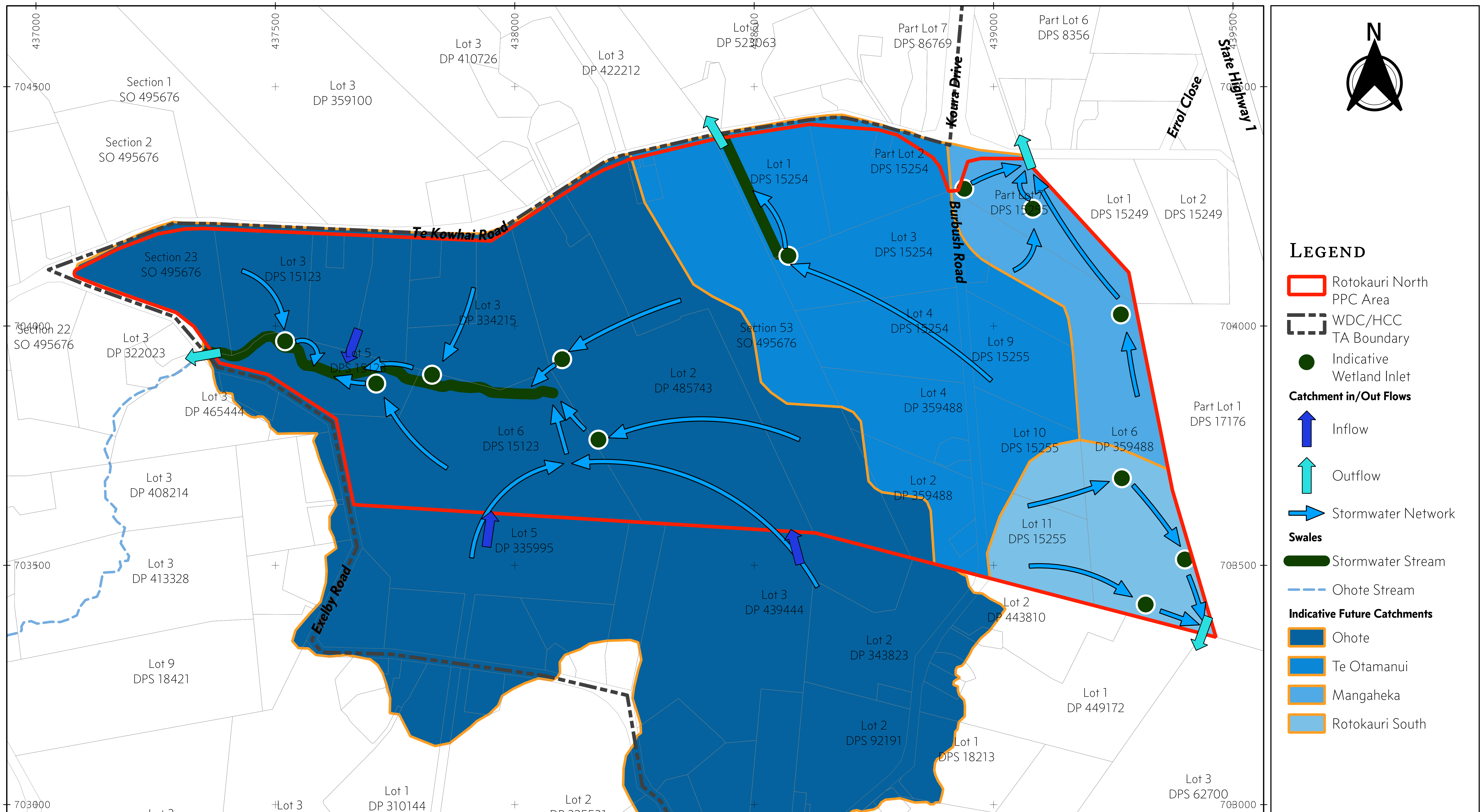
Project:
Rotokauri North
Private Plan Change (PPC)
Green Seed Consultants Limited

Title:
Proposed Catchment Boundaries

McKenzie&Co Consultants Ltd

Issue Status:	For Information
Project Number:	1693-0
Drawing Number:	031
Revision:	F
A3 Scale:	1:7500

APPENDIX B – PRIMARY NETWORK



Map Projection:
NZGD2000 / Mount Eden 2000 (EPSG: 2105)

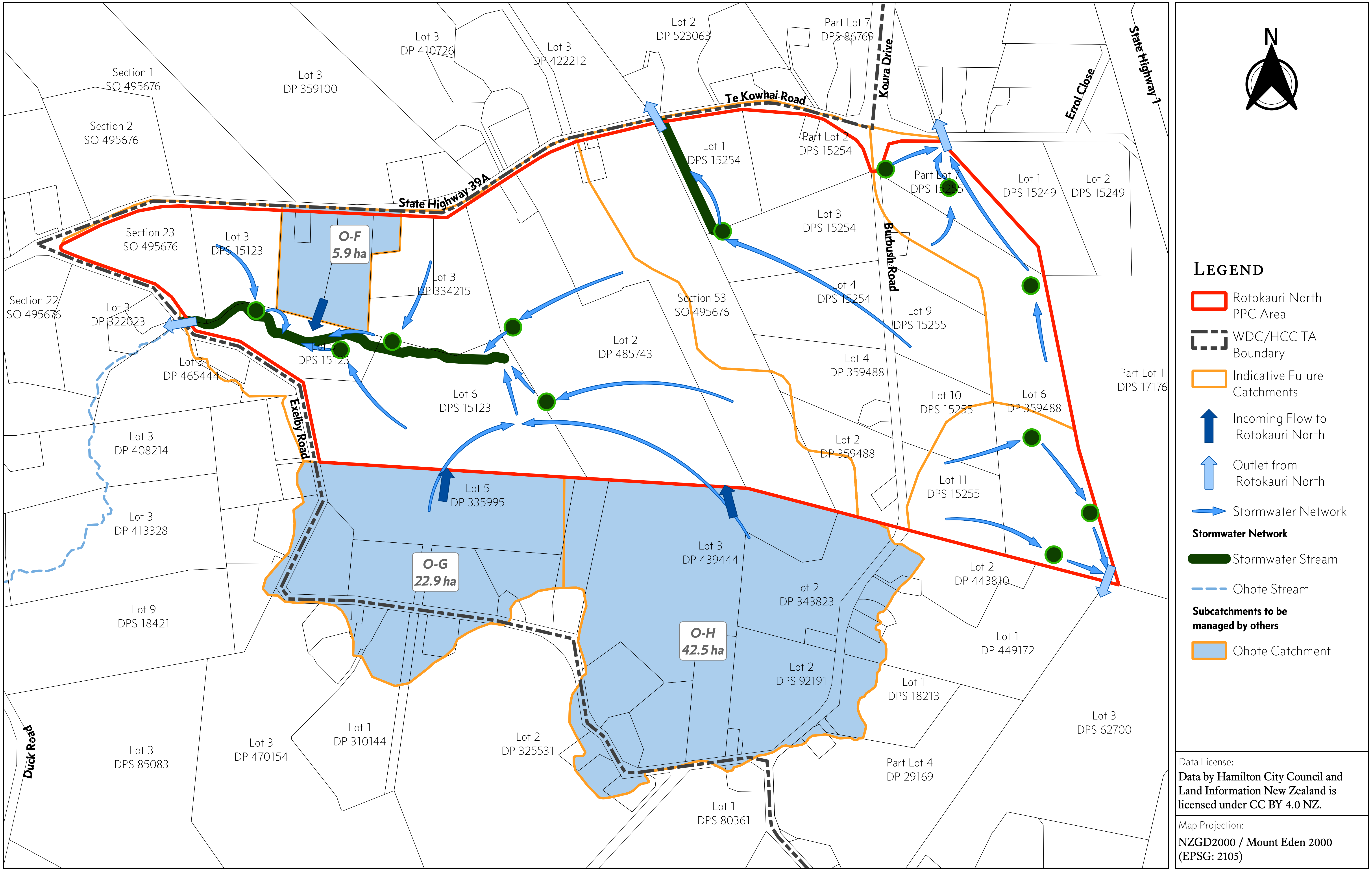
Drawn By: FW	Date: 26/04/2019	Signed:	
Checked By:	Date:	Signed:	
Approved By:	Date:	Signed:	
Plot Date: 26/04/2019			

Project:
Rotokauri North
Private Plan Change (PPC)
Green Seed Consultants Limited

Title:
Subcatchments with Indicative Swales and Wetland Locations

McKenzie&Co Consultants Ltd

Issue Status:	For Information
Project Number:	1693-0
Drawing Number:	032
Revision:	G
A3 Scale:	1:7500



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Checked By:	Date:	Signed:	
Approved By:	Date:	Signed:	
Plot Date: 28/04/2019			

Project:
Rotokauri North
Private Plan Change (PPC)
Green Seed Consultants Limited

Title:
Upstream Ohote Catchments to be managed by others

McKenzie&Co Consultants Ltd

Issue Status:	For Information
Project Number:	1693-0
Drawing Number:	033
Revision:	F
A3 Scale:	1:7500

APPENDIX C – WETLAND DESIGN

1693 Wetland Summary **27/11/2018**

Notes

1 Fall through wetland system is 1.8m, refer drawing 1693-0-908.

Wetland	WQV (m3)	EDV (m3)	Culvert Level	Drop to culvert (m)	Detention base RL	Outlet pipe fall (m)	Out Pool base RL	NWL	EDL	Inflow channel base RL	Channel depth
Ohote A	2216	5014	26.4	0.4	26.8	0.3	27.1	28.6	29.1	28.6	0.5
Ohote B	2559	5788	26.4	0.7	27.1	0.3	27.4	28.9	29.4	28.9	0.5
Ohote C	208	472	26.4	0.3	26.7	0.3	27.0	28.5	29.0	28.5	0.5
Ohote D	1176	2660	26.4	0.1	26.5	0.3	26.8	28.3	28.8	28.3	0.5
Ohote E	994	2248	26.4	0.0	26.4	0.3	26.7	28.2	28.7	28.2	0.5
Te Otamanui	4869	11014	28	0.0	28	0.3	28.3	29.8	30.3	29.8	0.5
Mangaheka A	222	503	28	0.0	28	0.3	28.3	29.8	30.3	29.8	1.1
Mangaheka B	567	1284	28	0.0	28	0.3	28.3	29.8	30.3	29.8	1.1
Mangaheka C	684	1547	28	0.2	28.2	0.3	28.5	30.0	30.5	30.0	1.1
Rotokauri A	304	687	29.5	0.3	29.8	0.3	30.1	31.6	32.1	31.6	0.2
Rotokauri B	113	256	29.5	0.1	29.6	0.3	29.9	31.4	31.9	31.4	1.0
Rotokauri C	115	261	29.5	0.0	29.5	0.3	29.8	31.3	31.8	31.3	1.1

McKENZIE&Co CONSULTANTS LTD

TP10 WETLAND DESIGN CALCULATIONS

PROJECT: Rotokauri BY: BH DATE: 29 November 2018

LOCATION: Rotokauri Checked:

Catchment: Ohote Point A

1 - WATER QUALITY AND EXTENDED DETENTION CALCULATIONS

Calculated in accordance with TP10, chapters 3 and 5

Total Area 177520 % Imp. 80 % Per. 20

Cover Description (cover type, treatment, and hydraulic condition)	Area (m2)	Curve number (CN)*	Product of CN x Area	Chapter 3, TP10: 2 year rainfall Figure A.1	Sd (MM)	Ia (MM)	Storage S (MM)	Runoff depth (MM)	Water Quality Runoff Volume (m3)	Chapter 5, TP10: ED depth (MM)	Runoff Depth (ED) (MM)	ED Vol (m3)
Catchment A - Pervious	35504	74	2627296	70.3	23.4	0	89.2	4.9	173.0	34.5	9.6	342
- Impervious	142016	98	13917568	70.3	23.4	5	5.2	14.4	2043.2	34.5	25.1	3563
Catchment B - Pervious	0	74	0	70.3	23.4	0	89.2	4.9	0.0	34.5	9.6	0
- Impervious	0	98	0	70.3	23.4	5	5.2	14.4	0.0	34.5	25.1	0
Subtotal	177520											
Totals	177520											
Total Area	**177520**							Total WQ Vol	**2216**	subtotal ED Vol		3905

2 - WETLAND POND VOLUME CALCULATIONS

WQV	2216	m3
extended detention reqd?	Yes	
subtotal ED volume	3905	m3
50 % reduction in WQV	1109	m3
Total vol ED reqd	**5014**	m3
forebay size 15% of WQV	332	m3
forebay depth	1.5	m
forebay area	222	m2

2 - WETLAND POND AREA CALCULATIONS

Assume banded wetland			% of area	Area (m2)	Avg Depth (m)	Volume (m3)	
Proposed Wetland area	4625.0	m2					
PSZ Macrophyte zone 0m - 0.2m deep from NWL			40%	1850	0.1	185	
PSZ Macrophyte zone 0.2m - 0.35m deep from NWL			40%	1850	0.275	509	
PSZ Inlet Pool 0.35m - 1.2m deep from NWL			10%	462.5	0.775	358	
PSZ Outlet Pool 0.35m - 1.5m deep from NWL			10%	462.5	0.925	428	
Total PSZ						1480	Greater than 1109 m3, OK

Check PSZ * 0.75 > WQV * 0.50 — 1110 m3 — Greater than 1109 m3, OK

					=		
NWL Dimensions @ 5:1	L		W		=	0 m2	Less than 4625 m2, TOO SMALL
NWL Dimensions @ 8:1	L	193	W	24	=	4632 m2	Greater than 4625 m2, OK

3 - OUTLET CONTROL - ED

3.1 Extended detention outlet

EDV 5014 m3

Qi 0.059 m3/s over 24 hrs

Max release rate

2 x Qi 0.118 m3/s At full EDV, max release rate is 2Qi

Assumed orifice outlet

Q =0.62*A*(2*g*h)^.5

Outlet Dia. 0.26 m

ED 0.50

h 0.37

ED Area **10028** m2

Q = 0.089 m3/s OK

Slot ED outlet Q = 1.7 W D ^1.5

weir width 0.099 m

h	**Q**
0	0
0.0500	0.0019
0.1000	0.0053
0.1500	0.0098
0.2000	0.0151
0.2500	0.0210
0.3000	0.0277
0.3500	0.0348
0.4000	0.0426
0.4500	0.0508
0.5000	0.0595 = 0.059

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TP10 WETLAND DESIGN CALCULATIONS

PROJECT: Rotokauri   BY: BH   DATE: 29 November 2018

LOCATION: Rotokauri   Checked:

Catchment: Ohote Point B

1 - WATER QUALITY AND EXTENDED DETENTION CALCULATIONS

Calculated in accordance with TP10, chapters 3 and 5

Total Area 204940   % Imp. 80   % Per. 20

Cover Description (cover type, treatment, and hydraulic condition)	Area (m2)	Curve number (CN)*	Product of CN x Area	Chapter 3, TP10: 2 year rainfall Figure A.1	Sd (MM)	Ia (MM)	Storage S (MM)	Runoff depth (MM)	Water Quality Runoff Volume (m3)	Chapter 5, TP10: ED depth (MM)	Runoff Depth (ED) (MM)	ED Vol (m3)
Catchment A - Pervious	40988	74	3033112	70.3	23.4	0	89.2	4.9	199.8	34.5	9.6	394
- Impervious	163952	98	16067296	70.3	23.4	5	5.2	14.4	2358.8	34.5	25.1	4114
Catchment B - Pervious	0	74	0	70.3	23.4	0	89.2	4.9	0.0	34.5	9.6	0
- Impervious	0	98	0	70.3	23.4	5	5.2	14.4	0.0	34.5	25.1	0
Subtotal	204940											
Totals	204940											
Total Area	**204940**							Total WQ Vol	**2559**	subtotal ED Vol		4508

2 - WETLAND POND VOLUME CALCULATIONS

WQV	2559 m3
extended detention reqd?	Yes
subtotal ED volume	4508 m3
50 % reduction in WQV	1280 m3
Total vol ED reqd	**5788** m3
forebay size 15% of WQV	384 m3
forebay depth	1.5 m
forebay area	256 m2

2 - WETLAND POND AREA CALCULATIONS

Assume banded wetland	% of area	Area (m2)	Avg Depth (m)	Volume (m3)
Proposed Wetland area 5334.0 m2				
PSZ Macrophyte zone 0m - 0.2m deep from NWL	40%	2133.6	0.1	213
PSZ Macrophyte zone 0.2m - 0.35m deep from NWL	40%	2133.6	0.275	587
PSZ Inlet Pool 0.35m - 1.2m deep from NWL	10%	533.4	0.775	413
PSZ Outlet Pool 0.35m - 1.5m deep from NWL	10%	533.4	0.925	493
Total PSZ				1707

Greater than 1280 m3, OK

Check PSZ * 0.75 > WQV * 0.50   1280 m3   Greater than 1280 m3, OK

NWL Dimensions @ 5:1   L   W   =   0 m2   Less than 5334 m2, TOO SMALL

NWL Dimensions @ 8:1   L 178   W 30   =   5340 m2   Greater than 5334 m2, OK

3 - OUTLET CONTROL - ED

3.1 Extended detention outlet

EDV	5788 m3	
Qi	0.067 m3/s	over 24 hrs
Max release rate		
2 x Qi	0.134 m3/s	At full EDV, max release rate is 2Qi
Assumed orifice outlet		
Q	=0.62*A*(2*g*h)^.5	
Outlet Dia.	0.28 m	
ED	0.50	
h	0.36	
ED Area	**11576** m2	
Q =	**0.101 m3/s**	**OK**

Slot ED outlet   Q = 1.7 W D ^1.5

weir width   0.112 m

h	**Q**
0	0
0.0500	0.0021
0.1000	0.0060
0.1500	0.0111
0.2000	0.0170
0.2500	0.0238
0.3000	0.0313
0.3500	0.0394
0.4000	0.0482
0.4500	0.0575
0.5000	0.0673 = 0.067

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TP10 WETLAND DESIGN CALCULATIONS

PROJECT: Rotokauri BY: BH DATE: 29 November 2018

LOCATION: Rotokauri Checked:

Catchment: Ohote Point C

1 - WATER QUALITY AND EXTENDED DETENTION CALCULATIONS

Calculated in accordance with TP10, chapters 3 and 5

Total Area 16670 % Imp. 80 % Per. 20

Cover Description (cover type, treatment, and hydraulic condition)	Area (m2)	Curve number (CN)*	Product of CN x Area	Chapter 3, TP10: 2 year rainfall Figure A.1	Sd (MM)	Ia (MM)	Storage S (MM)	Runoff depth (MM)	Water Quality Runoff Volume (m3)	Chapter 5, TP10: ED depth (MM)	Runoff Depth (ED) (MM)	ED Vol (m3)
Catchment A - Pervious	3334	74	246716	70.3	23.4	0	89.2	4.9	16.2	34.5	9.6	32
- Impervious	13336	98	1306928	70.3	23.4	5	5.2	14.4	191.9	34.5	25.1	335
Catchment B - Pervious	0	74	0	70.3	23.4	0	89.2	4.9	0.0	34.5	9.6	0
- Impervious	0	98	0	70.3	23.4	5	5.2	14.4	0.0	34.5	25.1	0
Subtotal	16670											
Totals	16670											
Total Area	**16670**							Total WQ Vol	**208**	subtotal ED Vol		367

2 - WETLAND POND VOLUME CALCULATIONS

WQV	208	m3
extended detention reqd?	Yes	
subtotal ED volume	367	m3
50 % reduction in WQV	105	m3
Total vol ED reqd	**472**	m3
forebay size 15% of WQV	31	m3
forebay depth	1.5	m
forebay area	21	m2

2 - WETLAND POND AREA CALCULATIONS

Assume banded wetland		% of area	Area (m2)	Avg Depth (m)	Volume (m3)
Proposed Wetland area	438.0 m2				
PSZ Macrophyte zone 0m - 0.2m deep from NWL		40%	175.2	0.1	18
PSZ Macrophyte zone 0.2m - 0.35m deep from NWL		40%	175.2	0.275	48
PSZ Inlet Pool 0.35m - 1.2m deep from NWL		10%	43.8	0.775	34
PSZ Outlet Pool 0.35m - 1.5m deep from NWL		10%	43.8	0.925	41
Total PSZ					140

Greater than 105 m3, OK

Check PSZ * 0.75 > WQV * 0.50 — 105 m3 — Greater than 105 m3, OK

NWL Dimensions @ 5:1	L		W		=	0 m2	Less than 438 m2, TOO SMALL
NWL Dimensions @ 8:1	L	55	W	8	=	440 m2	Greater than 438 m2, OK

3 - OUTLET CONTROL - ED

3.1 Extended detention outlet

EDV	472 m3	
Qi	0.006 m3/s	over 24 hrs
Max release rate		
2 x Qi	0.012 m3/s	At full EDV, max release rate is 2Qi

Assumed orifice outlet

Q =0.62*A*(2*g*h)^.5

Outlet Dia.	0.08	m
ED	0.50	
h	0.46	
ED Area	**943**	m2
Q =	**0.009 m3/s**	**OK**

Slot ED outlet

Q = 1.7 W D ^1.5

weir width 0.01 m

h	**Q**		
0	0		
0.0500	0.0002		
0.1000	0.0005		
0.1500	0.0010		
0.2000	0.0015		
0.2500	0.0021		
0.3000	0.0028		
0.3500	0.0035		
0.4000	0.0043		
0.4500	0.0051		
0.5000	0.0060	=	0.006

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TP10 WETLAND DESIGN CALCULATIONS

PROJECT:	Rotokauri	BY:	BH	DATE:	29 November 2018
LOCATION:	Rotokauri	Checked:			
Catchment:	Ohote Point D				

1 - WATER QUALITY AND EXTENDED DETENTION CALCULATIONS

Calculated in accordance with TP10, chapters 3 and 5

Total Area 94190 % Imp. 80 % Per. 20

				Chapter 3, TP10						Chapter 5, TP10		
Cover Description (cover type, treatment, and hydraulic condition)	Area (m2)	Curve number (CN)*	Product of CN x Area	2 year rainfall Figure A.1	Sd (MM)	Ia (MM)	Storage S (MM)	Runoff depth (MM)	Water Quality Runoff Volume (m3)	ED depth (MM)	Runoff Depth (ED) (MM)	ED Vol (m3)
Catchment A - Pervious	18838	74	1394012	70.3	23.4	0	89.2	4.9	91.8	34.5	9.6	181
- Impervious	75352	98	7384496	70.3	23.4	5	5.2	14.4	1084.1	34.5	25.1	1891
Catchment B - Pervious	0	74	0	70.3	23.4	0	89.2	4.9	0.0	34.5	9.6	0
- Impervious	0	98	0	70.3	23.4	5	5.2	14.4	0.0	34.5	25.1	0
Subtotal	94190											
Totals	94190											
Total Area	**94190**							Total WQ Vol	**1176**	subtotal ED Vol		2072

2 - WETLAND POND VOLUME CALCULATIONS

WQV	1176	m3
extended detention reqd?	Yes	
subtotal ED volume	2072	m3
50 % reduction in WQV	588	m3
Total vol ED reqd	**2660**	m3
forebay size 15% of WQV	176	m3
forebay depth	1.5	m
forebay area	118	m2

2 - WETLAND POND AREA CALCULATIONS

Assume banded wetland			% of area	Area (m2)	Avg Depth (m)	Volume (m3)
Proposed Wetland area	2451.0	m2				
PSZ Macrophyte zone 0m - 0.2m deep from NWL			40%	980.4	0.1	98
PSZ Macrophyte zone 0.2m - 0.35m deep from NWL			40%	980.4	0.275	270
PSZ Inlet Pool 0.35m - 1.2m deep from NWL			10%	245.1	0.775	190
PSZ Outlet Pool 0.35m - 1.5m deep from NWL			10%	245.1	0.925	227
Total PSZ						784

Greater than 588 m3, OK

Check PSZ * 0.75 > WQV * 0.50 — 588 m3 — Greater than 588 m3, OK

NWL Dimensions @ 5:1	L	80	W	17	=	1360 m2	Less than 2451 m2, TOO SMALL
NWL Dimensions @ 8:1	L	104	W	13	=	1352 m2	Less than 2451 m2, TOO SMALL

3 - OUTLET CONTROL - ED

3.1 Extended detention outlet

EDV	2660	m3	
Qi	0.031	m3/s	over 24 hrs
Max release rate			
2 x Qi	0.062	m3/s	At full EDV, max release rate is 2Qi

Assumed orifice outlet

Q =0.62*A*(2*g*h)^.5

Outlet Dia.	0.18	m
ED	0.50	
h	0.41	
ED Area	**5320**	m2
Q =	**0.045**	**m3/s** **OK**

Slot ED outlet

Q = 1.7 W D ^1.5

weir width 0.052 m

h	**Q**		
0	0		
0.0500	0.0010		
0.1000	0.0028		
0.1500	0.0051		
0.2000	0.0079		
0.2500	0.0111		
0.3000	0.0145		
0.3500	0.0183		
0.4000	0.0224		
0.4500	0.0267		
0.5000	0.0313	=	0.031

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TP10 WETLAND DESIGN CALCULATIONS

PROJECT: Rotokauri BY: BH DATE: 29 November 2018

LOCATION: Rotokauri Checked:

Catchment: Ohote Point E

1 - WATER QUALITY AND EXTENDED DETENTION CALCULATIONS

Calculated in accordance with TP10, chapters 3 and 5

Total Area 79590 % Imp. 80 % Per. 20

				Chapter 3, TP10						Chapter 5, TP10		
Cover Description (cover type, treatment, and hydraulic condition)	Area (m2)	Curve number (CN)*	Product of CN x Area	2 year rainfall Figure A.1	Sd (MM)	Ia (MM)	Storage S (MM)	Runoff depth (MM)	Water Quality Runoff Volume (m3)	ED depth (MM)	Runoff Depth (ED) (MM)	ED Vol (m3)
Catchment A - Pervious	15918	74	1177932	70.3	23.4	0	89.2	4.9	77.6	34.5	9.6	153
- Impervious	63672	98	6239856	70.3	23.4	5	5.2	14.4	916.1	34.5	25.1	1598
Catchment B - Pervious	0	74	0	70.3	23.4	0	89.2	4.9	0.0	34.5	9.6	0
- Impervious	0	98	0	70.3	23.4	5	5.2	14.4	0.0	34.5	25.1	0
Subtotal	79590											
Totals	79590											
Total Area	**79590**							Total WQ Vol	**994**	subtotal ED Vol		1751

2 - WETLAND POND VOLUME CALCULATIONS

WQV	994	m3
extended detention reqd?	Yes	
subtotal ED volume	1751	m3
50 % reduction in WQV	497	m3
Total vol ED reqd	**2248**	m3
forebay size 15% of WQV	149	m3
forebay depth	1.5	m
forebay area	99	m2

2 - WETLAND POND AREA CALCULATIONS

Assume banded wetland			% of area	Area (m2)	Avg Depth (m)	Volume (m3)
Proposed Wetland area	2071.0	m2				
PSZ Macrophyte zone 0m - 0.2m deep from NWL			40%	828.4	0.1	83
PSZ Macrophyte zone 0.2m - 0.35m deep from NWL			40%	828.4	0.275	228
PSZ Inlet Pool 0.35m - 1.2m deep from NWL			10%	207.1	0.775	161
PSZ Outlet Pool 0.35m - 1.5m deep from NWL			10%	207.1	0.925	192
Total PSZ						663

Greater than 497 m3, OK

Check PSZ * 0.75 > WQV * 0.50 497 m3 Greater than 497 m3, OK

NWL Dimensions @ 5:1	L		W		=	0 m2	Less than 2071 m2, TOO SMALL
NWL Dimensions @ 8:1	L	130	W	17	=	2210 m2	Greater than 2071 m2, OK

3 - OUTLET CONTROL - ED

3.1 Extended detention outlet

EDV 2248 m3

Qi 0.027 m3/s over 24 hrs

Max release rate

2 x Qi 0.054 m3/s At full EDV, max release rate is 2Qi

Assumed orifice outlet

Q =0.62*A*(2*g*h)^.5

Outlet Dia. 0.17 m

ED 0.50

h 0.42

ED Area **4495** m2

Q = 0.040 m3/s OK

Slot ED outlet Q = 1.7 W D ^1.5

weir width 0.045 m

h	**Q**		
0	0		
0.0500	0.0009		
0.1000	0.0024		
0.1500	0.0044		
0.2000	0.0068		
0.2500	0.0096		
0.3000	0.0126		
0.3500	0.0158		
0.4000	0.0194		
0.4500	0.0231		
0.5000	0.0270	=	0.027

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TP10 WETLAND DESIGN CALCULATIONS

PROJECT: Rotokauri   BY: BH   DATE: 29 November 2018

LOCATION: Rotokauri   Checked:

Catchment: Mangaheka Point A

1 - WATER QUALITY AND EXTENDED DETENTION CALCULATIONS

Calculated in accordance with TP10, chapters 3 and 5

Total Area 390000   % Imp. 80   % Per. 20

Cover Description (cover type, treatment, and hydraulic condition)	Area (m2)	Curve number (CN)*	Product of CN x Area	Chapter 3, TP10: 2 year rainfall Figure A.1	Sd (MM)	Ia (MM)	Storage S (MM)	Runoff depth (MM)	Water Quality Runoff Volume (m3)	Chapter 5, TP10: ED depth (MM)	Runoff Depth (ED) (MM)	ED Vol (m3)
Catchment A - Pervious	78000	74	5772000	70.3	23.4	0	89.2	4.9	380.1	34.5	9.6	750
- Impervious	312000	98	30576000	70.3	23.4	5	5.2	14.4	4488.9	34.5	25.1	7828
Catchment B - Pervious	0	74	0	70.3	23.4	0	89.2	4.9	0.0	34.5	9.6	0
- Impervious	0	98	0	70.3	23.4	5	5.2	14.4	0.0	34.5	25.1	0
Subtotal	390000											
Totals	390000											
Total Area	**390000**							Total WQ Vol	**4869**	subtotal ED Vol		8579

2 - WETLAND POND VOLUME CALCULATIONS

WQV	4869	m3
extended detention reqd?	Yes	
subtotal ED volume	8579	m3
50 % reduction in WQV	2435	m3
Total vol ED reqd	**11014**	m3
forebay size 15% of WQV	730	m3
forebay depth	1.5	m
forebay area	487	m2

2 - WETLAND POND AREA CALCULATIONS

Assume banded wetland	% of area	Area (m2)	Avg Depth (m)	Volume (m3)
Proposed Wetland area 10150.0 m2				
PSZ Macrophyte zone 0m - 0.2m deep from NWL	40%	4060	0.1	406
PSZ Macrophyte zone 0.2m - 0.35m deep from NWL	40%	4060	0.275	1117
PSZ Inlet Pool 0.35m - 1.2m deep from NWL	10%	1015	0.775	787
PSZ Outlet Pool 0.35m - 1.5m deep from NWL	10%	1015	0.925	939
Total PSZ				3248

Greater than 2435 m3, OK

Check PSZ * 0.75 > WQV * 0.50   2436 m3   Greater than 2435 m3, OK

NWL Dimensions @ 5:1   L 205   W 50   = 10250 m2   Greater than 10150 m2, OK

NWL Dimensions @ 8:1   L   W   = 0 m2   Less than 10150 m2, TOO SMALL

3 - OUTLET CONTROL - ED

3.1 Extended detention outlet

EDV	11014	m3	
Qi	0.128	m3/s	over 24 hrs
Max release rate			
2 x Qi	0.256	m3/s	At full EDV, max release rate is 2Qi

Assumed orifice outlet

Q =0.62*A*(2*g*h)^.5

Outlet Dia. 0.3 m

ED	0.50	
h	0.35	
ED Area	**22027**	m2
Q =	**0.115**	**m3/s** **OK**

Slot ED outlet   Q = 1.7 W D ^1.5

weir width 0.213 m

h	**Q**
0	0
0.0500	0.0040
0.1000	0.0115
0.1500	0.0210
0.2000	0.0324
0.2500	0.0453
0.3000	0.0595
0.3500	0.0750
0.4000	0.0916
0.4500	0.1093
0.5000	0.1280 = 0.128

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TP10 WETLAND DESIGN CALCULATIONS

PROJECT: Rotokauri BY: BH DATE: 29 November 2018
LOCATION: Rotokauri Checked:

Catchment: Mangaheka Point A

1 - WATER QUALITY AND EXTENDED DETENTION CALCULATIONS

Calculated in accordance with TP10, chapters 3 and 5

Total Area 17790 % Imp. 80 % Per. 20

Cover Description (cover type, treatment, and hydraulic condition)	Area (m2)	Curve number (CN)*	Product of CN x Area	Chapter 3, TP10: 2 year rainfall Figure A.1	Sd (MM)	Ia (MM)	Storage S (MM)	Runoff depth (MM)	Water Quality Runoff Volume (m3)	Chapter 5, TP10: ED depth (MM)	Runoff Depth (ED) (MM)	ED Vol (m3)
Catchment A - Pervious	3558	74	263292	70.3	23.4	0	89.2	4.9	17.3	34.5	9.6	34
- Impervious	14232	98	1394736	70.3	23.4	5	5.2	14.4	204.8	34.5	25.1	357
Catchment B - Pervious	0	74	0	70.3	23.4	0	89.2	4.9	0.0	34.5	9.6	0
- Impervious	0	98	0	70.3	23.4	5	5.2	14.4	0.0	34.5	25.1	0
Subtotal	17790											
Totals	17790											
Total Area	**17790**							Total WQ Vol	**222**	subtotal ED Vol		391

2 - WETLAND POND VOLUME CALCULATIONS

WQV	222	m3
extended detention reqd?	Yes	
subtotal ED volume	391	m3
50 % reduction in WQV	112	m3
Total vol ED reqd	**503**	m3
forebay size 15% of WQV	33	m3
forebay depth	1.5	m
forebay area	22	m2

2 - WETLAND POND AREA CALCULATIONS

Assume banded wetland		% of area	Area (m2)	Avg Depth (m)	Volume (m3)
Proposed Wetland area	467.0 m2				
PSZ Macrophyte zone 0m - 0.2m deep from NWL		40%	186.8	0.1	19
PSZ Macrophyte zone 0.2m - 0.35m deep from NWL		40%	186.8	0.275	51
PSZ Inlet Pool 0.35m - 1.2m deep from NWL		10%	46.7	0.775	36
PSZ Outlet Pool 0.35m - 1.5m deep from NWL		10%	46.7	0.925	43
Total PSZ					149

Greater than 112 m3, OK

Check PSZ * 0.75 > WQV * 0.50 112 m3 Greater than 112 m3, OK

NWL Dimensions @ 5:1 L W = 0 m2 Less than 467 m2, TOO SMALL
NWL Dimensions @ 8:1 L 59 W 8 = 472 m2 Greater than 467 m2, OK

3 - OUTLET CONTROL - ED

3.1 Extended detention outlet

Slot ED outlet Q = 1.7 W D ^1.5
weir width 0.01 m

EDV	503 m3	
Qi	0.006 m3/s	over 24 hrs
Max release rate		
2 x Qi	0.012 m3/s	At full EDV, max release rate is 2Qi
Assumed orifice outlet		
Q	=0.62*A*(2*g*h)^.5	
Outlet Dia.	0.05 m	
ED	0.50	
h	0.48	
ED Area	**1007** m2	
Q =	**0.004 m3/s**	**OK**

h	Q
0	0
0.0500	0.0002
0.1000	0.0005
0.1500	0.0010
0.2000	0.0015
0.2500	0.0021
0.3000	0.0028
0.3500	0.0035
0.4000	0.0043
0.4500	0.0051
0.5000	0.0060 = 0.006

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TP10 WETLAND DESIGN CALCULATIONS

PROJECT: Rotokauri BY: BH DATE: 29 November 2018

LOCATION: Rotokauri Checked:

Catchment: Mangaheka Point B

1 - WATER QUALITY AND EXTENDED DETENTION CALCULATIONS

Calculated in accordance with TP10, chapters 3 and 5

Total Area 45450 % Imp. 80 % Per. 20

Cover Description (cover type, treatment, and hydraulic condition)	Area (m2)	Curve number (CN)*	Product of CN x Area	Chapter 3, TP10 2 year rainfall Figure A.1	Sd (MM)	Ia (MM)	Storage S (MM)	Runoff depth (MM)	Water Quality Runoff Volume (m3)	Chapter 5, TP10 ED depth (MM)	Runoff Depth (ED) (MM)	ED Vol (m3)
Catchment A - Pervious	9090	74	672660	70.3	23.4	0	89.2	4.9	44.3	34.5	9.6	87
- Impervious	36360	98	3563280	70.3	23.4	5	5.2	14.4	523.1	34.5	25.1	912
Catchment B - Pervious	0	74	0	70.3	23.4	0	89.2	4.9	0.0	34.5	9.6	0
- Impervious	0	98	0	70.3	23.4	5	5.2	14.4	0.0	34.5	25.1	0
Subtotal	45450											
Totals	45450											
Total Area	**45450**							Total WQ Vol	**567**	subtotal ED Vol		1000

2 - WETLAND POND VOLUME CALCULATIONS

WQV	567	m3
extended detention reqd?	Yes	
subtotal ED volume	1000	m3
50 % reduction in WQV	284	m3
Total vol ED reqd	**1284**	m3
forebay size 15% of WQV	85	m3
forebay depth	1.5	m
forebay area	57	m2

2 - WETLAND POND AREA CALCULATIONS

Assume banded wetland			% of area	Area (m2)	Avg Depth (m)	Volume (m3)
Proposed Wetland area	1184.0	m2				
PSZ Macrophyte zone 0m - 0.2m deep from NWL			40%	473.6	0.1	47
PSZ Macrophyte zone 0.2m - 0.35m deep from NWL			40%	473.6	0.275	130
PSZ Inlet Pool 0.35m - 1.2m deep from NWL			10%	118.4	0.775	92
PSZ Outlet Pool 0.35m - 1.5m deep from NWL			10%	118.4	0.925	110
Total PSZ						379

Greater than 284 m3, OK

Check PSZ * 0.75 > WQV * 0.50 284 m3 Greater than 284 m3, OK

NWL Dimensions @ 5:1	L	75	W	16	=	1200 m2	Greater than 1184 m2, OK
NWL Dimensions @ 8:1	L		W		=	0 m2	Less than 1184 m2, TOO SMALL

3 - OUTLET CONTROL - ED

3.1 Extended detention outlet

EDV	1284	m3	
Qi	0.015	m3/s	over 24 hrs
Max release rate			
2 x Qi	0.030	m3/s	At full EDV, max release rate is 2Qi

Assumed orifice outlet

Q =0.62*A*(2*g*h)^.5

Outlet Dia.	0.05	m
ED	0.50	
h	0.48	
ED Area	**2567**	m2
Q =	**0.004**	**m3/s** OK

Slot ED outlet

Q = 1.7 W D ^1.5

weir width 0.025 m

h	**Q**		
0	0		
0.0500	0.0005		
0.1000	0.0013		
0.1500	0.0025		
0.2000	0.0038		
0.2500	0.0053		
0.3000	0.0070		
0.3500	0.0088		
0.4000	0.0108		
0.4500	0.0128		
0.5000	0.0150	=	0.015

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TP10 WETLAND DESIGN CALCULATIONS

PROJECT: Rotokauri BY: BH DATE: 29 November 2018

LOCATION: Rotokauri Checked:

Catchment: Mangaheka Point C

1 - WATER QUALITY AND EXTENDED DETENTION CALCULATIONS

Calculated in accordance with TP10, chapters 3 and 5

Total Area 54770 % Imp. 80 % Per. 20

				Chapter 3, TP10						Chapter 5, TP10		
Cover Description (cover type, treatment, and hydraulic condition)	Area (m2)	Curve number (CN)*	Product of CN x Area	2 year rainfall Figure A.1	Sd (MM)	Ia (MM)	Storage S (MM)	Runoff depth (MM)	Water Quality Runoff Volume (m3)	ED depth (MM)	Runoff Depth (ED) (MM)	ED Vol (m3)
Catchment A - Pervious	10954	74	810596	70.3	23.4	0	89.2	4.9	53.4	34.5	9.6	105
- Impervious	43816	98	4293968	70.3	23.4	5	5.2	14.4	630.4	34.5	25.1	1099
Catchment B - Pervious	0	74	0	70.3	23.4	0	89.2	4.9	0.0	34.5	9.6	0
- Impervious	0	98	0	70.3	23.4	5	5.2	14.4	0.0	34.5	25.1	0
Subtotal	54770											
Totals	54770											
Total Area	**54770**							Total WQ Vol	**684**	subtotal ED Vol		1205

2 - WETLAND POND VOLUME CALCULATIONS

WQV	684	m3
extended detention reqd?	Yes	
subtotal ED volume	1205	m3
50 % reduction in WQV	342	m3
Total vol ED reqd	**1547**	m3
forebay size 15% of WQV	103	m3
forebay depth	1.5	m
forebay area	68	m2

2 - WETLAND POND AREA CALCULATIONS

Assume banded wetland		% of area	Area (m2)	Avg Depth (m)	Volume (m3)
Proposed Wetland area	1426.0 m2				
PSZ Macrophyte zone 0m - 0.2m deep from NWL		40%	570.4	0.1	57
PSZ Macrophyte zone 0.2m - 0.35m deep from NWL		40%	570.4	0.275	157
PSZ Inlet Pool 0.35m - 1.2m deep from NWL		10%	142.6	0.775	111
PSZ Outlet Pool 0.35m - 1.5m deep from NWL		10%	142.6	0.925	132
Total PSZ					456

Greater than 342 m3, OK

Check PSZ * 0.75 > WQV * 0.50 342 m3 Greater than 342 m3, OK

NWL Dimensions @ 5:1	L		W		=	0 m2	Less than 1426 m2, TOO SMALL
NWL Dimensions @ 8:1	L	158	W	20	=	3160 m2	Greater than 1426 m2, OK

3 - OUTLET CONTROL - ED

3.1 Extended detention outlet

EDV	1547 m3	
Qi	0.018 m3/s	over 24 hrs
Max release rate		
2 x Qi	0.036 m3/s	At full EDV, max release rate is 2Qi

Assumed orifice outlet

Q =0.62*A*(2*g*h)^.5

Outlet Dia.	0.05 m
ED	0.50
h	0.48
ED Area	**3094** m2
Q =	**0.004 m3/s** **OK**

Slot ED outlet

Q = 1.7 W D ^1.5

weir width 0.03 m

h	**Q**		
0	0		
0.0500	0.0006		
0.1000	0.0016		
0.1500	0.0030		
0.2000	0.0046		
0.2500	0.0064		
0.3000	0.0084		
0.3500	0.0106		
0.4000	0.0129		
0.4500	0.0154		
0.5000	0.0180	=	0.018

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TP10 WETLAND DESIGN CALCULATIONS

PROJECT:	Rotokauri	BY:	BH	DATE:	29 November 2018
LOCATION:	Rotokauri	Checked:			
Catchment:	Rotokauri Point A				

1 - WATER QUALITY AND EXTENDED DETENTION CALCULATIONS

Calculated in accordance with TP10, chapters 3 and 5

Total Area 24340 % Imp. 80 % Per. 20

Cover Description (cover type, treatment, and hydraulic condition)	Area (m2)	Curve number (CN)*	Product of CN x Area	Chapter 3, TP10 2 year rainfall Figure A.1	Sd (MM)	Ia (MM)	Storage S (MM)	Runoff depth (MM)	Water Quality Runoff Volume (m3)	Chapter 5, TP10 ED depth (MM)	Runoff Depth (ED) (MM)	ED Vol (m3)
Catchment A - Pervious	4868	74	360232	70.3	23.4	0	89.2	4.9	23.7	34.5	9.6	47
- Impervious	19472	98	1908256	70.3	23.4	5	5.2	14.4	280.2	34.5	25.1	489
Catchment B - Pervious	0	74	0	70.3	23.4	0	89.2	4.9	0.0	34.5	9.6	0
- Impervious	0	98	0	70.3	23.4	5	5.2	14.4	0.0	34.5	25.1	0
Subtotal	24340											
Totals	24340											
Total Area	**24340**							Total WQ Vol	**304**	subtotal ED Vol		535

2 - WETLAND POND VOLUME CALCULATIONS

WQV	304	m3
extended detention reqd?	Yes	
subtotal ED volume	535	m3
50 % reduction in WQV	152	m3
Total vol ED reqd	**687**	m3
forebay size 15% of WQV	46	m3
forebay depth	1.5	m
forebay area	30	m2

2 - WETLAND POND AREA CALCULATIONS

Assume banded wetland		% of area	Area (m2)	Avg Depth (m)	Volume (m3)
Proposed Wetland area	635.0 m2				
PSZ Macrophyte zone 0m - 0.2m deep from NWL		40%	254	0.1	25
PSZ Macrophyte zone 0.2m - 0.35m deep from NWL		40%	254	0.275	70
PSZ Inlet Pool 0.35m - 1.2m deep from NWL		10%	63.5	0.775	49
PSZ Outlet Pool 0.35m - 1.5m deep from NWL		10%	63.5	0.925	59
Total PSZ					203

Greater than 152 m3, OK

Check PSZ * 0.75 > WQV * 0.50 — 152 m3 — Greater than 152 m3, OK

NWL Dimensions @ 5:1	L		W		=	0 m2	Less than 635 m2, TOO SMALL
NWL Dimensions @ 8:1	L	72	W	9	=	648 m2	Greater than 635 m2, OK

3 - OUTLET CONTROL - ED

3.1 Extended detention outlet

EDV	687 m3	
Qi	0.008 m3/s	over 24 hrs
Max release rate		
2 x Qi	0.016 m3/s	At full EDV, max release rate is 2Qi

Assumed orifice outlet

Q =0.62*A*(2*g*h)^.5

Outlet Dia.	0.09 m
ED	0.50
h	0.46
ED Area	**1375** m2
Q =	**0.012 m3/s** OK

Slot ED outlet

Q = 1.7 W D ^1.5

weir width 0.014 m

h	**Q**
0	0
0.0500	0.0003
0.1000	0.0008
0.1500	0.0014
0.2000	0.0021
0.2500	0.0030
0.3000	0.0039
0.3500	0.0049
0.4000	0.0060
0.4500	0.0072
0.5000	0.0084 = 0.008

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TP10 WETLAND DESIGN CALCULATIONS

PROJECT:	Rotokauri	BY:	BH	DATE:	29 November 2018
LOCATION:	Rotokauri	Checked:			

Catchment: Rotokauri Point B

1 - WATER QUALITY AND EXTENDED DETENTION CALCULATIONS

Calculated in accordance with TP10, chapters 3 and 5

Total Area 9040 % Imp. 80 % Per. 20

Cover Description (cover type, treatment, and hydraulic condition)	Area (m2)	Curve number (CN)*	Product of CN x Area	Chapter 3, TP10 2 year rainfall Figure A.1	Sd (MM)	Ia (MM)	Storage S (MM)	Runoff depth (MM)	Water Quality Runoff Volume (m3)	Chapter 5, TP10 ED depth (MM)	Runoff Depth (ED) (MM)	ED Vol (m3)
Catchment A - Pervious	1808	74	133792	70.3	23.4	0	89.2	4.9	8.8	34.5	9.6	17
- Impervious	7232	98	708736	70.3	23.4	5	5.2	14.4	104.0	34.5	25.1	181
Catchment B - Pervious	0	74	0	70.3	23.4	0	89.2	4.9	0.0	34.5	9.6	0
- Impervious	0	98	0	70.3	23.4	5	5.2	14.4	0.0	34.5	25.1	0
Subtotal	9040											
Totals	9040											
Total Area	**9040**							Total WQ Vol	**113**	subtotal ED Vol		199

2 - WETLAND POND VOLUME CALCULATIONS

WQV	113 m3
extended detention reqd?	Yes
subtotal ED volume	199 m3
50 % reduction in WQV	57 m3
Total vol ED reqd	**256** m3
forebay size 15% of WQV	17 m3
forebay depth	1.5 m
forebay area	11 m2

2 - WETLAND POND AREA CALCULATIONS

Assume banded wetland	% of area	Area (m2)	Avg Depth (m)	Volume (m3)
Proposed Wetland area 240.0 m2				
PSZ Macrophyte zone 0m - 0.2m deep from NWL	40%	96	0.1	10
PSZ Macrophyte zone 0.2m - 0.35m deep from NWL	40%	96	0.275	26
PSZ Inlet Pool 0.35m - 1.2m deep from NWL	10%	24	0.775	19
PSZ Outlet Pool 0.35m - 1.5m deep from NWL	10%	24	0.925	22
Total PSZ				77

Greater than 57 m3, OK

Check PSZ * 0.75 > WQV * 0.50 — 58 m3 — Greater than 57 m3, OK

NWL Dimensions @ 5:1	L		W		=	0 m2	Less than 240 m2, TOO SMALL
NWL Dimensions @ 8:1	L	42	W	6	=	252 m2	Greater than 240 m2, OK

3 - OUTLET CONTROL - ED

3.1 Extended detention outlet

Slot ED outlet

Q = 1.7 W D ^1.5
weir width 0.005 m

h	**Q**
0	0
0.0500	0.0001
0.1000	0.0003
0.1500	0.0005
0.2000	0.0008
0.2500	0.0011
0.3000	0.0014
0.3500	0.0018
0.4000	0.0022
0.4500	0.0026
0.5000	0.0030 = 0.003

EDV 256 m3
Qi 0.003 m3/s over 24 hrs

Max release rate
2 x Qi 0.006 m3/s At full EDV, max release rate is 2Qi

Assumed orifice outlet

Q =0.62*A*(2*g*h)^.5

Outlet Dia. 0.05 m

ED 0.50
h 0.48
ED Area **512** m2
Q = 0.004 m3/s OK

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TP10 WETLAND DESIGN CALCULATIONS

PROJECT: Rotokauri BY: BH DATE: 29 November 2018
LOCATION: Rotokauri Checked:

Catchment: Rotokauri Point C

1 - WATER QUALITY AND EXTENDED DETENTION CALCULATIONS

Calculated in accordance with TP10, chapters 3 and 5
Total Area 9240 % Imp. 80 % Per. 20

				Chapter 3, TP10						Chapter 5, TP10		
Cover Description (cover type, treatment, and hydraulic condition)	Area (m2)	Curve number (CN)*	Product of CN x Area	2 year rainfall Figure A.1	Sd (MM)	Ia (MM)	Storage S (MM)	Runoff depth (MM)	Water Quality Runoff Volume (m3)	ED depth (MM)	Runoff Depth (ED) (MM)	ED Vol (m3)
Catchment A - Pervious	1848	74	136752	70.3	23.4	0	89.2	4.9	9.0	34.5	9.6	18
- Impervious	7392	98	724416	70.3	23.4	5	5.2	14.4	106.4	34.5	25.1	185
Catchment B - Pervious	0	74	0	70.3	23.4	0	89.2	4.9	0.0	34.5	9.6	0
- Impervious	0	98	0	70.3	23.4	5	5.2	14.4	0.0	34.5	25.1	0
Subtotal	9240											
Totals	9240											
Total Area	**9240**							Total WQ Vol	**115**	subtotal ED Vol		203

2 - WETLAND POND VOLUME CALCULATIONS

WQV	115	m3
extended detention reqd?	Yes	
subtotal ED volume	203	m3
50 % reduction in WQV	58	m3
Total vol ED reqd	**261**	m3
forebay size 15% of WQV	17	m3
forebay depth	1.5	m
forebay area	12	m2

2 - WETLAND POND AREA CALCULATIONS

Assume banded wetland			% of area	Area (m2)	Avg Depth (m)	Volume (m3)	
Proposed Wetland area	242.0	m2					
PSZ Macrophyte zone 0m - 0.2m deep from NWL			40%	96.8	0.1	10	
PSZ Macrophyte zone 0.2m - 0.35m deep from NWL			40%	96.8	0.275	27	
PSZ Inlet Pool 0.35m - 1.2m deep from NWL			10%	24.2	0.775	19	
PSZ Outlet Pool 0.35m - 1.5m deep from NWL			10%	24.2	0.925	22	
Total PSZ						77	Greater than 58 m3, OK

Check PSZ * 0.75 > WQV * 0.50 — 58 m3 — Greater than 58 m3, OK

NWL Dimensions @ 5:1	L		W		=	0 m2	Less than 242 m2, TOO SMALL
NWL Dimensions @ 8:1	L	41	W	6	=	246 m2	Greater than 242 m2, OK

3 - OUTLET CONTROL - ED

3.1 Extended detention outlet

EDV 261 m3
Qi 0.004 m3/s over 24 hrs

Max release rate
2 x Qi 0.008 m3/s At full EDV, max release rate is 2Qi

Assumed orifice outlet

Q =0.62*A*(2*g*h)^.5

Outlet Dia. 0.06 m

ED 0.50
h 0.47
ED Area **522** m2
Q = 0.005 m3/s OK

Slot ED outlet

Q = 1.7 W D ^1.5
weir width 0.007 m

h	**Q**
0	0
0.0500	0.0001
0.1000	0.0004
0.1500	0.0007
0.2000	0.0011
0.2500	0.0015
0.3000	0.0020
0.3500	0.0025
0.4000	0.0030
0.4500	0.0036
0.5000	0.0042 = 0.004

APPENDIX D – DEFAULT MUSIC PARAMETERS

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MUSIC - Default Parameters

PROJECT NAME:	Rotokauri North	Created By BJR	Date 30/11/2018
PROJECT Nos:	1693	Checked By	Date -

Contaminant Load Defaults - Mixed Surface

Zoning/Surface Type: Mixed

Total Suspended Solids Stormflow Concentration Parameters	
Mean log (mg/L)	2.200
Standard Deviation log (mg/L)	0.320

Total Suspended Solids Baseflow Concentration Parameters	
Mean log (mg/L)	1.100
Standard Deviation log (mg/L)	0.170

Total Phosphorus Stormflow Concentration Parameters	
Mean log (mg/L)	-0.450
Standard Deviation log (mg/L)	0.250

Total Phosphorus Baseflow Concentration Parameters	
Mean log (mg/L)	-0.820
Standard Deviation log (mg/L)	0.190

Total Nitrogen Stormflow Concentration Parameters	
Mean log (mg/L)	0.420
Standard Deviation log (mg/L)	0.190

Total Nitrogen Baseflow Concentration Parameters	
Mean log (mg/L)	0.320
Standard Deviation log (mg/L)	0.120

Contaminant Load Defaults - Roof

Zoning/Surface Type: Roof

Total Suspended Solids Stormflow Concentration Parameters

Mean log (mg/L)	1.300
Standard Deviation log (mg/L)	0.320

Total Suspended Solids Baseflow Concentration Parameters

Mean log (mg/L)	1.100
Standard Deviation log (mg/L)	0.170

Total Phosphorus Stormflow Concentration Parameters

Mean log (mg/L)	-0.890
Standard Deviation log (mg/L)	0.250

Total Phosphorus Baseflow Concentration Parameters

Mean log (mg/L)	-0.820
Standard Deviation log (mg/L)	0.190

Total Nitrogen Stormflow Concentration Parameters

Mean log (mg/L)	0.300
Standard Deviation log (mg/L)	0.190

Total Nitrogen Baseflow Concentration Parameters

Mean log (mg/L)	0.320
Standard Deviation log (mg/L)	0.120

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Contaminant Load Defaults - Sealed Road

Zoning/Surface Type: Sealedroad

Total Suspended Solids Stormflow Concentration Parameters

Mean log (mg/L)	2.430
Standard Deviation log (mg/L)	0.320

Total Suspended Solids Baseflow Concentration Parameters

Mean log (mg/L)	1.200
Standard Deviation log (mg/L)	0.170

Total Phosphorus Stormflow Concentration Parameters

Mean log (mg/L)	-0.300
Standard Deviation log (mg/L)	0.250

Total Phosphorus Baseflow Concentration Parameters

Mean log (mg/L)	-0.850
Standard Deviation log (mg/L)	0.190

Total Nitrogen Stormflow Concentration Parameters

Mean log (mg/L)	0.340
Standard Deviation log (mg/L)	0.190

Total Nitrogen Baseflow Concentration Parameters

Mean log (mg/L)	0.110
Standard Deviation log (mg/L)	0.120

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Rainwater Tank Defaults

Low Flow By-Pass (cubic metres per sec)			0.000
High Flow By-pass (cubic metres per sec)			100.000
Surface Area (square metres)			5.0
Depth above overflow (metres)			0.2
Volume below overflow pipe (kL)			10.0
Overflow Pipe Diameter (mm)			50.0
Orifice Discharge Coefficient			0.60
Number of CSTR Cells			2
	k (m/yr)	C* (mg/L)	C** (mg/L)
Total Suspended Solids	400	12.000	12.000
Total Phosphorus	300	0.130	0.130
Total Nitrogen	40	1.400	1.400
Threshold Hydraulic Loading for C** (m/yr)			0

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Swale Defaults

Low Flow By-Pass (cubic metres per sec)	0.000
Length (metres)	100.0
Bed Slope (%)	3.0
Base Width (metres)	1.0
Top Width (metres)	5.0
Depth (metres)	0.50
Vegetation Height (metres)	0.250
Seepage Loss (mm/hr)	0.00
Number of CSTR Cells	10

	k (m/yr)	C* (mg/L)	C** (mg/L)
Total Suspended Solids	8000	20.000	14.000
Total Phosphorus	6000	0.130	0.130
Total Nitrogen	500	1.400	1.400
Threshold Hydraulic Loading for C** (m/yr)			3500

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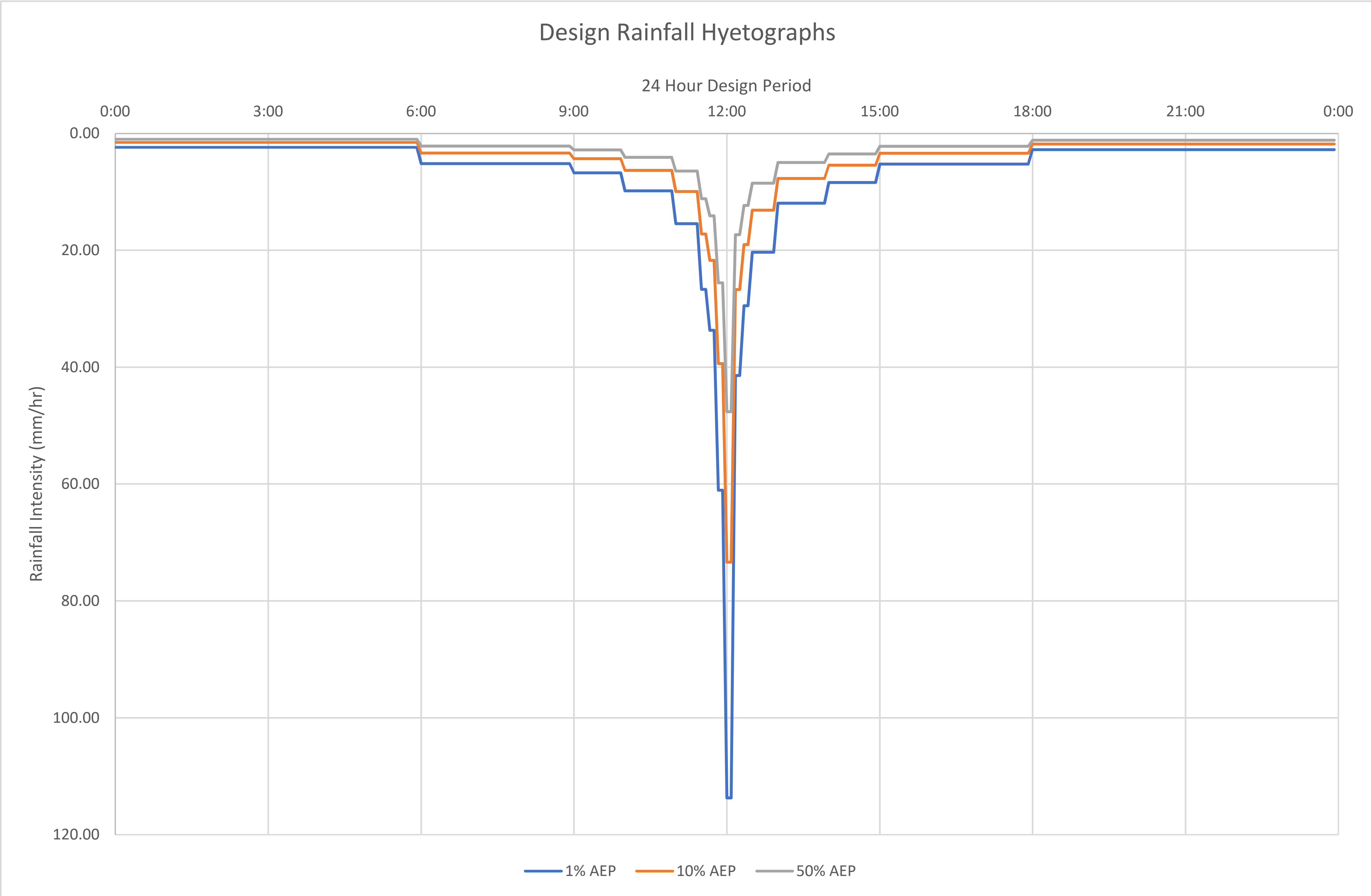
Wetland Defaults

Low Flow By-Pass (cubic metres per sec)	0.000
High Flow By-pass (cubic metres per sec)	100.000
Inlet Pond Volume (cubic metres)	0.0
Surface Area (square metres)	50.0
Extended Detention Depth (metres)	1.0
Permanent Pool Volume (cubic metres)	50.0
Vegetation Cover (% of surface area)	50.0
Seepage Loss (mm/hr)	0.00
Evaporative Loss as % of PET	125.00
Equivalent Pipe Diameter (mm)	200.0
Overflow Weir Width (metres)	3.0
Orifice Discharge Coefficient	0.60
Weir Coefficient	1.70
Number of CSTR Cells	4

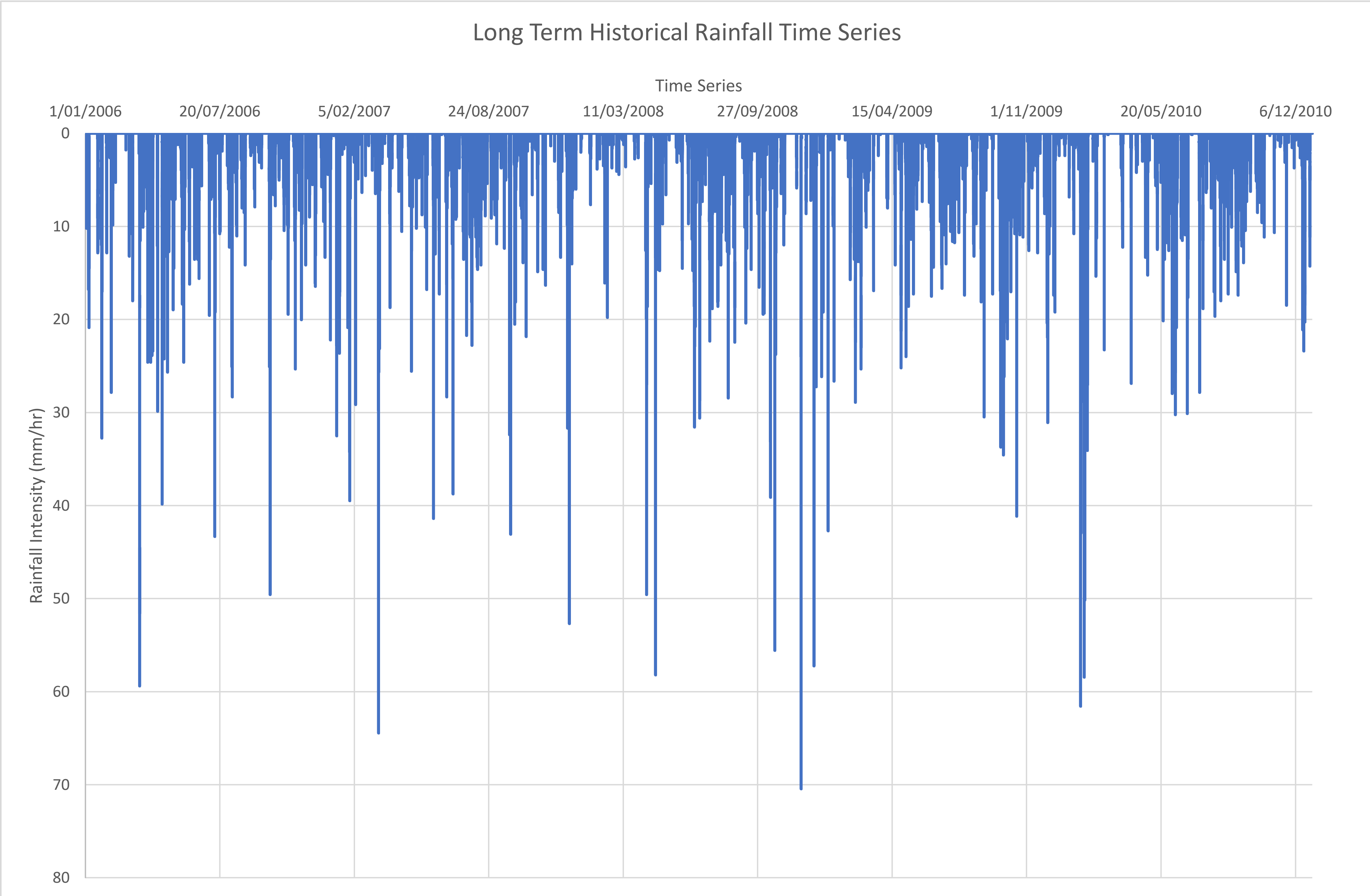
	k (m/yr)	C* (mg/L)	C** (mg/L)
Total Suspended Solids	1500	6.000	6.000
Total Phosphorus	1000	0.060	0.060
Total Nitrogen	150	1.000	1.000

Threshold Hydraulic Loading for C** (m/yr)	3500

APPENDIX E – DESIGN RAINFALL HYETOGRAPHS

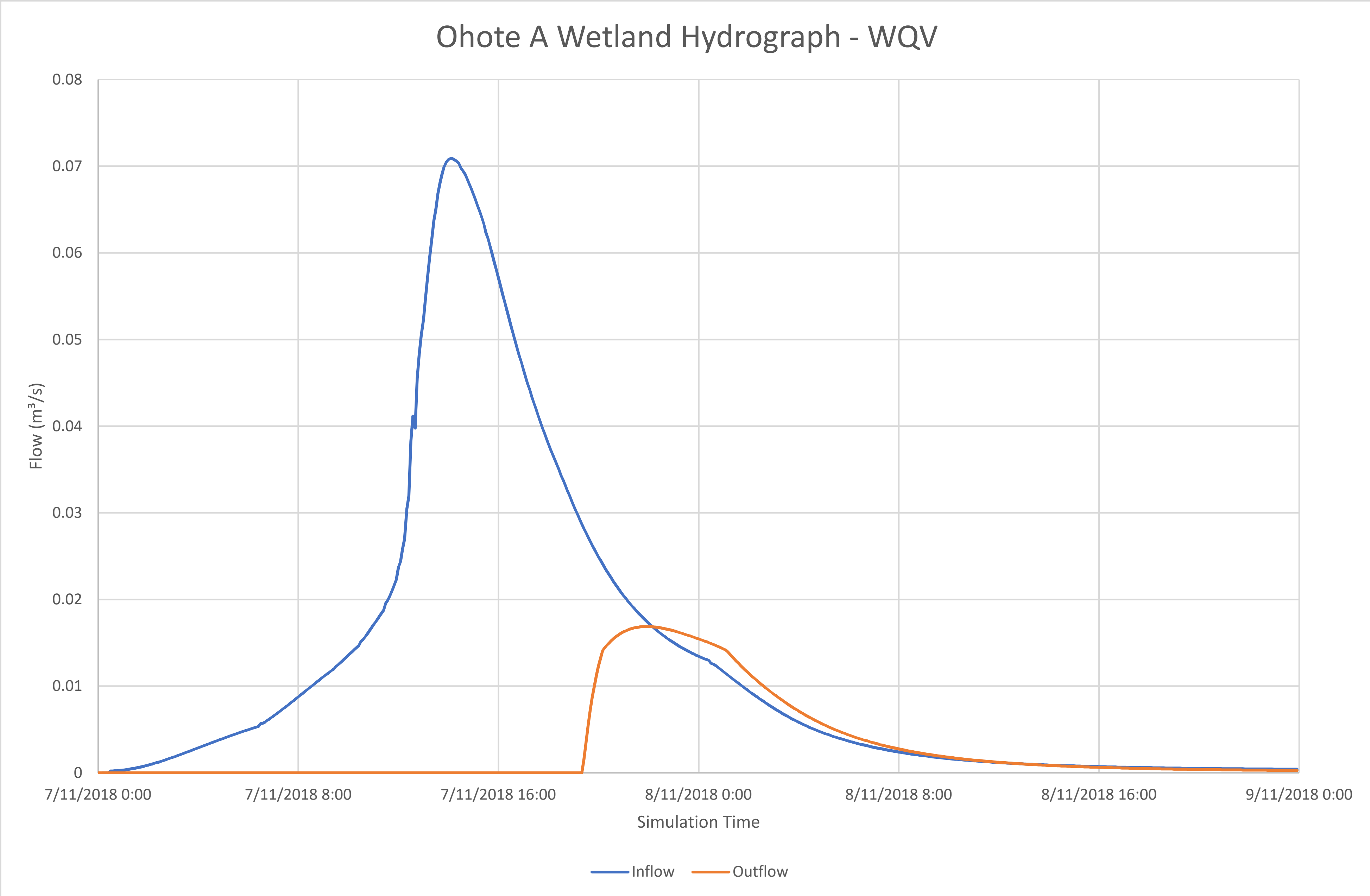


Design Rainfall Hyetographs
24 Hour Design Period
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
0:00
Rainfall Intensity (mm/hr)
0.00
20.00
40.00
60.00
80.00
100.00
120.00
1% AEP
10% AEP
50% AEP

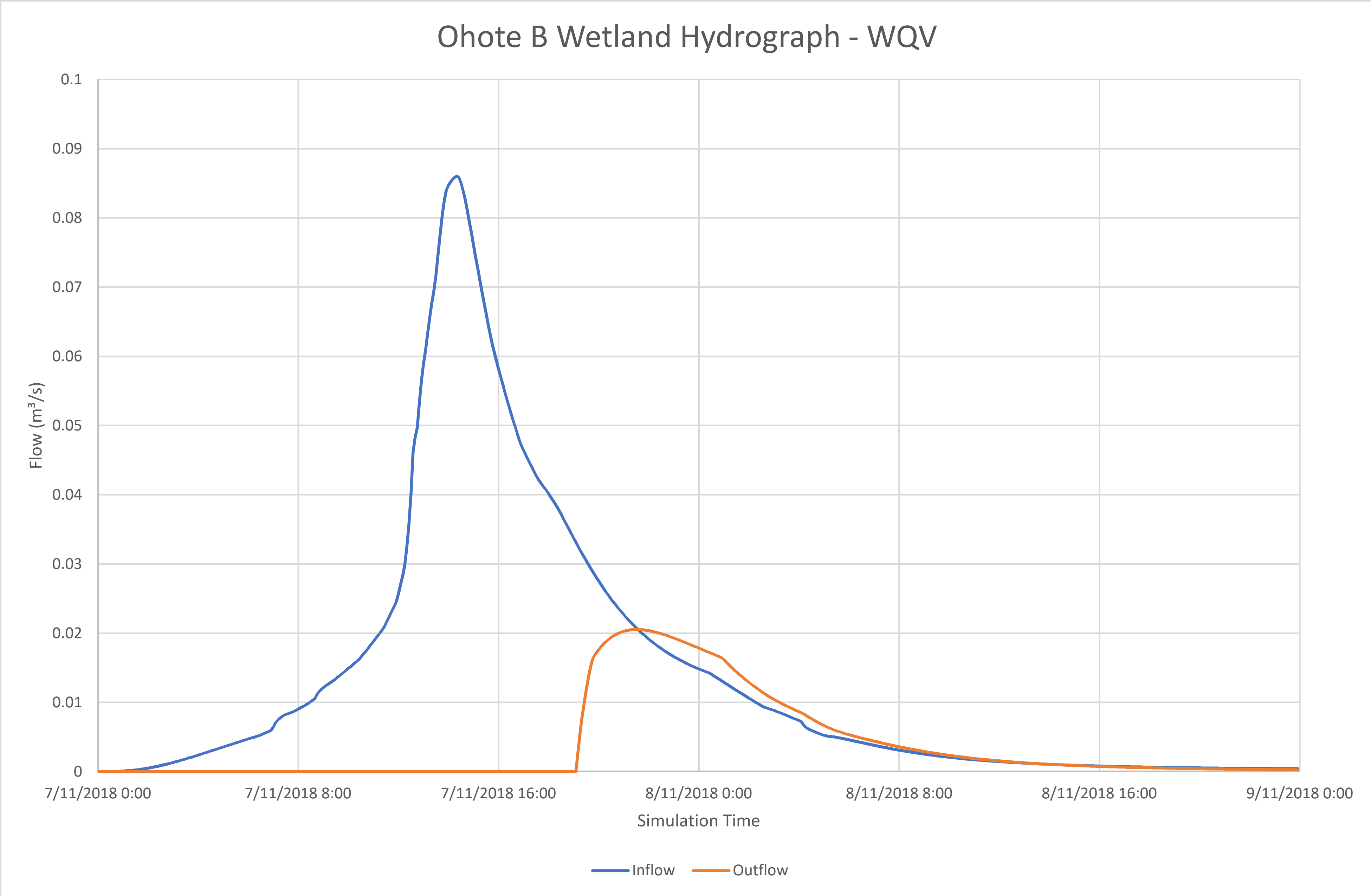


Long Term Historical Rainfall Time Series
Time Series
1/01/2006
20/07/2006
5/02/2007
24/08/2007
11/03/2008
27/09/2008
15/04/2009
1/11/2009
20/05/2010
6/12/2010
0
10
20
30
40
50
60
70
80
Rainfall Intensity (mm/hr)

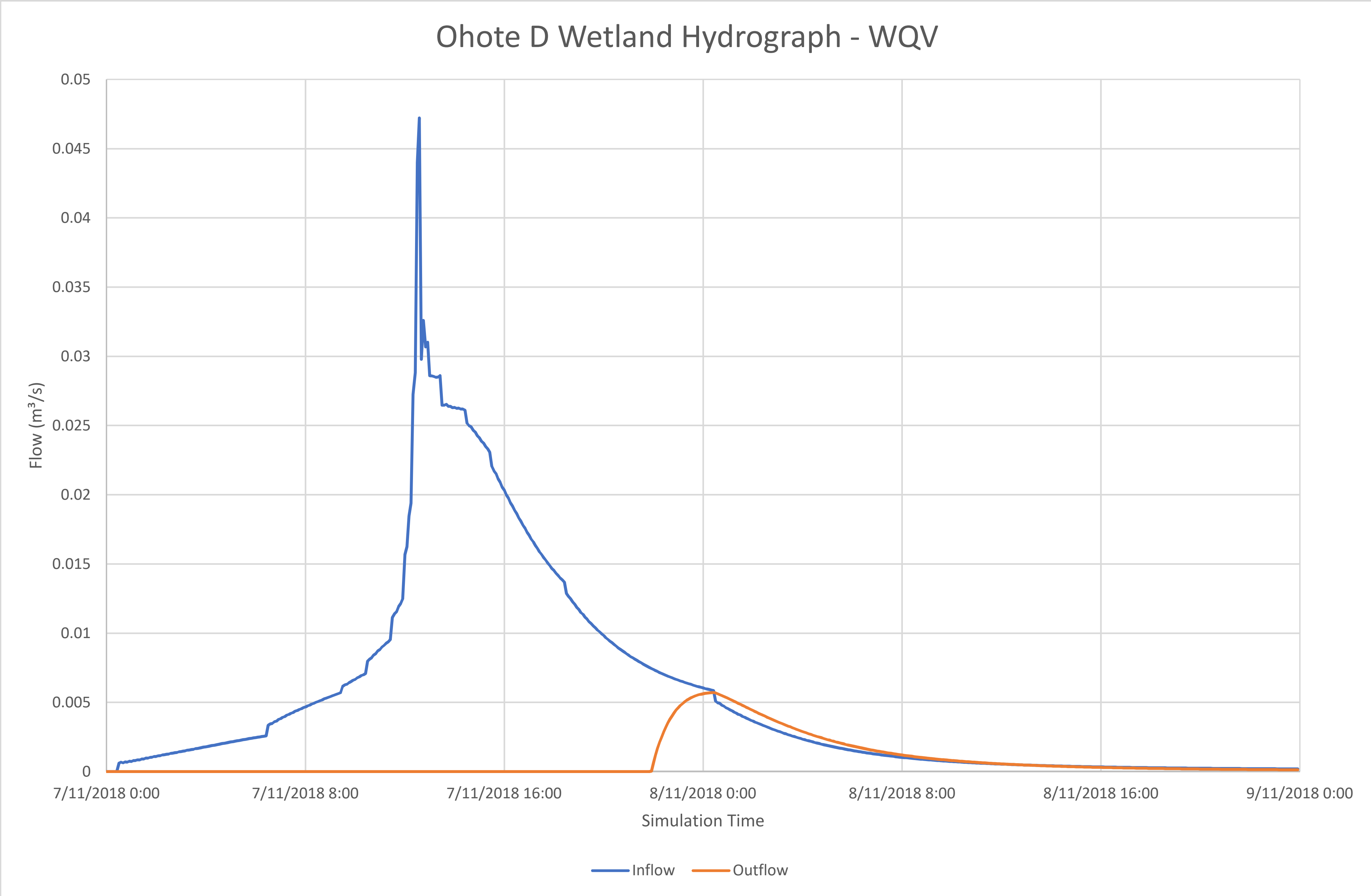
APPENDIX F – WETLAND HYDROGRAPHS



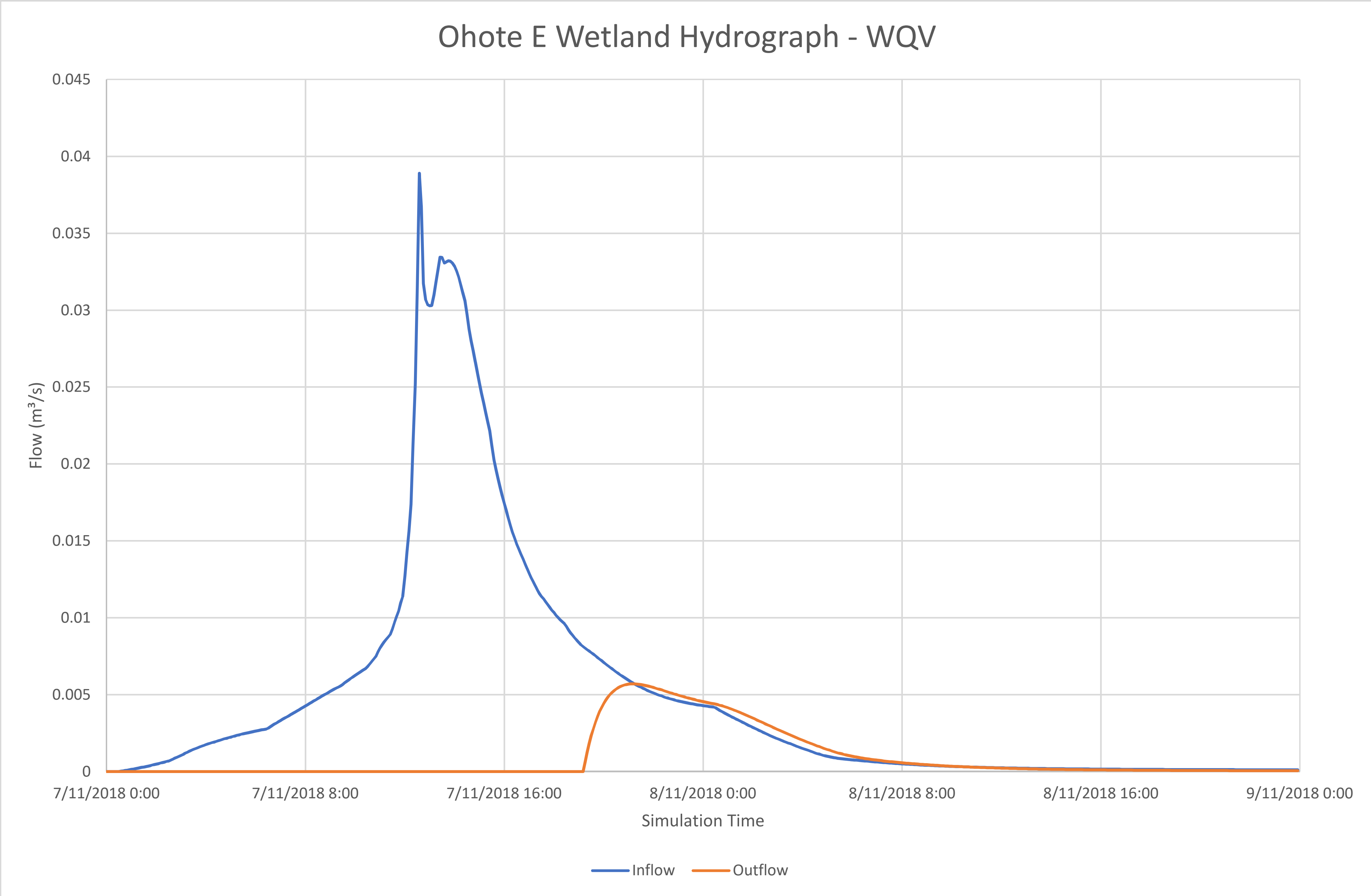
Ohote A Wetland Hydrograph - WQV
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
Flow (m³/s)
7/11/2018 0:00
7/11/2018 8:00
7/11/2018 16:00
8/11/2018 0:00
8/11/2018 8:00
8/11/2018 16:00
9/11/2018 0:00
Simulation Time
Inflow
Outflow



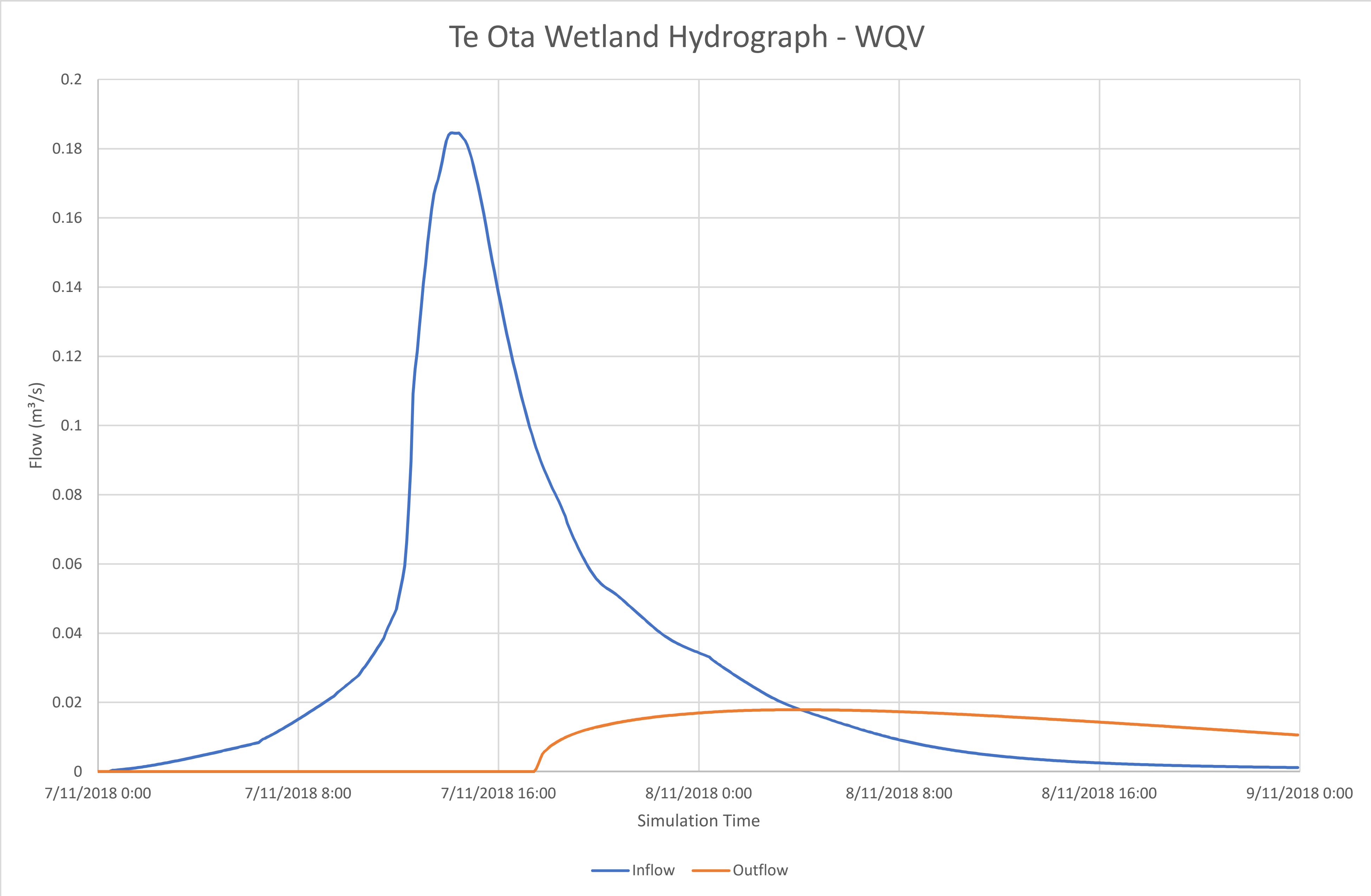
Ohote B Wetland Hydrograph - WQV
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
Flow (m³/s)
7/11/2018 0:00
7/11/2018 8:00
7/11/2018 16:00
8/11/2018 0:00
8/11/2018 8:00
8/11/2018 16:00
9/11/2018 0:00
Simulation Time
Inflow
Outflow



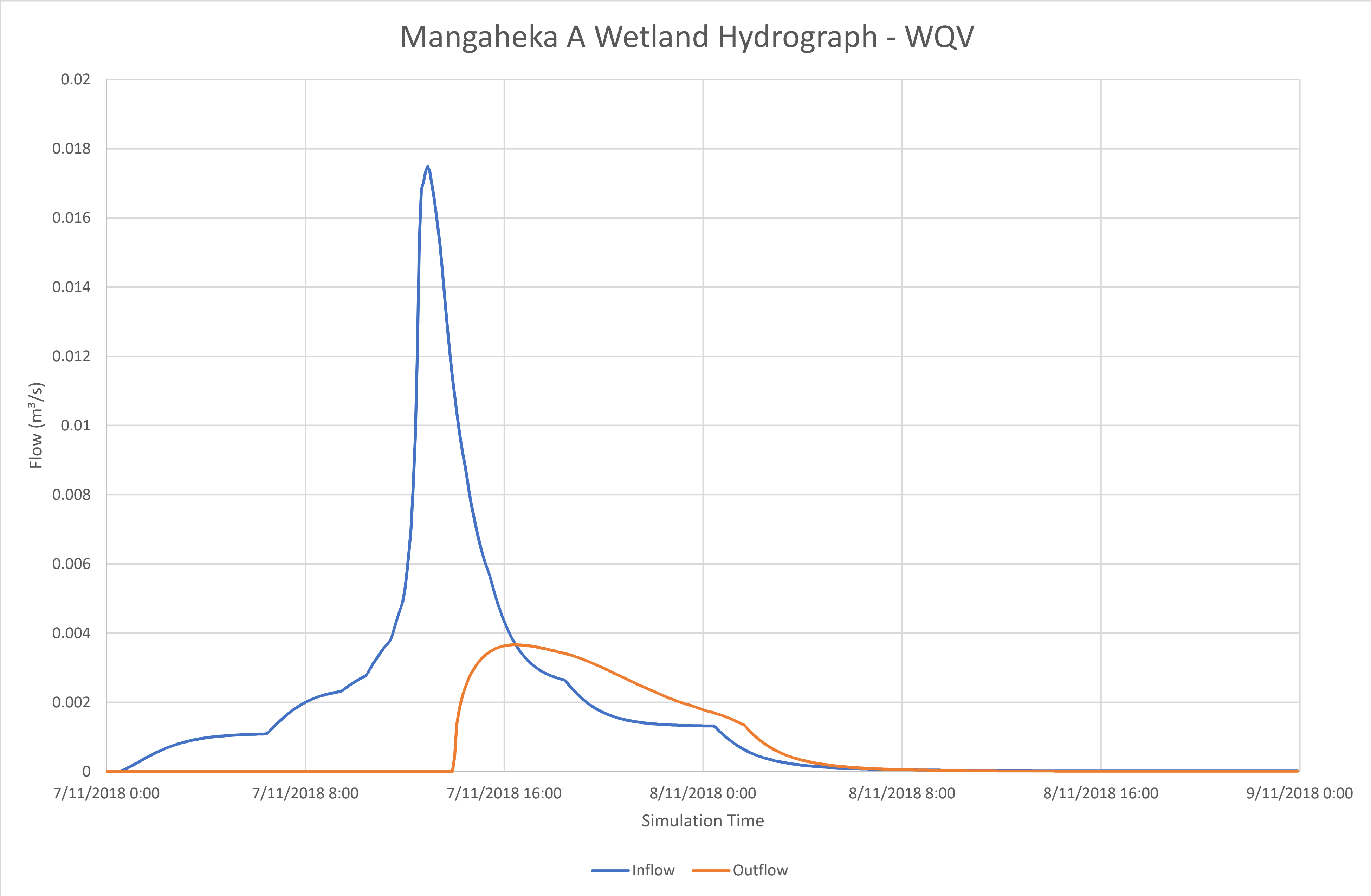
Ohote D Wetland Hydrograph - WQV
Flow (m³/s)
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
7/11/2018 0:00
7/11/2018 8:00
7/11/2018 16:00
8/11/2018 0:00
8/11/2018 8:00
8/11/2018 16:00
9/11/2018 0:00
Simulation Time
Inflow
Outflow



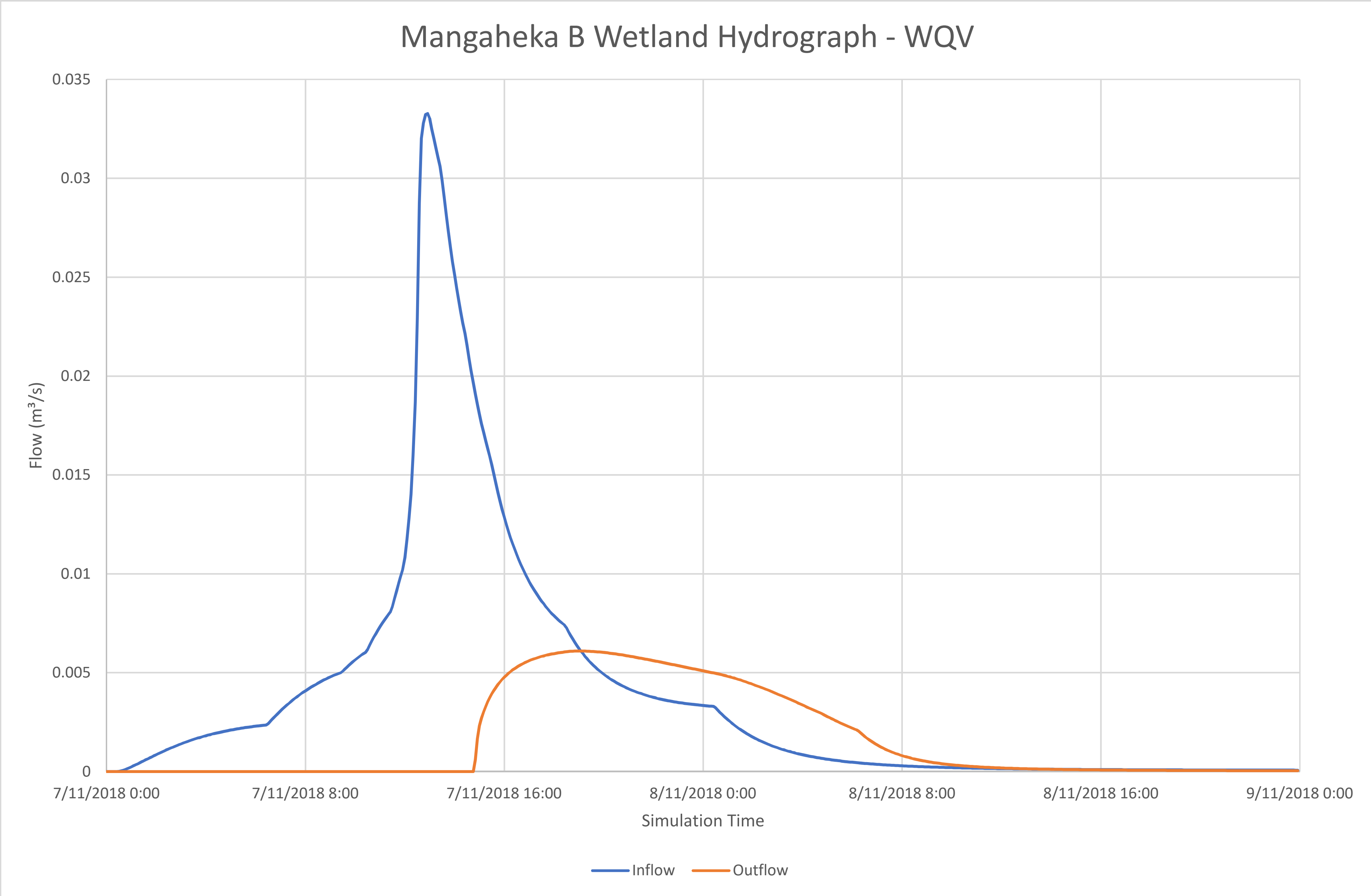
Ohote E Wetland Hydrograph - WQV
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
Flow (m³/s)
7/11/2018 0:00
7/11/2018 8:00
7/11/2018 16:00
8/11/2018 0:00
8/11/2018 8:00
8/11/2018 16:00
9/11/2018 0:00
Simulation Time
Inflow
Outflow



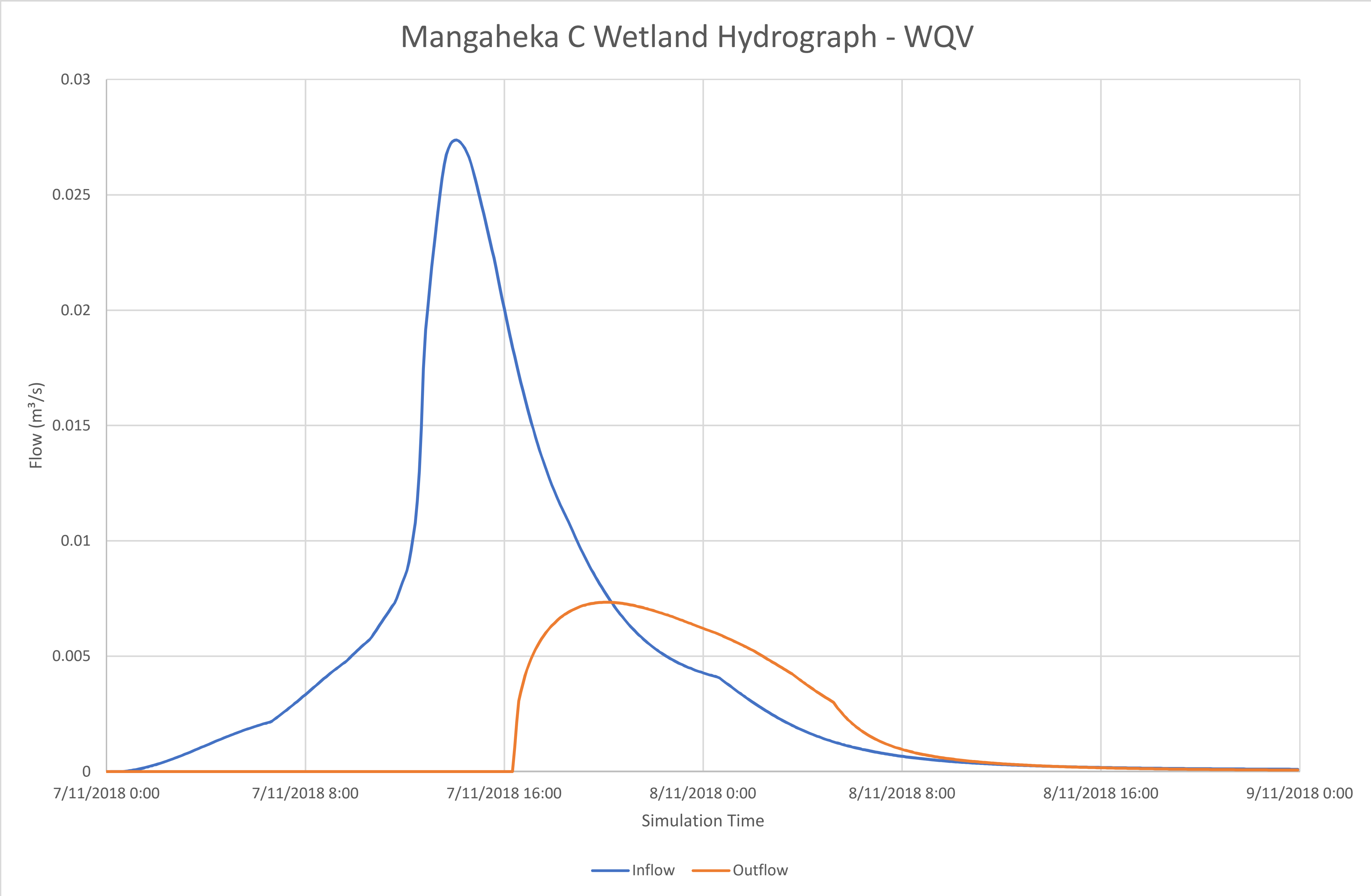
Te Ota Wetland Hydrograph - WQV
Flow (m³/s)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
7/11/2018 0:00
7/11/2018 8:00
7/11/2018 16:00
8/11/2018 0:00
8/11/2018 8:00
8/11/2018 16:00
9/11/2018 0:00
Simulation Time
Inflow
Outflow



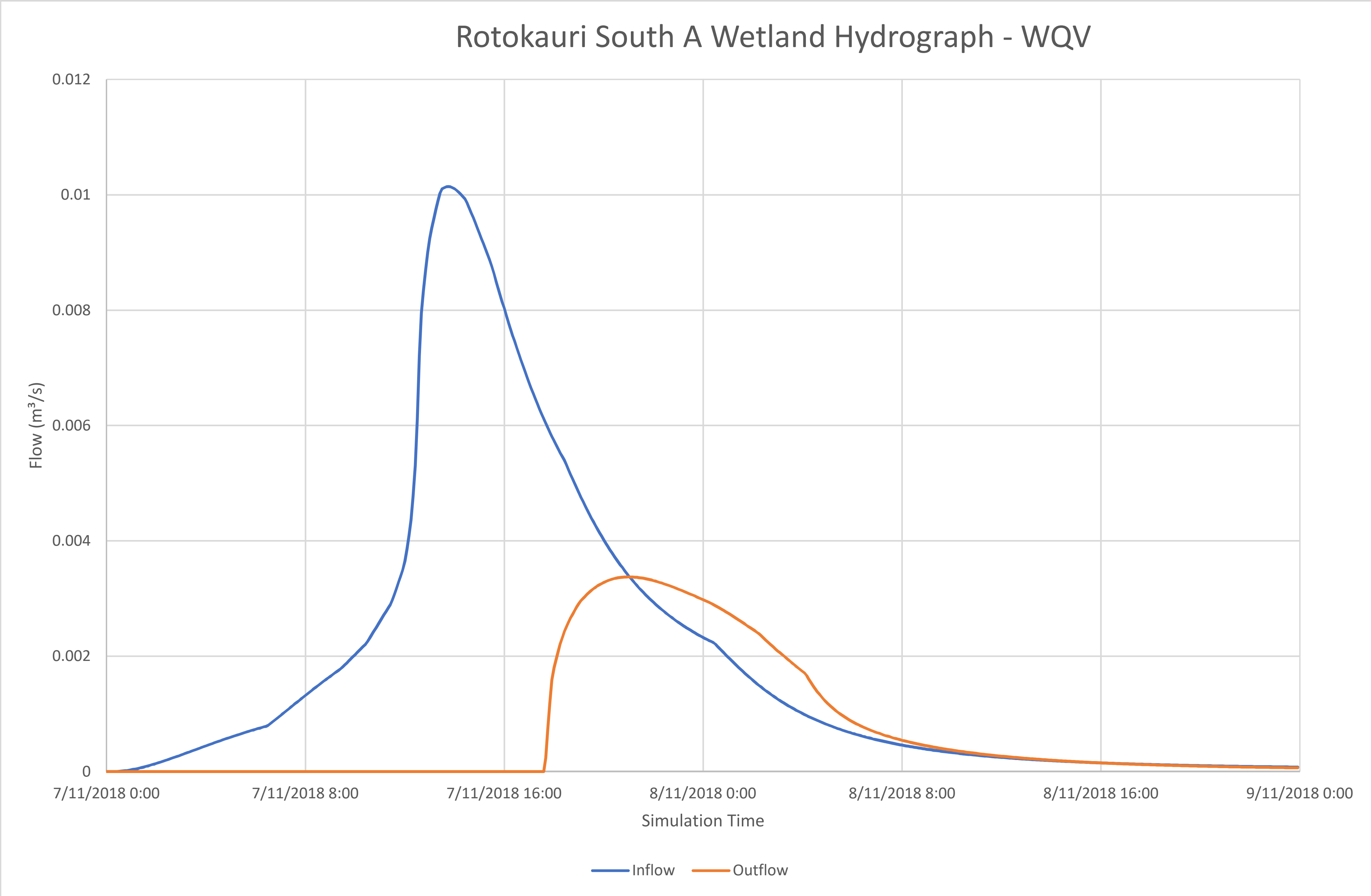
Mangaheka A Wetland Hydrograph - WQV
Flow (m³/s)
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
7/11/2018 0:00
7/11/2018 8:00
7/11/2018 16:00
8/11/2018 0:00
8/11/2018 8:00
8/11/2018 16:00
9/11/2018 0:00
Simulation Time
Inflow
Outflow



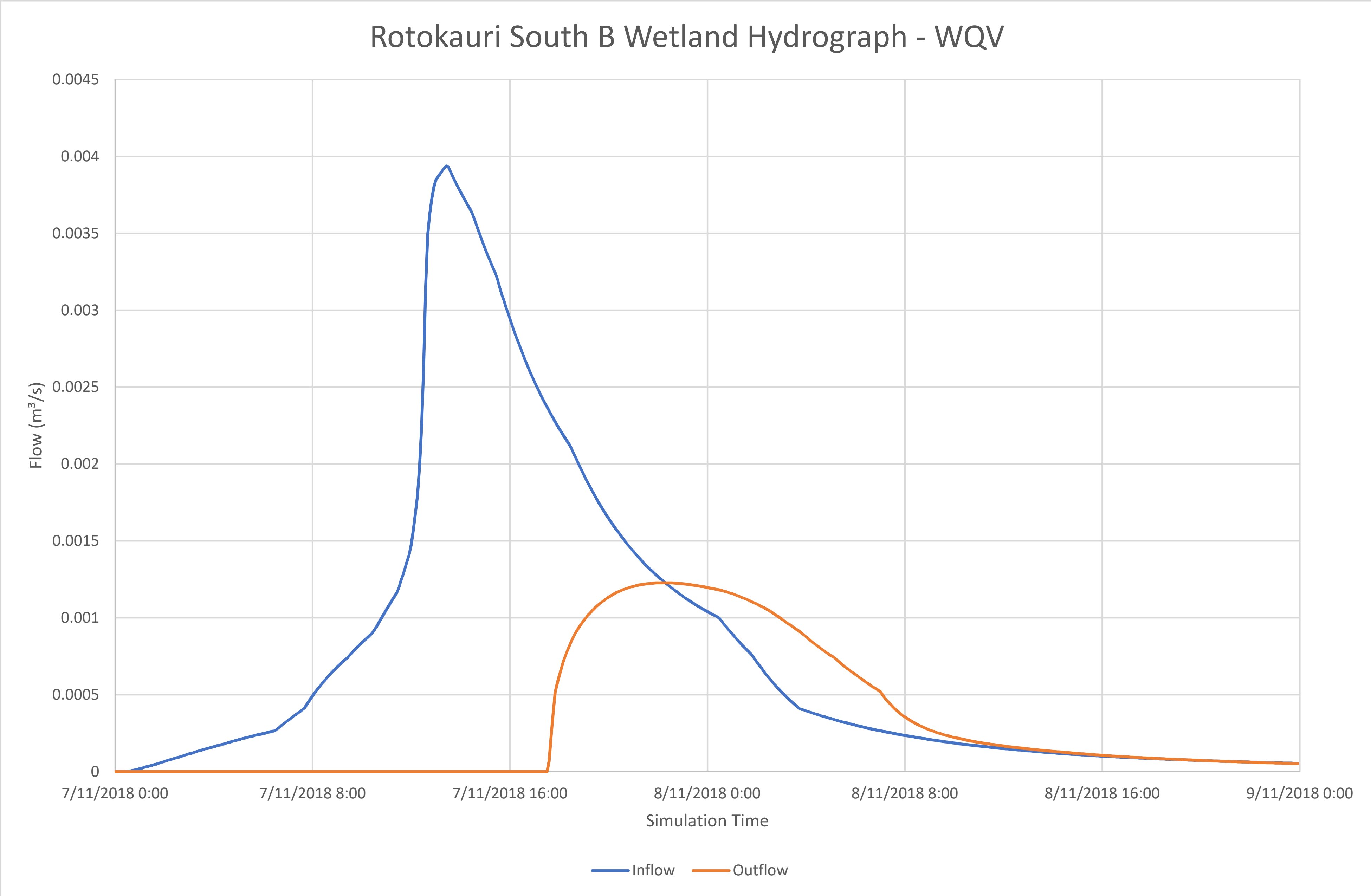
Mangaheka B Wetland Hydrograph - WQV
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
Flow (m³/s)
7/11/2018 0:00
7/11/2018 8:00
7/11/2018 16:00
8/11/2018 0:00
8/11/2018 8:00
8/11/2018 16:00
9/11/2018 0:00
Simulation Time
Inflow
Outflow



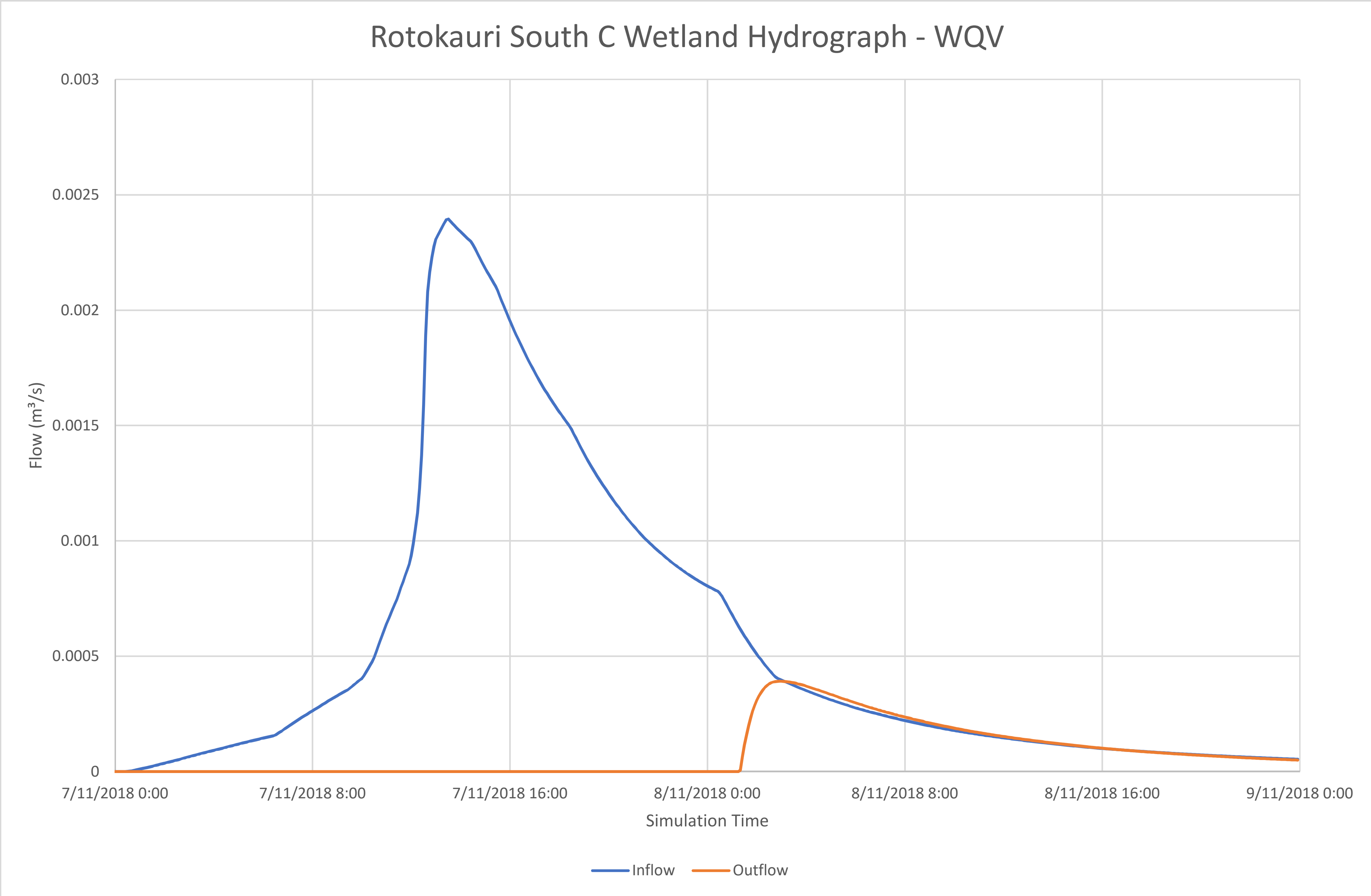
Mangaheka C Wetland Hydrograph - WQV
Flow (m³/s)
0.03
0.025
0.02
0.015
0.01
0.005
0
7/11/2018 0:00
7/11/2018 8:00
7/11/2018 16:00
8/11/2018 0:00
8/11/2018 8:00
8/11/2018 16:00
9/11/2018 0:00
Simulation Time
Inflow
Outflow



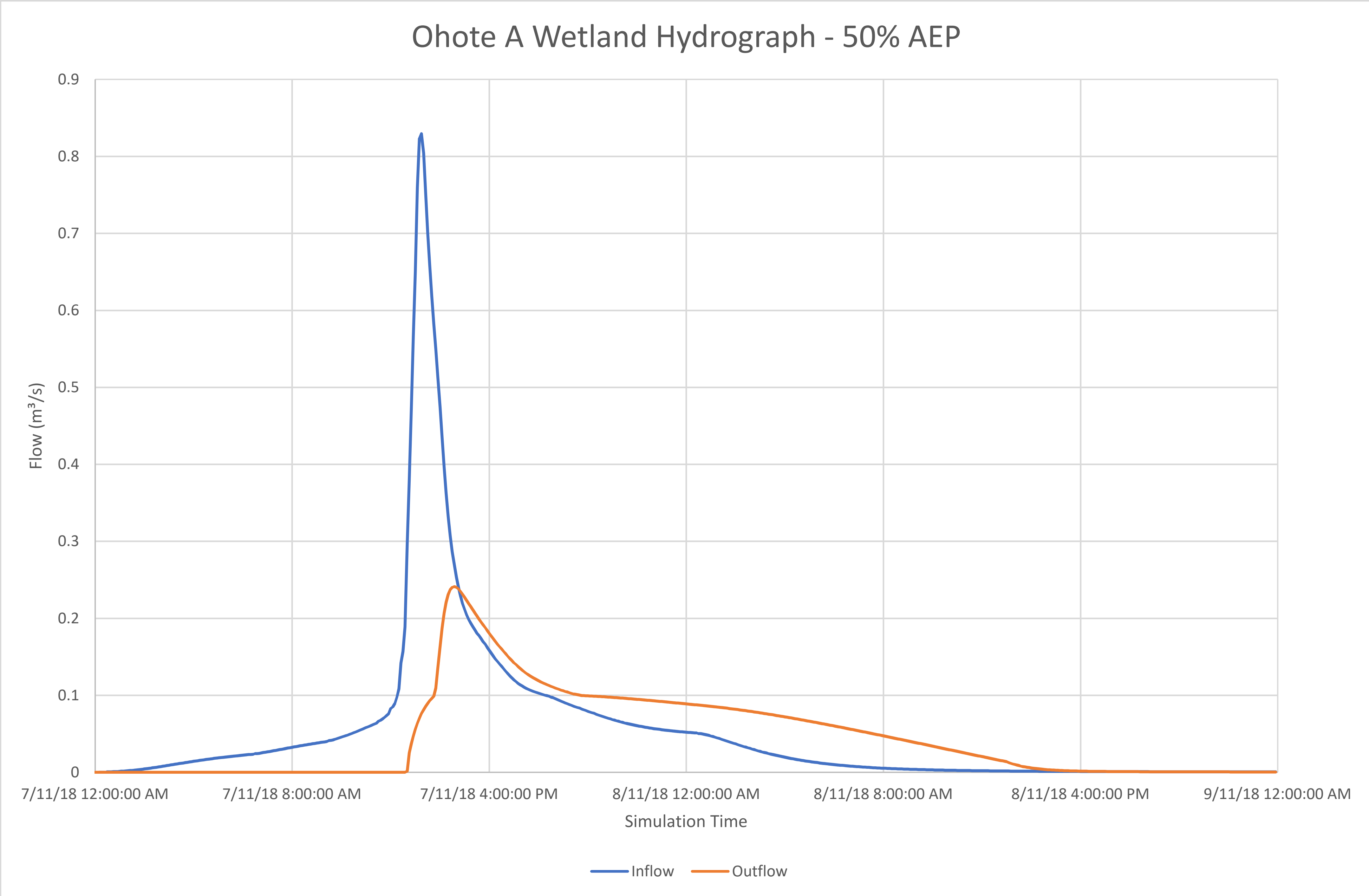
Rotokauri South A Wetland Hydrograph - WQV
0.012
0.01
0.008
0.006
0.004
0.002
0
Flow (m³/s)
7/11/2018 0:00
7/11/2018 8:00
7/11/2018 16:00
8/11/2018 0:00
8/11/2018 8:00
8/11/2018 16:00
9/11/2018 0:00
Simulation Time
Inflow
Outflow



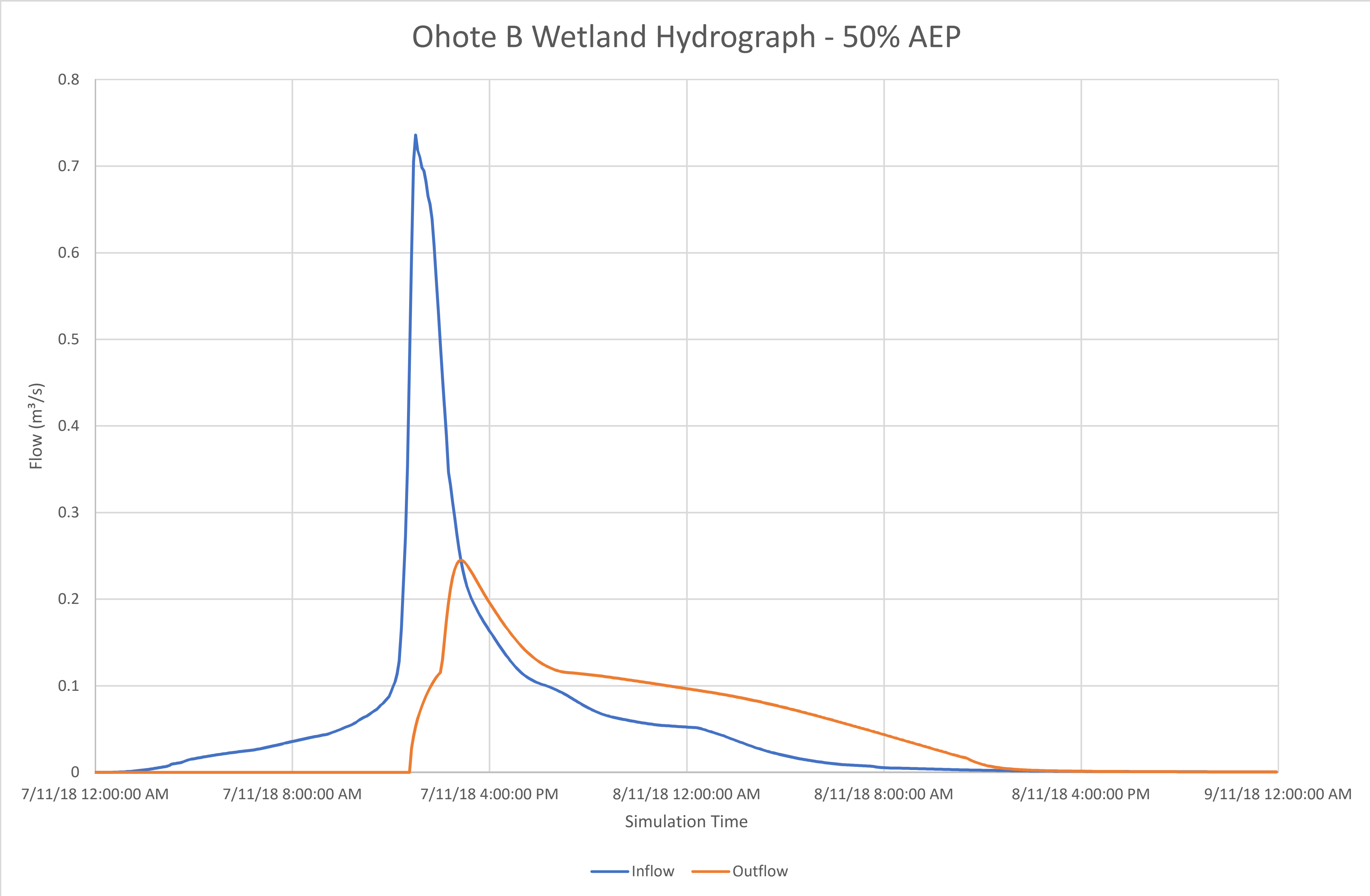
Rotokauri South B Wetland Hydrograph - WQV
0.0045
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
Flow (m³/s)
7/11/2018 0:00
7/11/2018 8:00
7/11/2018 16:00
8/11/2018 0:00
8/11/2018 8:00
8/11/2018 16:00
9/11/2018 0:00
Simulation Time
Inflow
Outflow



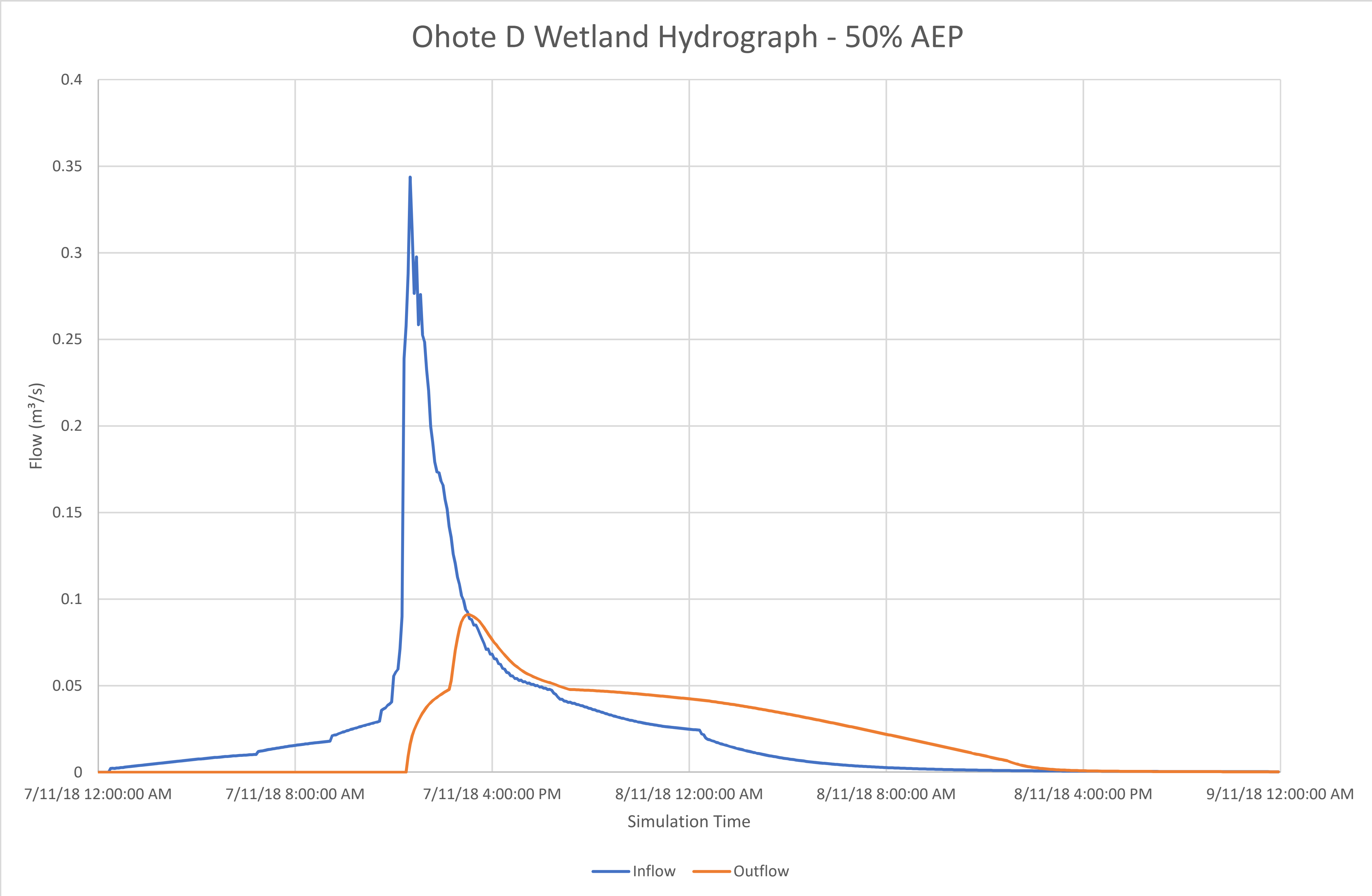
Rotokauri South C Wetland Hydrograph - WQV
Flow (m³/s)
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
7/11/2018 0:00
7/11/2018 8:00
7/11/2018 16:00
8/11/2018 0:00
8/11/2018 8:00
8/11/2018 16:00
9/11/2018 0:00
Simulation Time
Inflow
Outflow



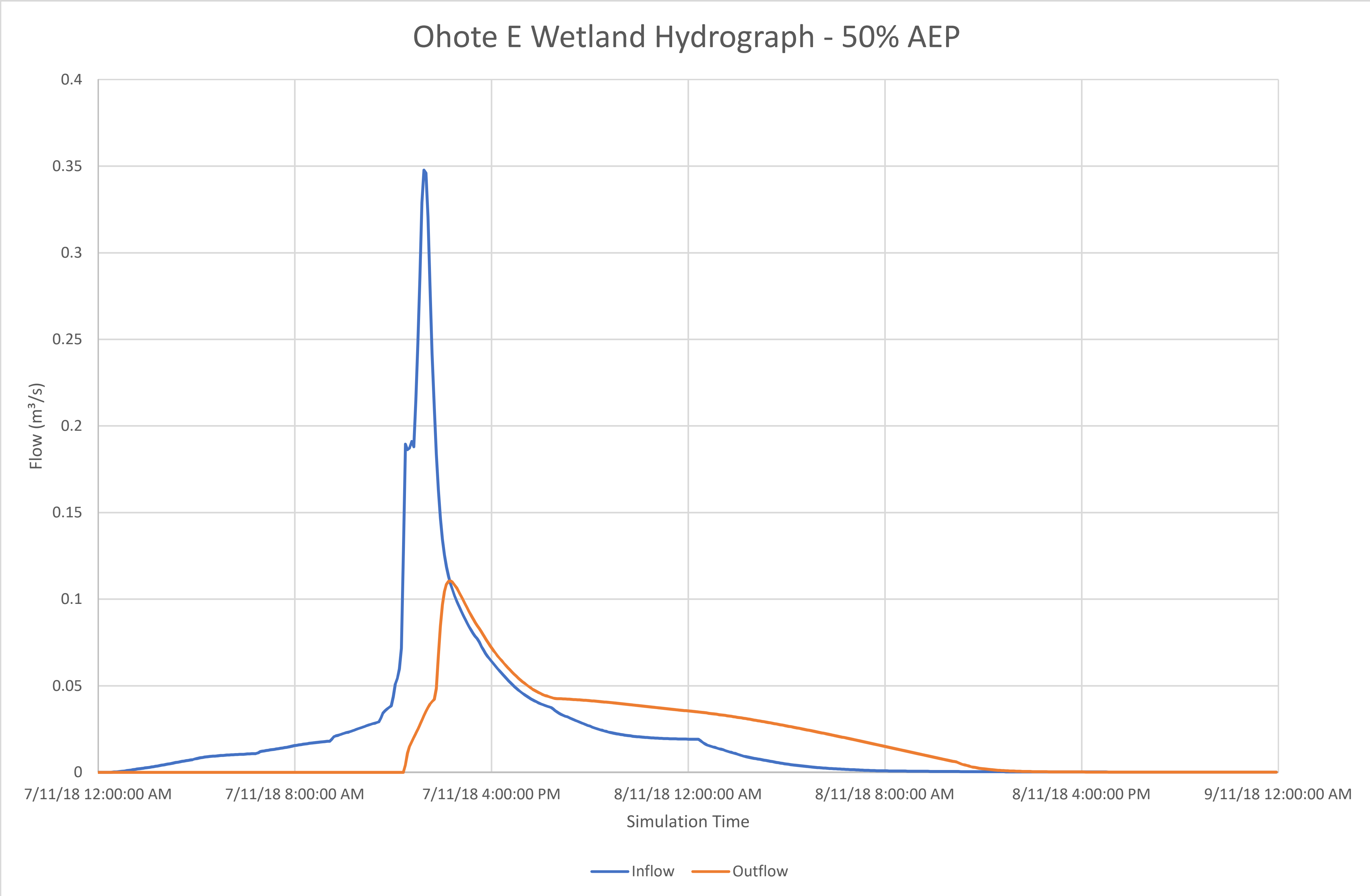
Ohote A Wetland Hydrograph - 50% AEP
Flow (m³/s)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
7/11/18 12:00:00 AM
7/11/18 8:00:00 AM
7/11/18 4:00:00 PM
8/11/18 12:00:00 AM
8/11/18 8:00:00 AM
8/11/18 4:00:00 PM
9/11/18 12:00:00 AM
Simulation Time
Inflow
Outflow



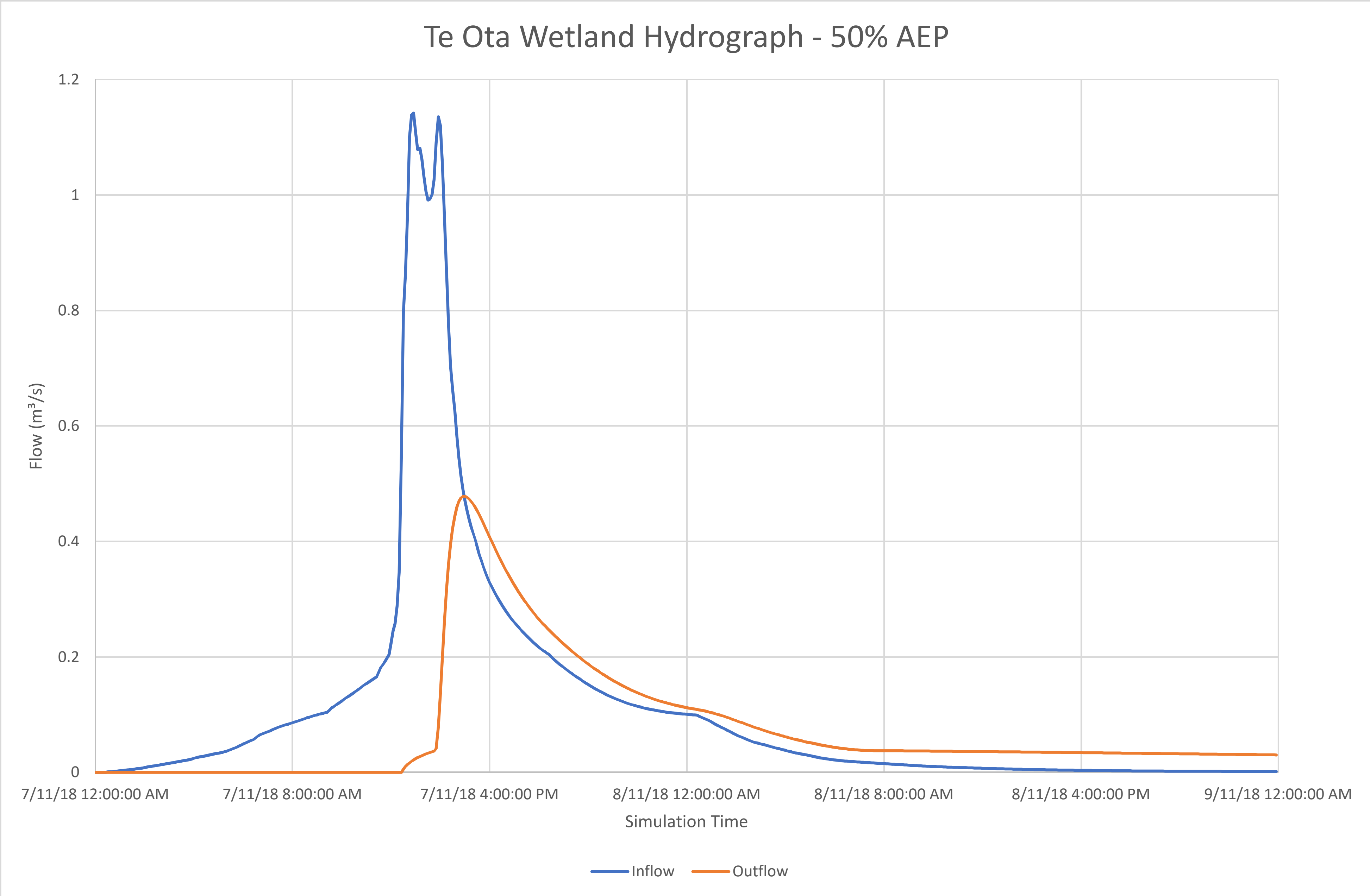
Ohote B Wetland Hydrograph - 50% AEP
Flow (m³/s)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
7/11/18 12:00:00 AM
7/11/18 8:00:00 AM
7/11/18 4:00:00 PM
8/11/18 12:00:00 AM
8/11/18 8:00:00 AM
8/11/18 4:00:00 PM
9/11/18 12:00:00 AM
Simulation Time
Inflow
Outflow



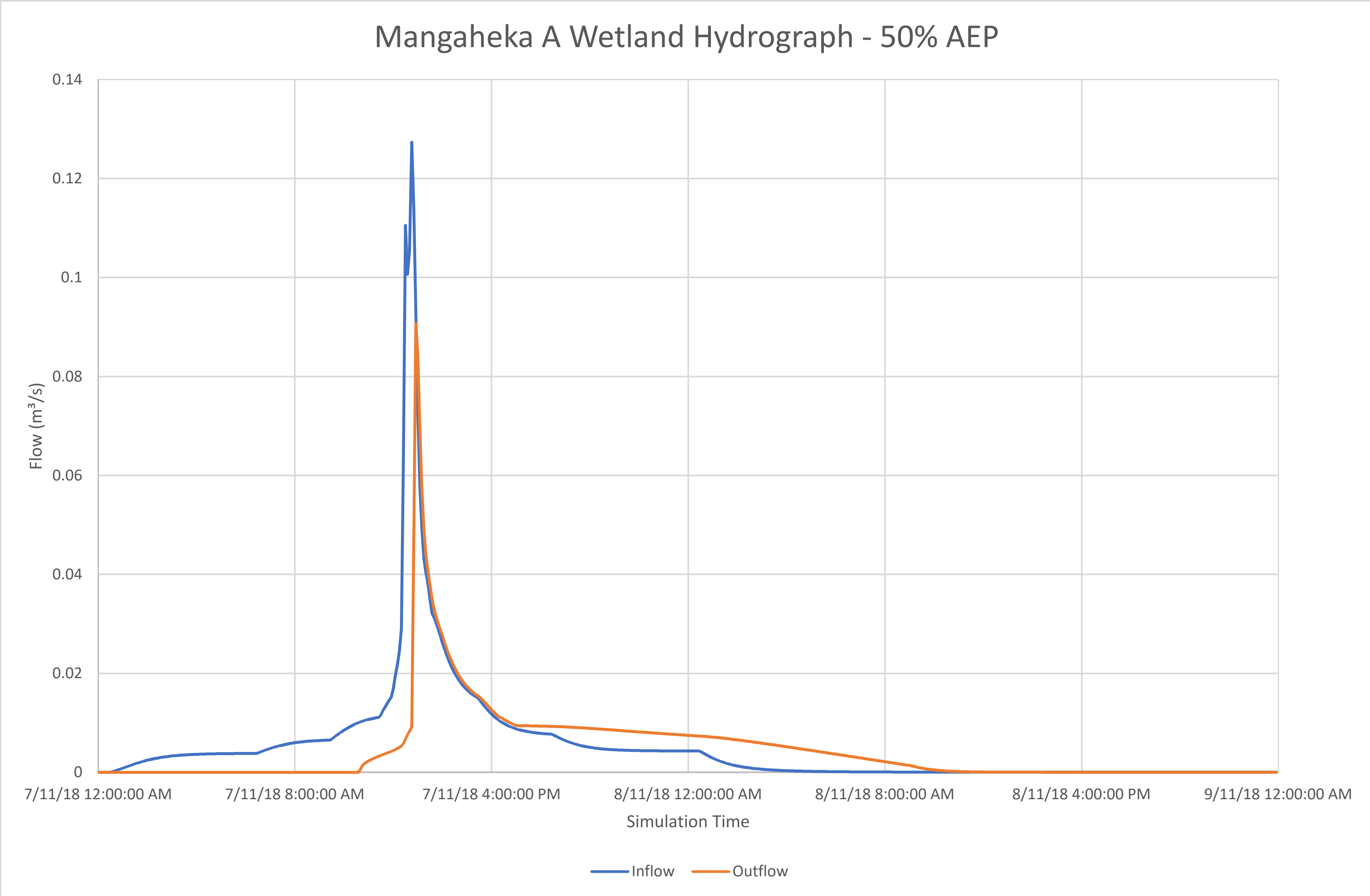
Ohote D Wetland Hydrograph - 50% AEP
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Flow (m³/s)
7/11/18 12:00:00 AM
7/11/18 8:00:00 AM
7/11/18 4:00:00 PM
8/11/18 12:00:00 AM
8/11/18 8:00:00 AM
8/11/18 4:00:00 PM
9/11/18 12:00:00 AM
Simulation Time
Inflow
Outflow

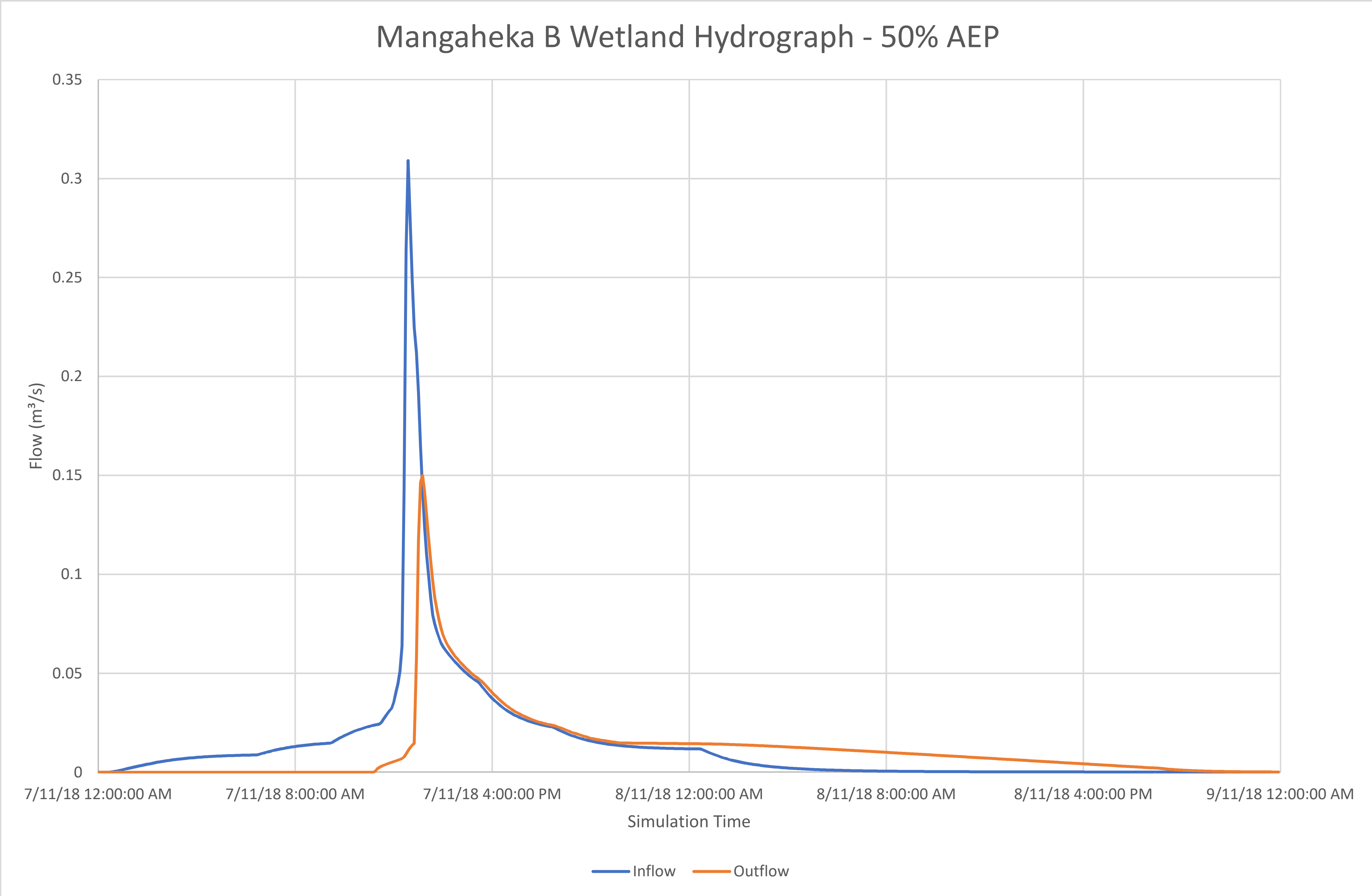


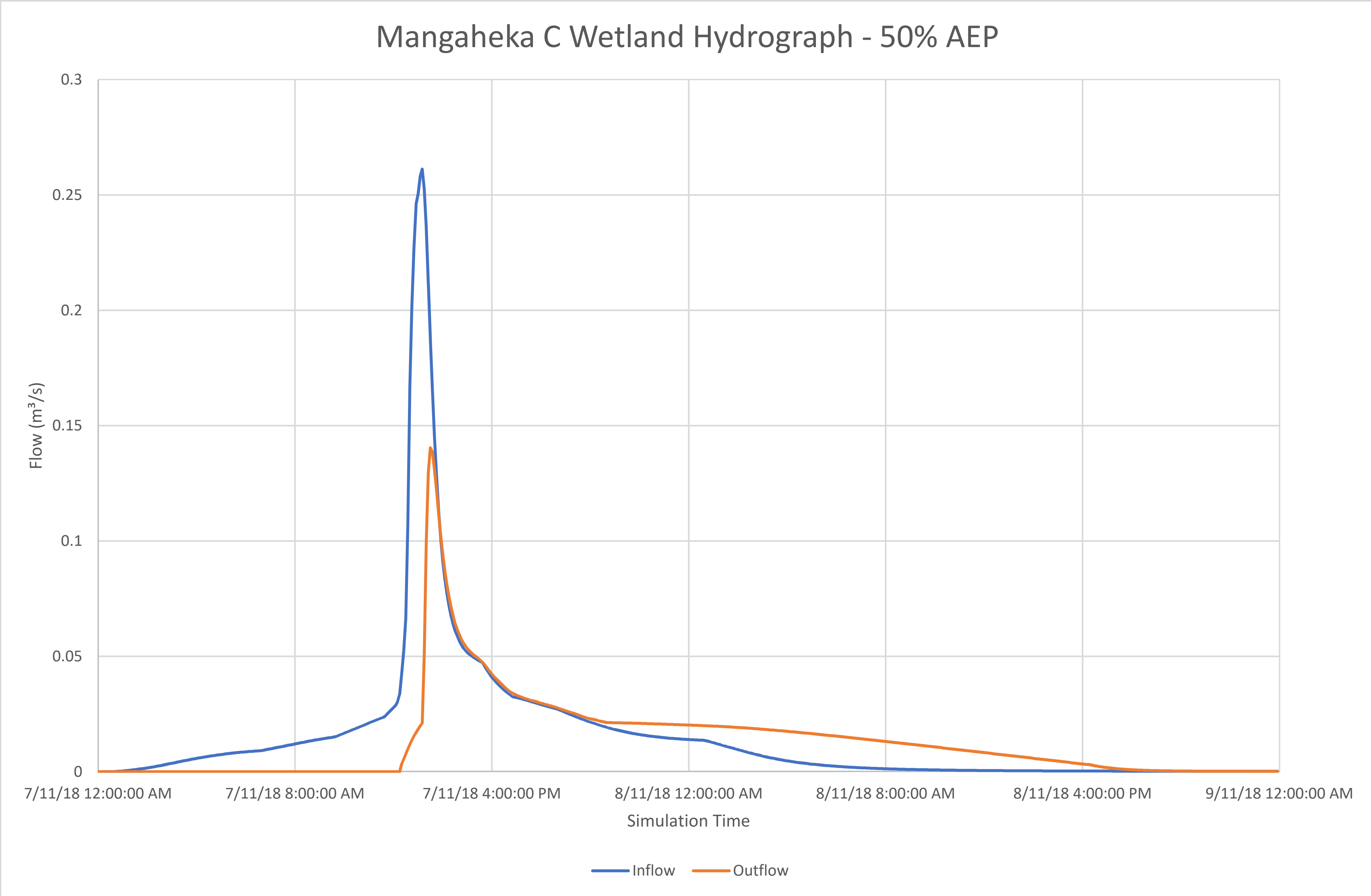
Ohote E Wetland Hydrograph - 50% AEP
Flow (m^3/s)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
7/11/18 12:00:00 AM
7/11/18 8:00:00 AM
7/11/18 4:00:00 PM
8/11/18 12:00:00 AM
8/11/18 8:00:00 AM
8/11/18 4:00:00 PM
9/11/18 12:00:00 AM
Simulation Time
Inflow
Outflow

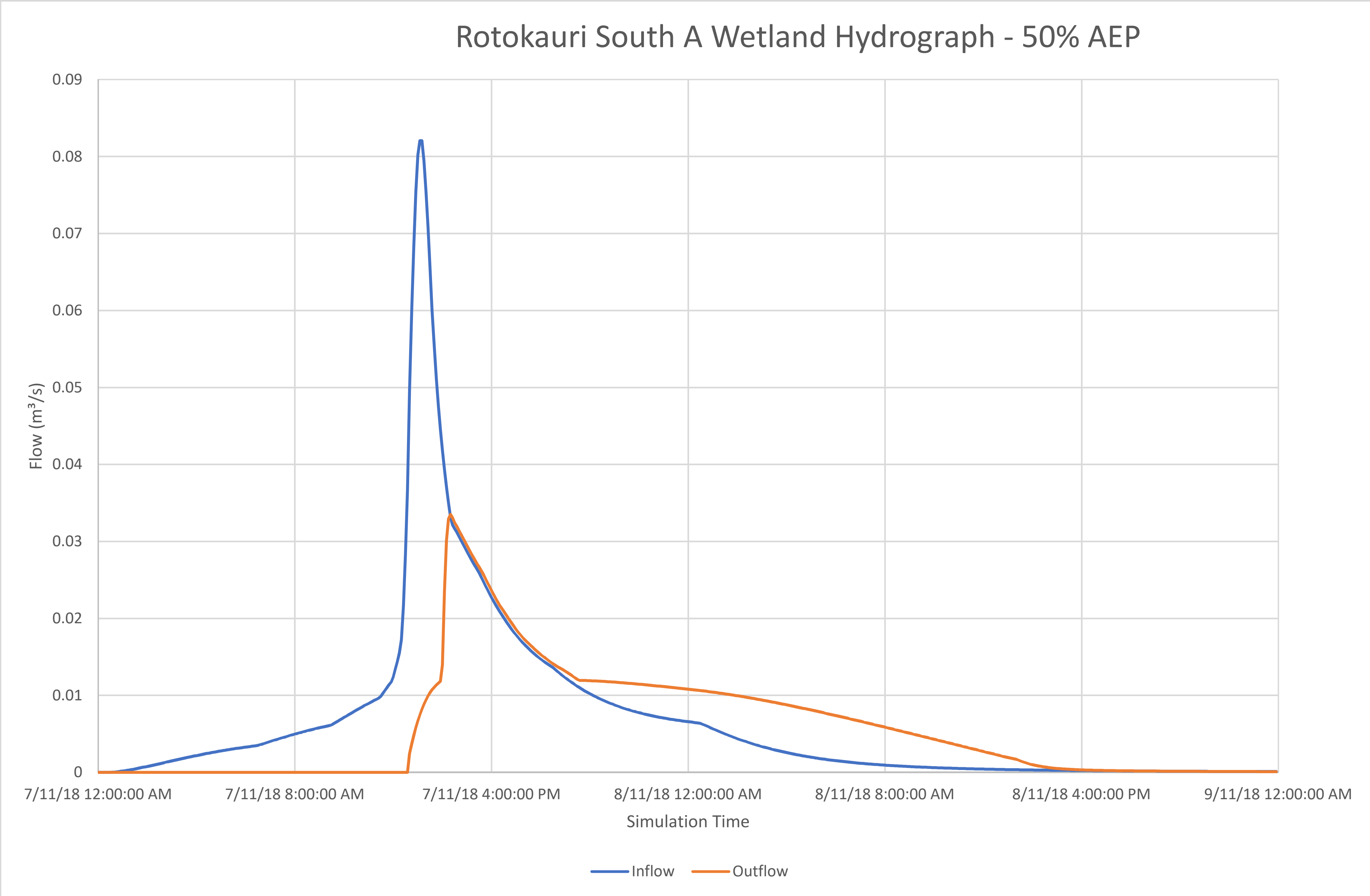


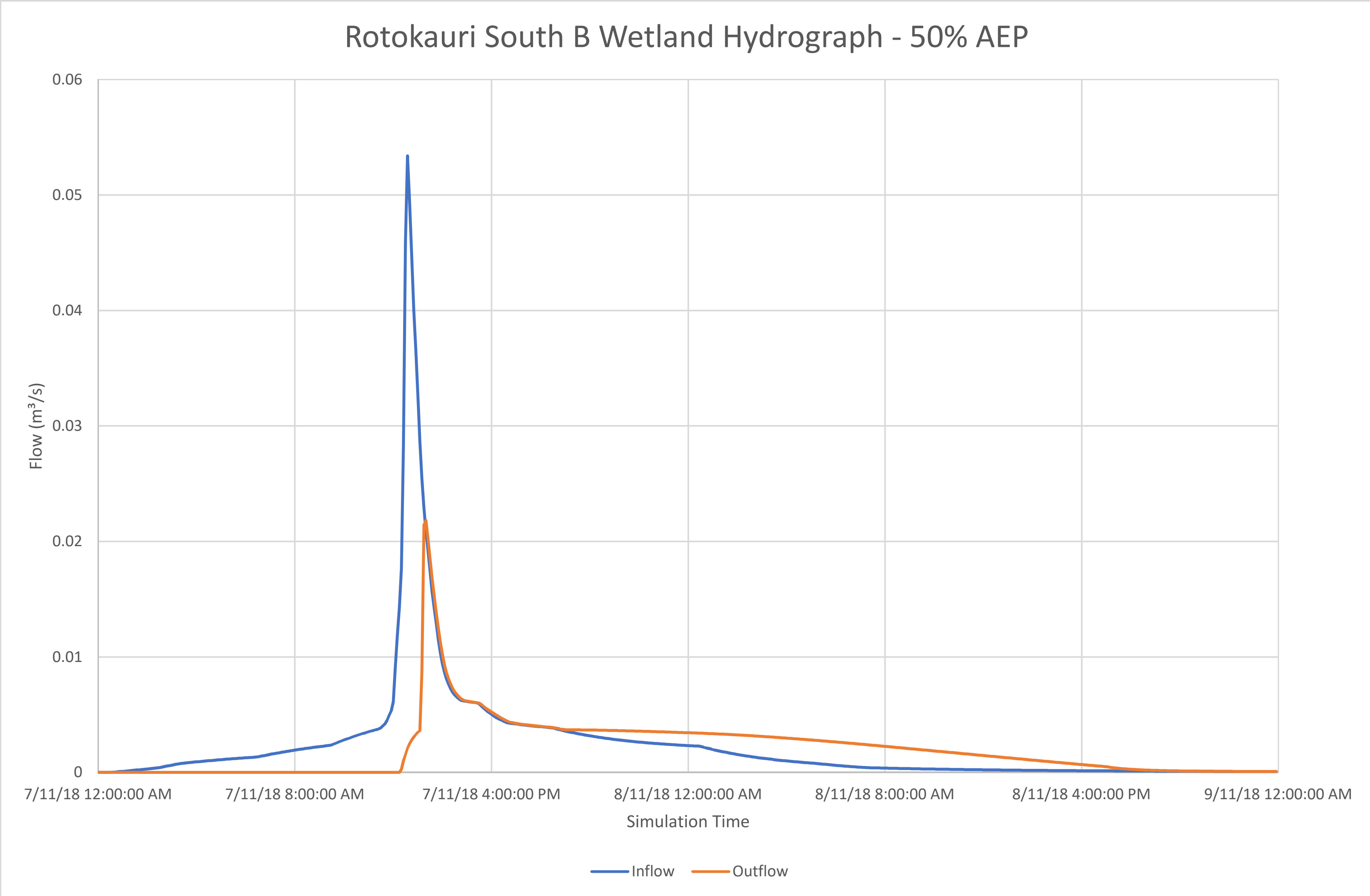
Te Ota Wetland Hydrograph - 50% AEP
Flow (m³/s)
1.2
1
0.8
0.6
0.4
0.2
0
7/11/18 12:00:00 AM
7/11/18 8:00:00 AM
7/11/18 4:00:00 PM
8/11/18 12:00:00 AM
8/11/18 8:00:00 AM
8/11/18 4:00:00 PM
9/11/18 12:00:00 AM
Simulation Time
Inflow
Outflow

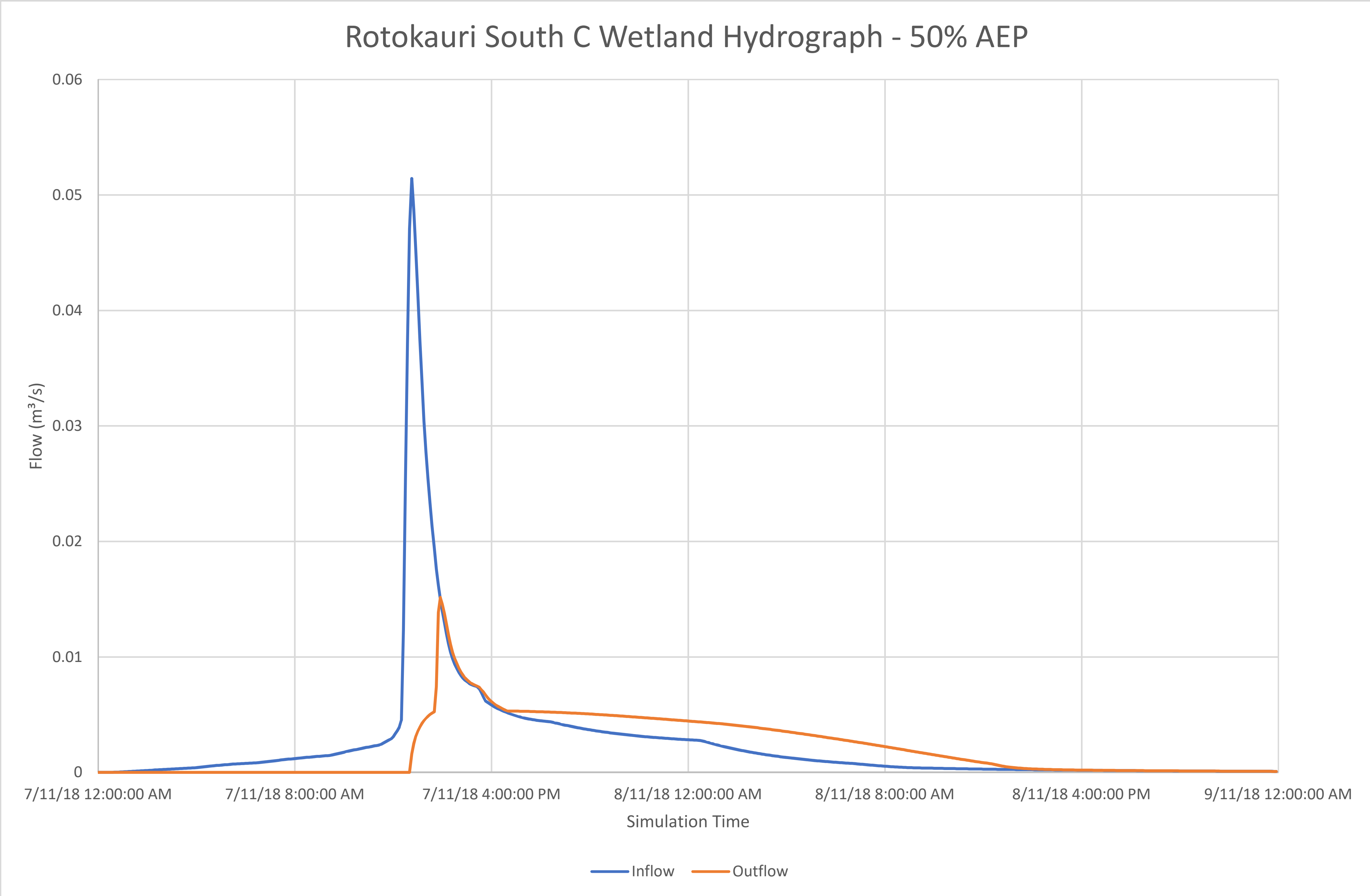

Mangaheka A Wetland Hydrograph - 50% AEP
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Flow (m³/s)
7/11/18 12:00:00 AM
7/11/18 8:00:00 AM
7/11/18 4:00:00 PM
8/11/18 12:00:00 AM
8/11/18 8:00:00 AM
8/11/18 4:00:00 PM
9/11/18 12:00:00 AM
Simulation Time
Inflow
Outflow


Mangaheka B Wetland Hydrograph - 50% AEP
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Flow (m³/s)
7/11/18 12:00:00 AM
7/11/18 8:00:00 AM
7/11/18 4:00:00 PM
8/11/18 12:00:00 AM
8/11/18 8:00:00 AM
8/11/18 4:00:00 PM
9/11/18 12:00:00 AM
Simulation Time
Inflow
Outflow

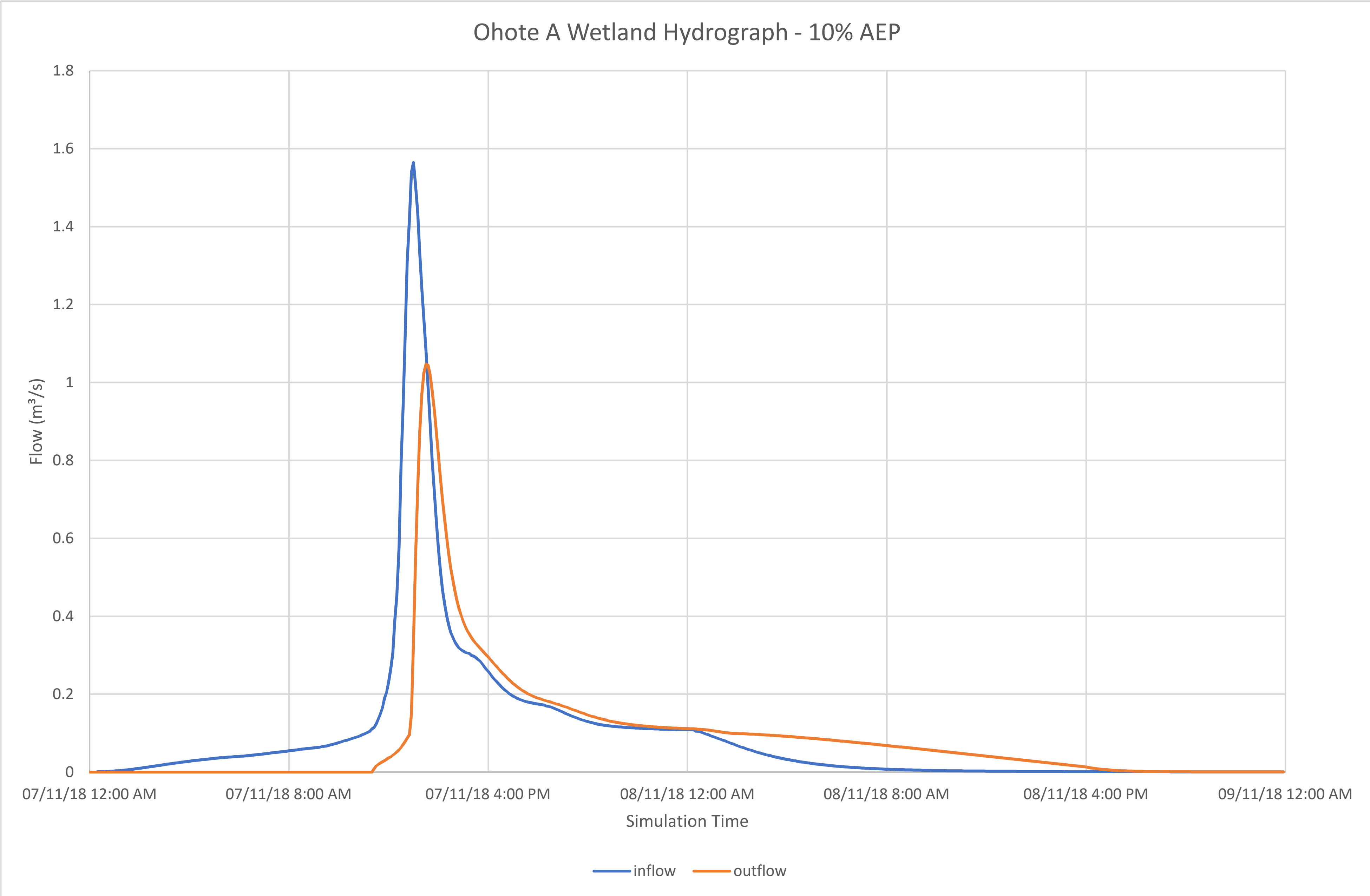

Mangaheka C Wetland Hydrograph - 50% AEP
Flow (m³/s)
0.3
0.25
0.2
0.15
0.1
0.05
0
7/11/18 12:00:00 AM
7/11/18 8:00:00 AM
7/11/18 4:00:00 PM
8/11/18 12:00:00 AM
8/11/18 8:00:00 AM
8/11/18 4:00:00 PM
9/11/18 12:00:00 AM
Simulation Time
Inflow
Outflow

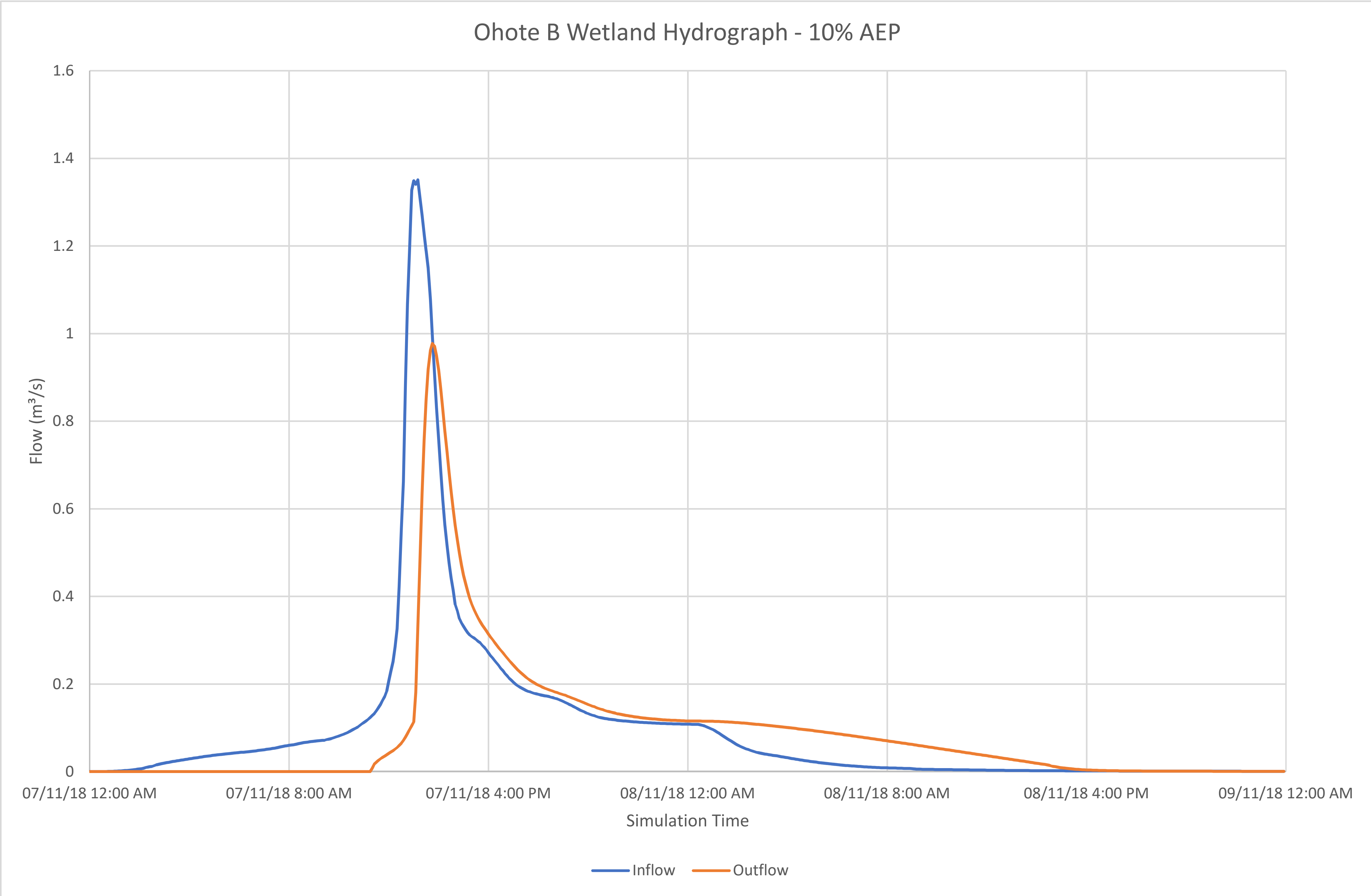

Rotokauri South A Wetland Hydrograph - 50% AEP
Flow (m³/s)
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
7/11/18 12:00:00 AM
7/11/18 8:00:00 AM
7/11/18 4:00:00 PM
8/11/18 12:00:00 AM
8/11/18 8:00:00 AM
8/11/18 4:00:00 PM
9/11/18 12:00:00 AM
Simulation Time
Inflow
Outflow


Rotokauri South B Wetland Hydrograph - 50% AEP
0.06
0.05
0.04
0.03
0.02
0.01
0
Flow (m³/s)
7/11/18 12:00:00 AM
7/11/18 8:00:00 AM
7/11/18 4:00:00 PM
8/11/18 12:00:00 AM
8/11/18 8:00:00 AM
8/11/18 4:00:00 PM
9/11/18 12:00:00 AM
Simulation Time
Inflow
Outflow

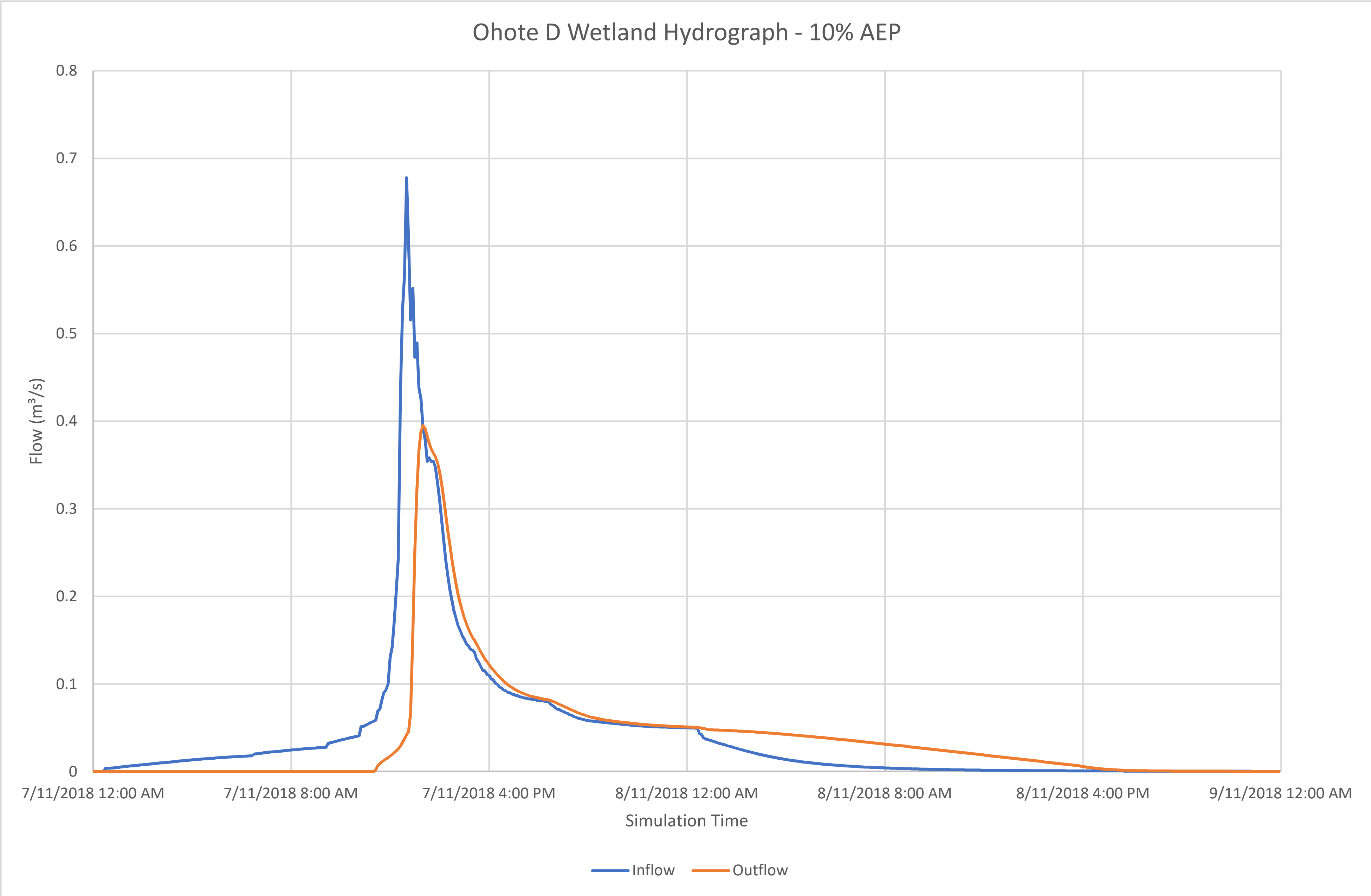


Rotokauri South C Wetland Hydrograph - 50% AEP
Flow (m³/s)
0.06
0.05
0.04
0.03
0.02
0.01
0
7/11/18 12:00:00 AM
7/11/18 8:00:00 AM
7/11/18 4:00:00 PM
8/11/18 12:00:00 AM
8/11/18 8:00:00 AM
8/11/18 4:00:00 PM
9/11/18 12:00:00 AM
Simulation Time
Inflow
Outflow

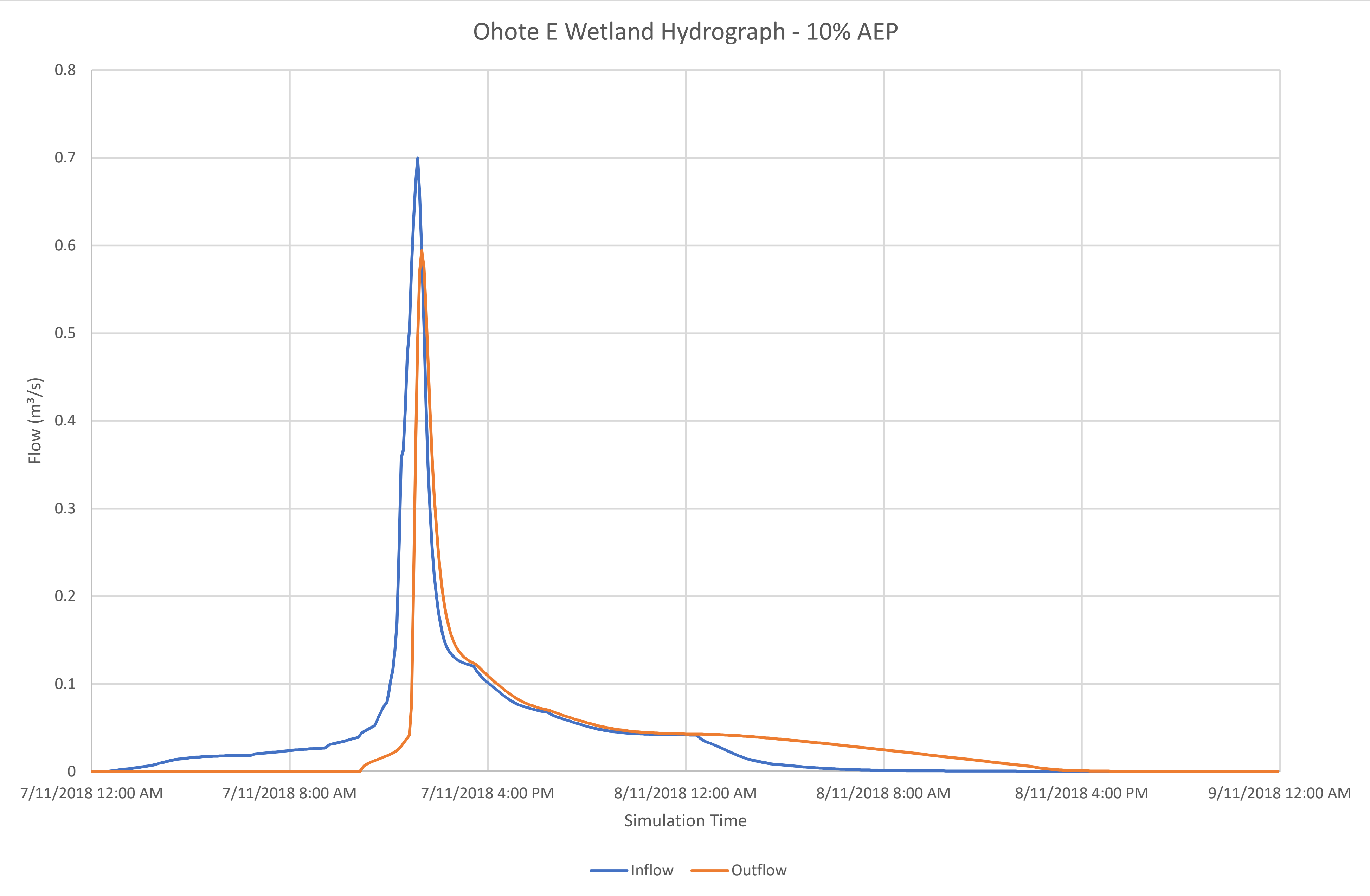

Ohote A Wetland Hydrograph - 10% AEP
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Flow (m³/s)
07/11/18 12:00 AM
07/11/18 8:00 AM
07/11/18 4:00 PM
08/11/18 12:00 AM
08/11/18 8:00 AM
08/11/18 4:00 PM
09/11/18 12:00 AM
Simulation Time
inflow
outflow



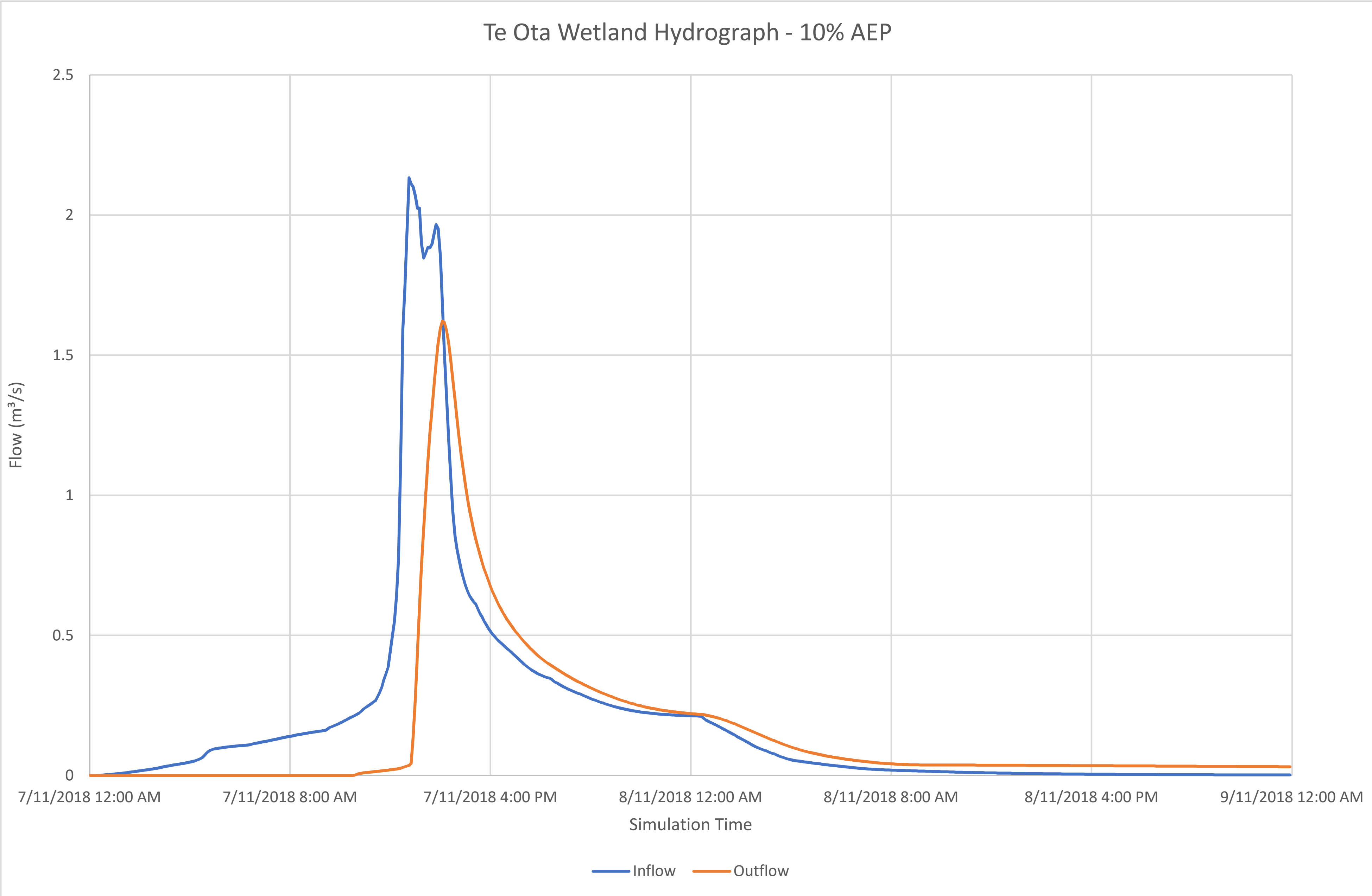
Ohote B Wetland Hydrograph - 10% AEP
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Flow (m³/s)
07/11/18 12:00 AM
07/11/18 8:00 AM
07/11/18 4:00 PM
08/11/18 12:00 AM
08/11/18 8:00 AM
08/11/18 4:00 PM
09/11/18 12:00 AM
Simulation Time
Inflow
Outflow

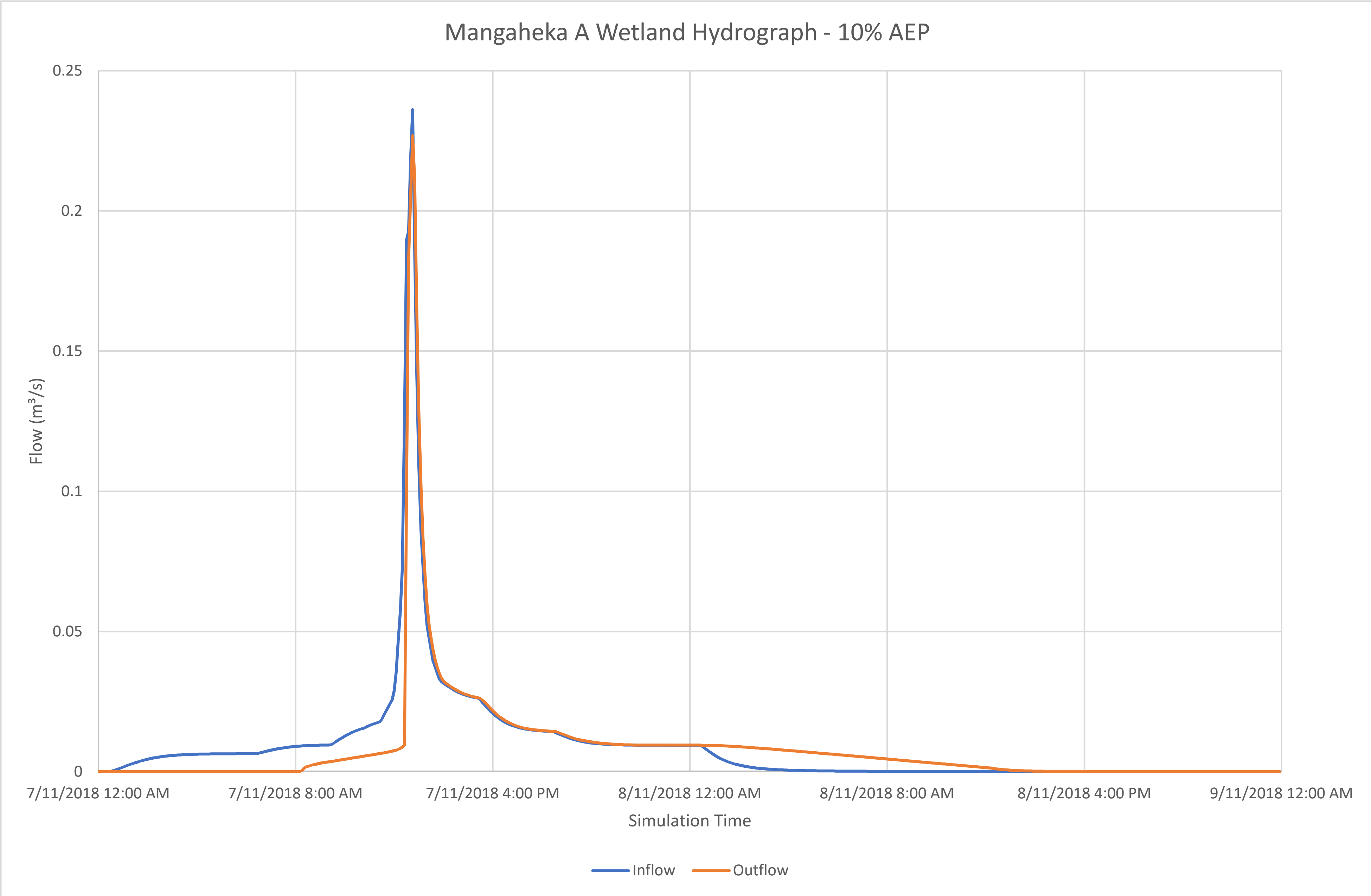


Ohote D Wetland Hydrograph - 10% AEP
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Flow (m³/s)
7/11/2018 12:00 AM
7/11/2018 8:00 AM
7/11/2018 4:00 PM
8/11/2018 12:00 AM
8/11/2018 8:00 AM
8/11/2018 4:00 PM
9/11/2018 12:00 AM
Simulation Time
Inflow
Outflow

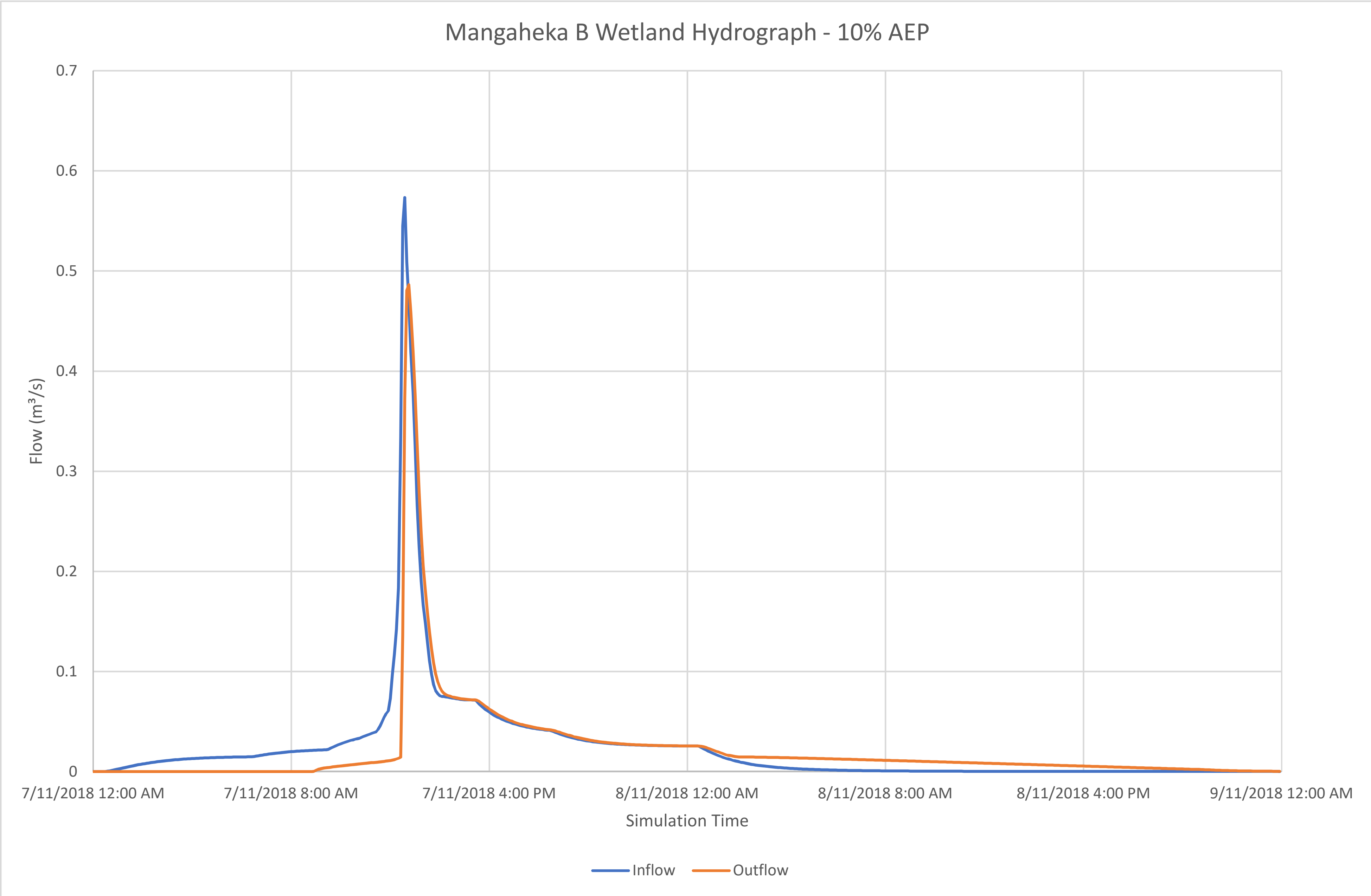


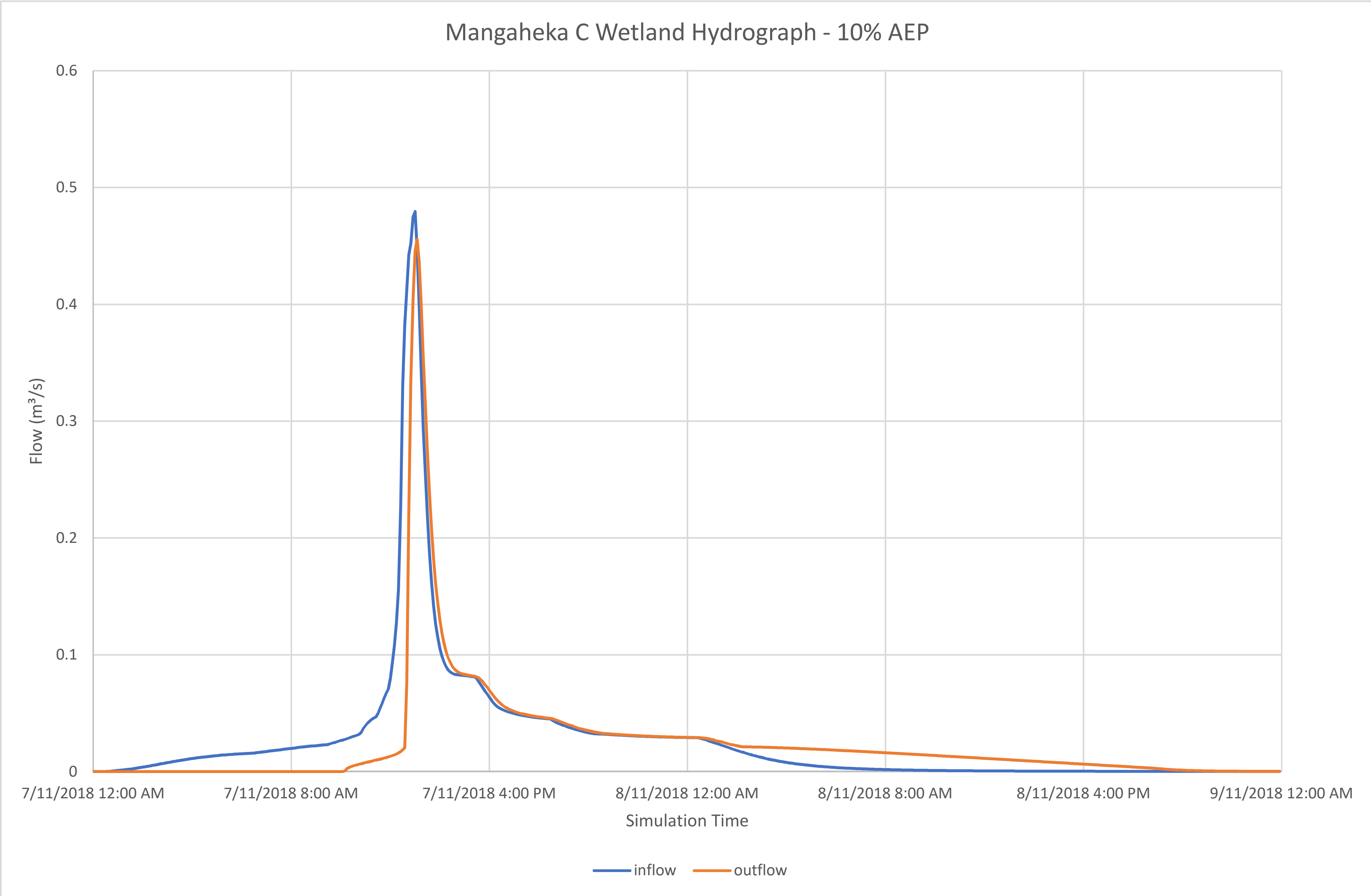
Ohote E Wetland Hydrograph - 10% AEP
Flow (m^3/s)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
7/11/2018 12:00 AM
7/11/2018 8:00 AM
7/11/2018 4:00 PM
8/11/2018 12:00 AM
8/11/2018 8:00 AM
8/11/2018 4:00 PM
9/11/2018 12:00 AM
Simulation Time
Inflow
Outflow


Te Ota Wetland Hydrograph - 10% AEP
Flow (m³/s)
2.5
2
1.5
1
0.5
0
7/11/2018 12:00 AM
7/11/2018 8:00 AM
7/11/2018 4:00 PM
8/11/2018 12:00 AM
8/11/2018 8:00 AM
8/11/2018 4:00 PM
9/11/2018 12:00 AM
Simulation Time
Inflow
Outflow

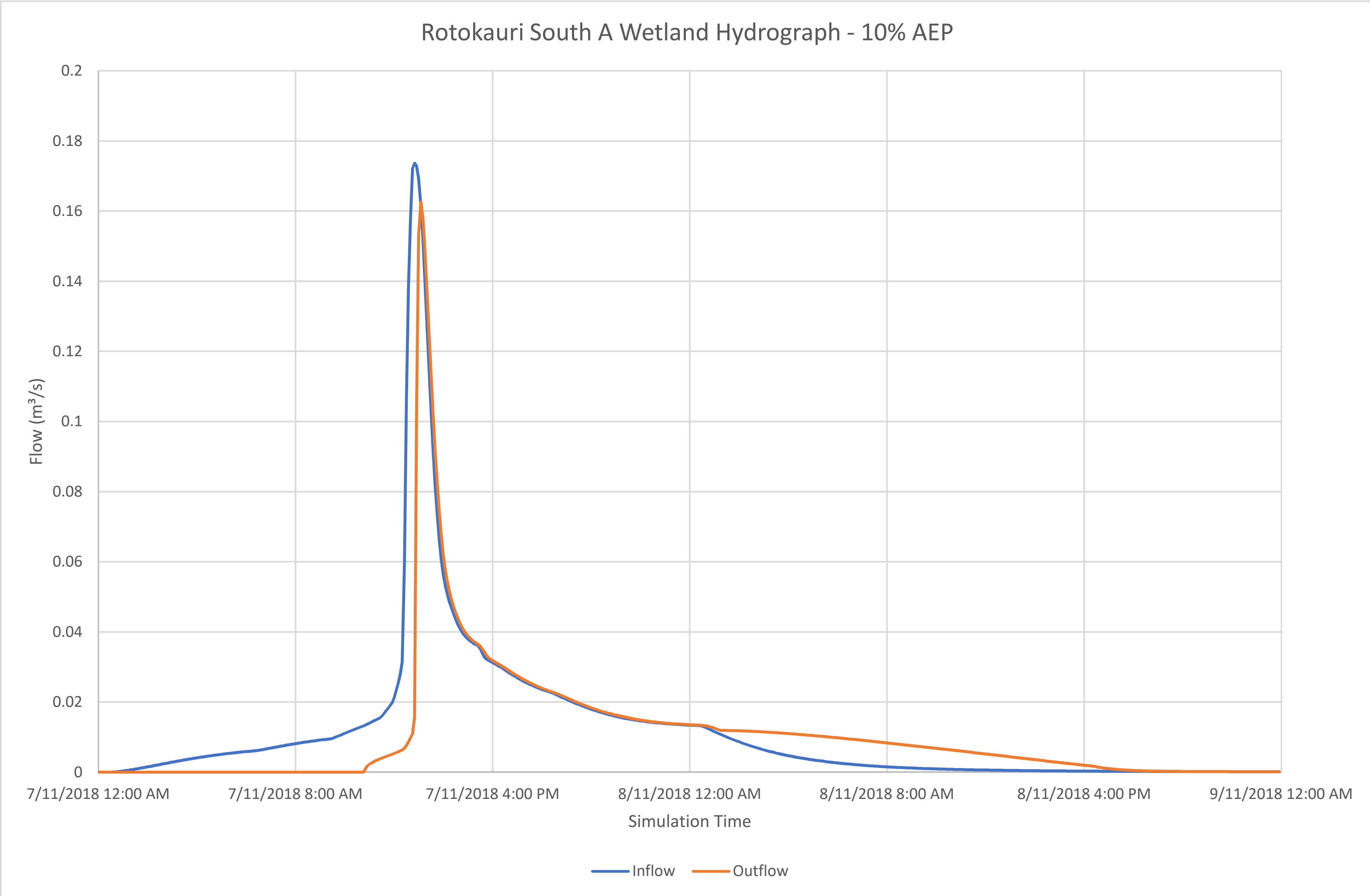


Mangaheka A Wetland Hydrograph - 10% AEP
0.25
0.2
0.15
0.1
0.05
0
Flow (m³/s)
7/11/2018 12:00 AM
7/11/2018 8:00 AM
7/11/2018 4:00 PM
8/11/2018 12:00 AM
8/11/2018 8:00 AM
8/11/2018 4:00 PM
9/11/2018 12:00 AM
Simulation Time
Inflow
Outflow

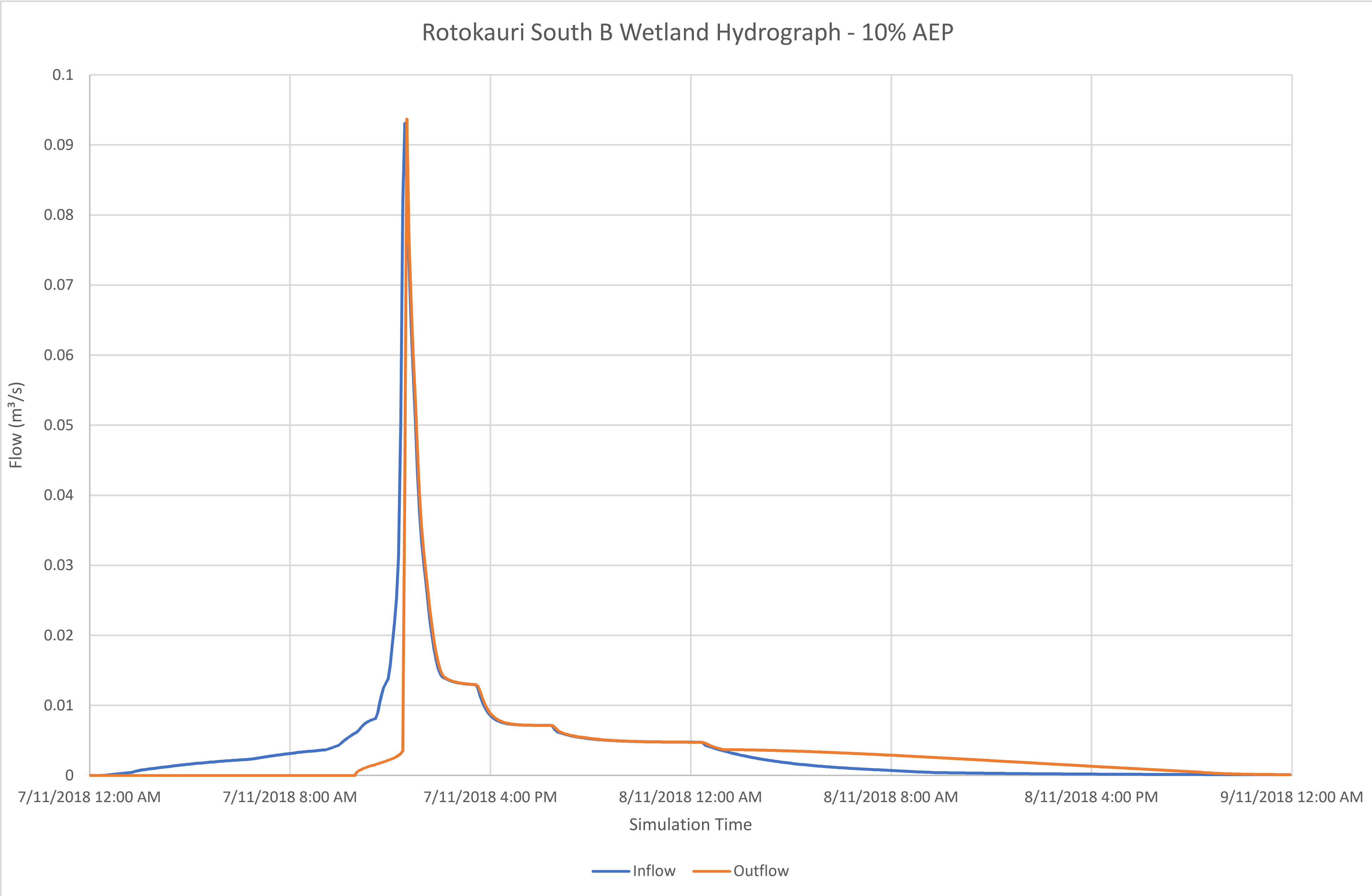

Mangaheka B Wetland Hydrograph - 10% AEP
Flow (m³/s)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
7/11/2018 12:00 AM
7/11/2018 8:00 AM
7/11/2018 4:00 PM
8/11/2018 12:00 AM
8/11/2018 8:00 AM
8/11/2018 4:00 PM
9/11/2018 12:00 AM
Simulation Time
Inflow
Outflow



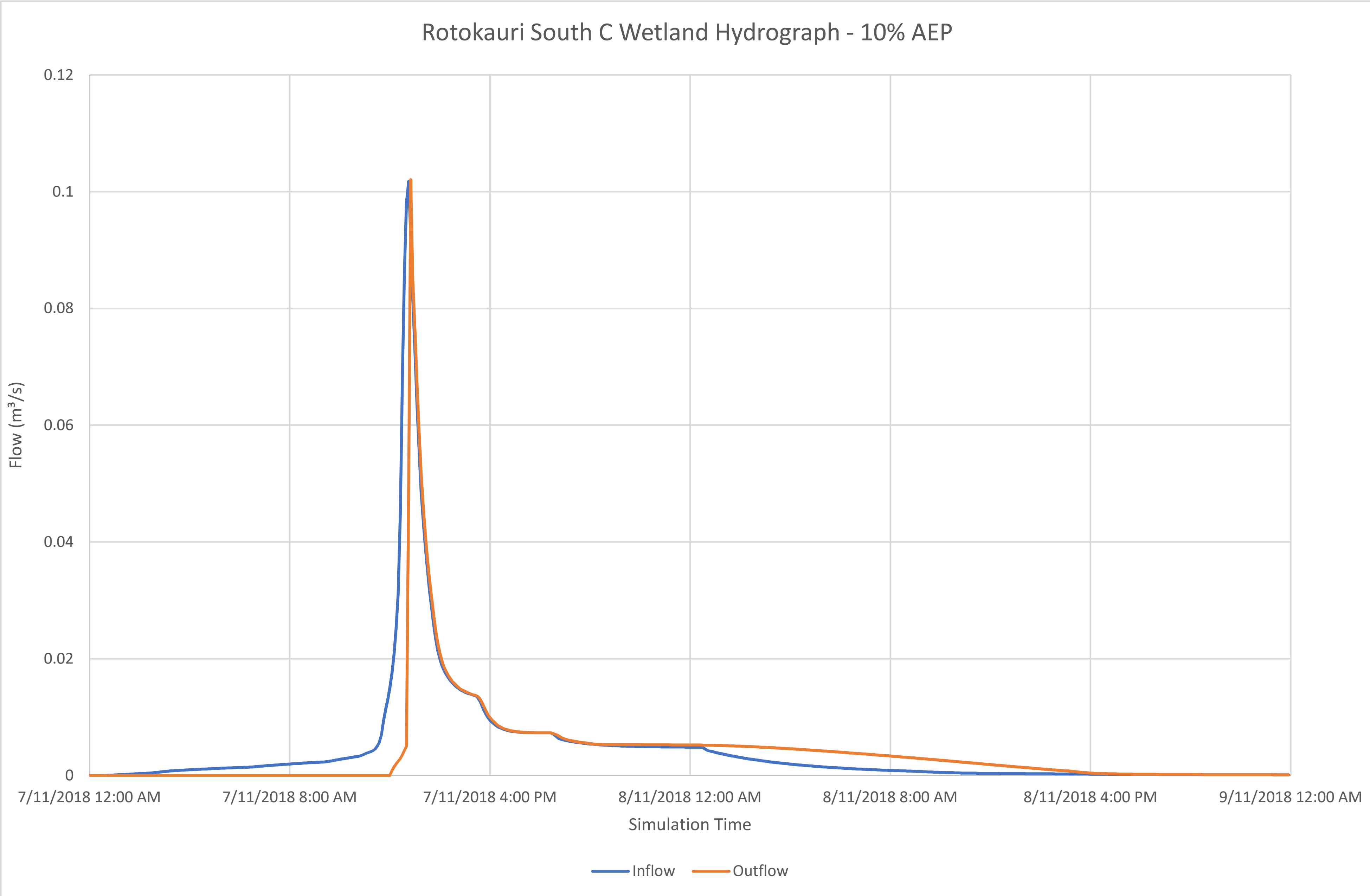
Mangaheka C Wetland Hydrograph - 10% AEP
Flow (m³/s)
0.6
0.5
0.4
0.3
0.2
0.1
0
7/11/2018 12:00 AM
7/11/2018 8:00 AM
7/11/2018 4:00 PM
8/11/2018 12:00 AM
8/11/2018 8:00 AM
8/11/2018 4:00 PM
9/11/2018 12:00 AM
Simulation Time
inflow
outflow

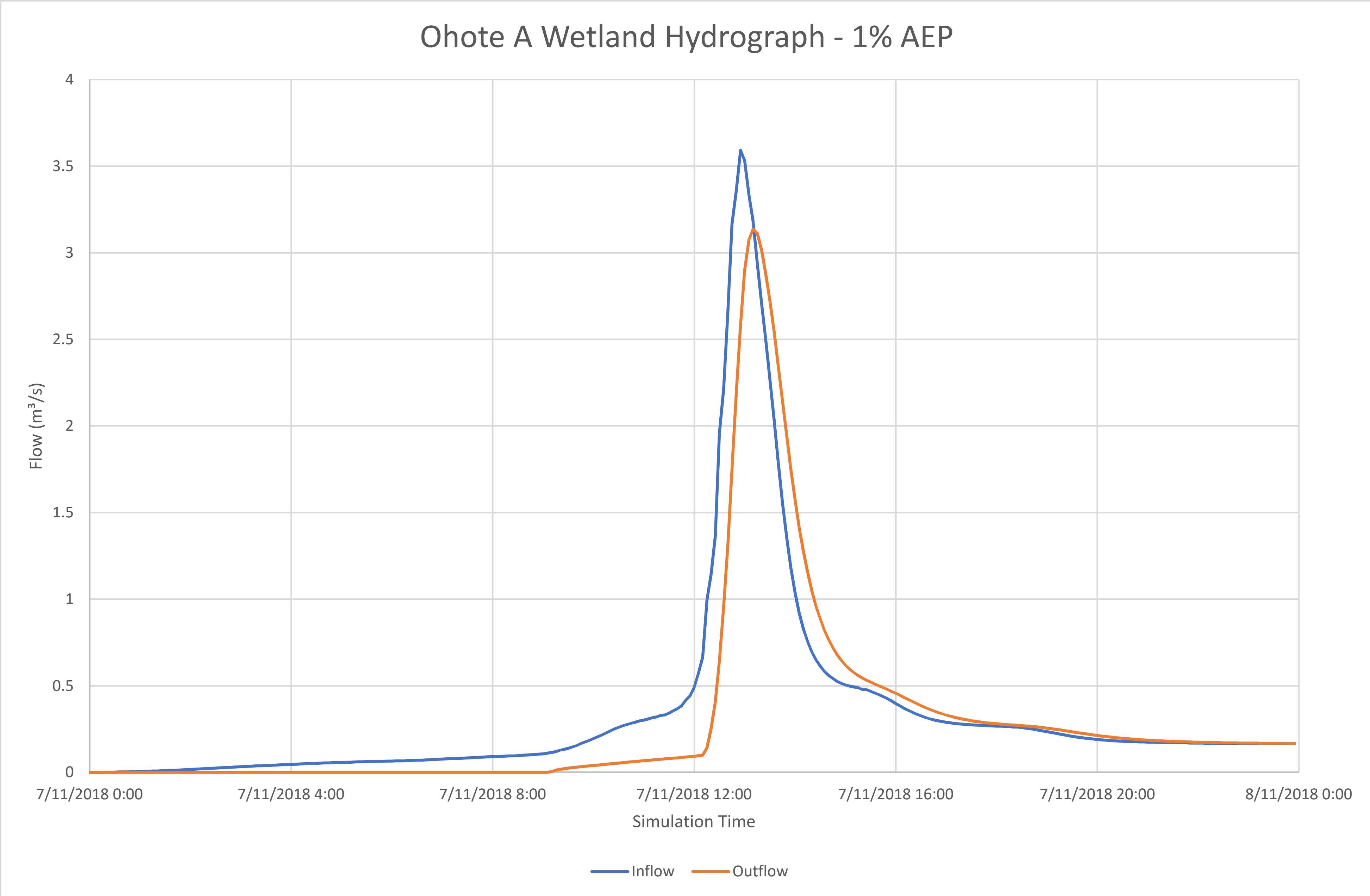


Rotokauri South A Wetland Hydrograph - 10% AEP
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Flow (m³/s)
7/11/2018 12:00 AM
7/11/2018 8:00 AM
7/11/2018 4:00 PM
8/11/2018 12:00 AM
8/11/2018 8:00 AM
8/11/2018 4:00 PM
9/11/2018 12:00 AM
Simulation Time
Inflow
Outflow

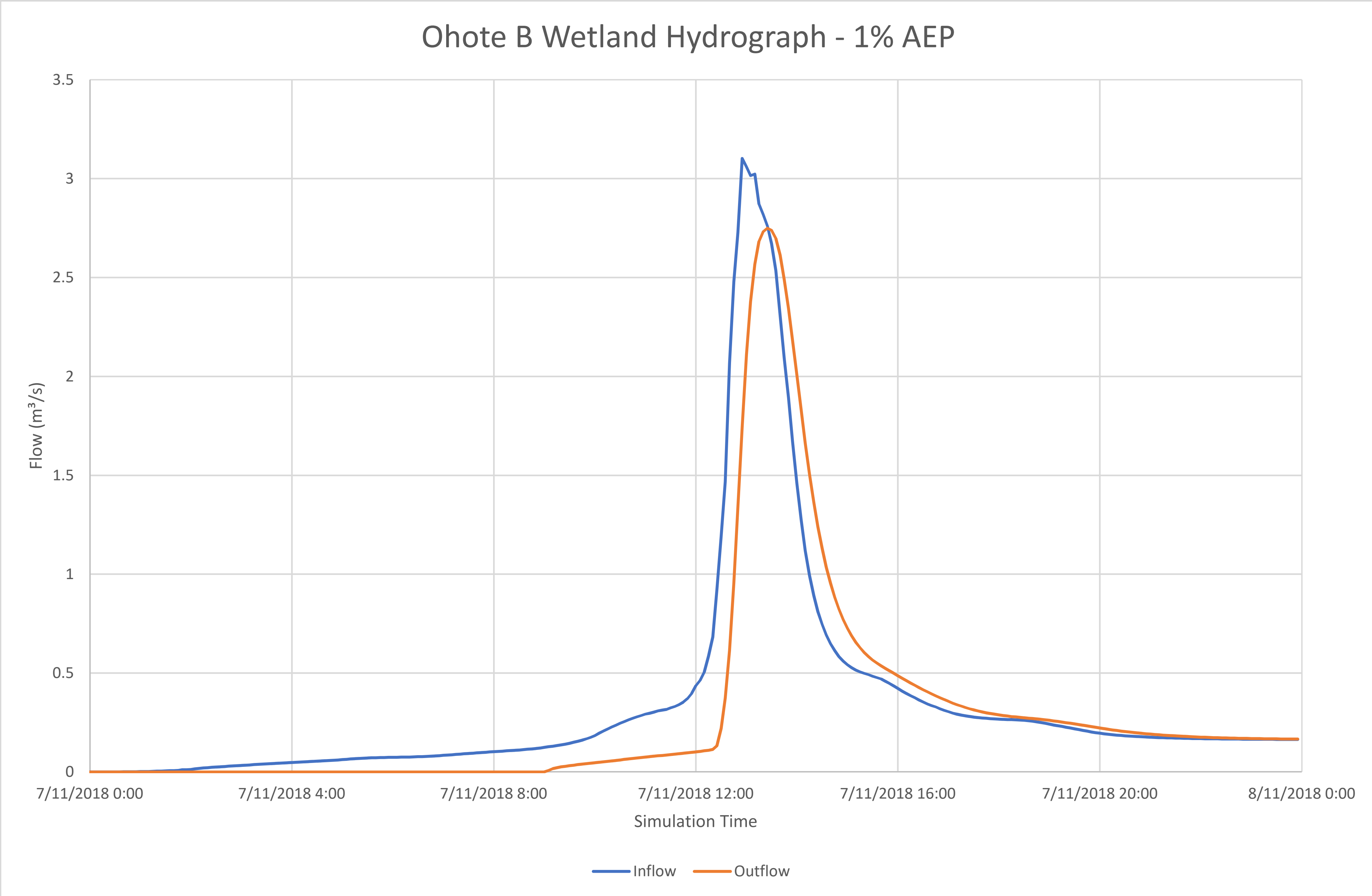


Rotokauri South B Wetland Hydrograph - 10% AEP
Flow (m³/s)
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
7/11/2018 12:00 AM
7/11/2018 8:00 AM
7/11/2018 4:00 PM
8/11/2018 12:00 AM
8/11/2018 8:00 AM
8/11/2018 4:00 PM
9/11/2018 12:00 AM
Simulation Time
Inflow
Outflow

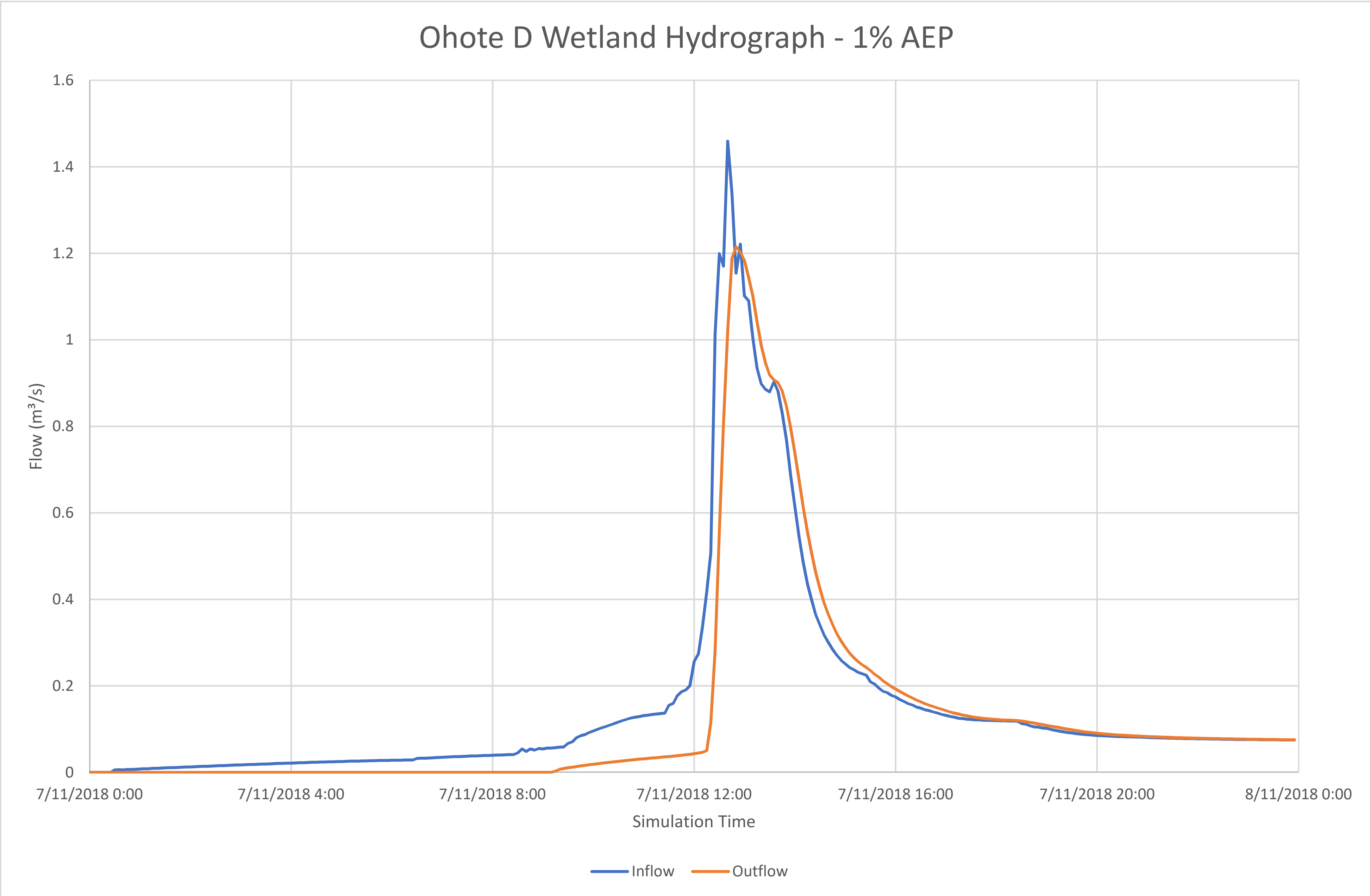

Rotokauri South C Wetland Hydrograph - 10% AEP
Flow (m³/s)
0.12
0.1
0.08
0.06
0.04
0.02
0
7/11/2018 12:00 AM
7/11/2018 8:00 AM
7/11/2018 4:00 PM
8/11/2018 12:00 AM
8/11/2018 8:00 AM
8/11/2018 4:00 PM
9/11/2018 12:00 AM
Simulation Time
Inflow
Outflow

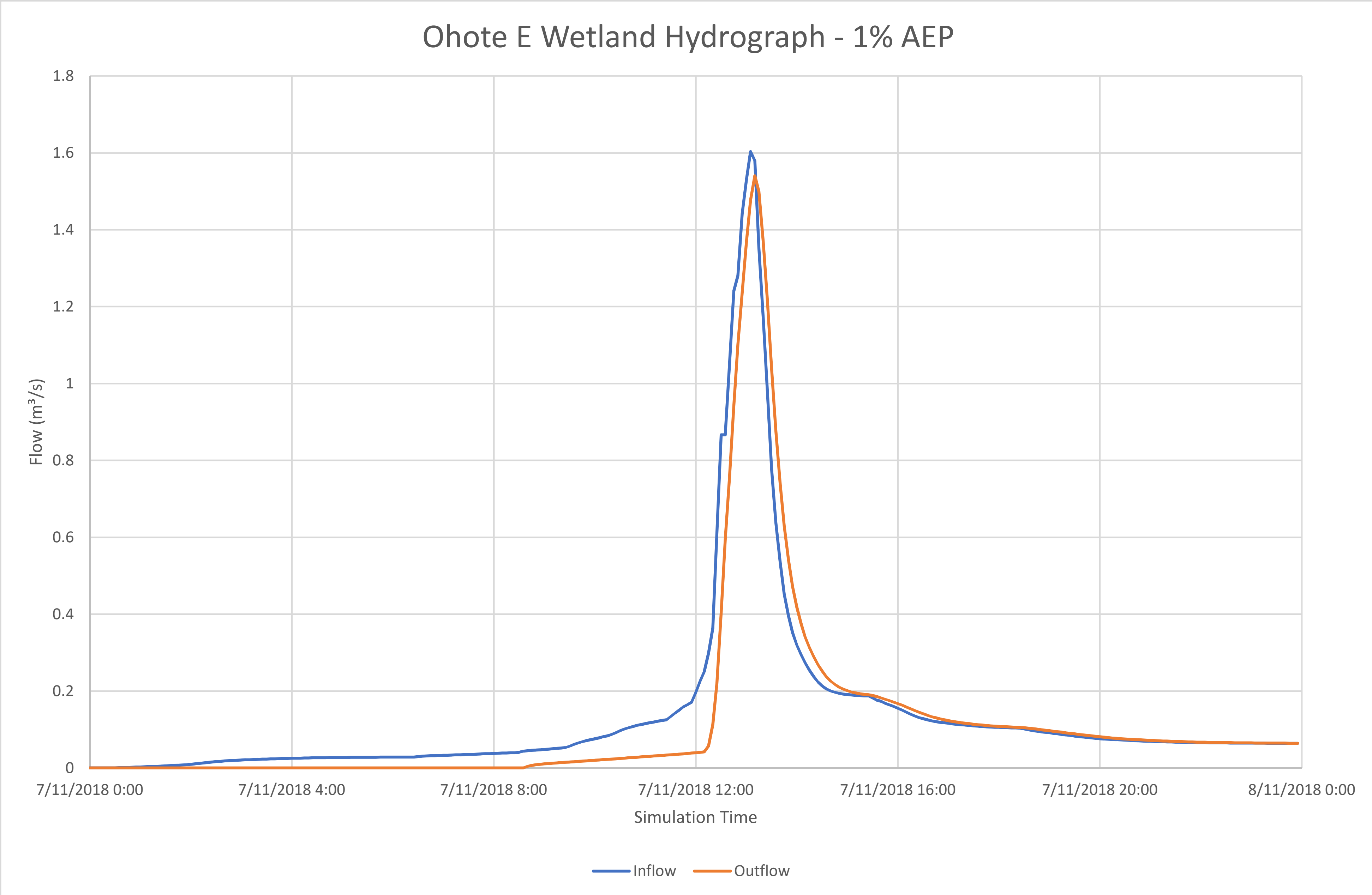


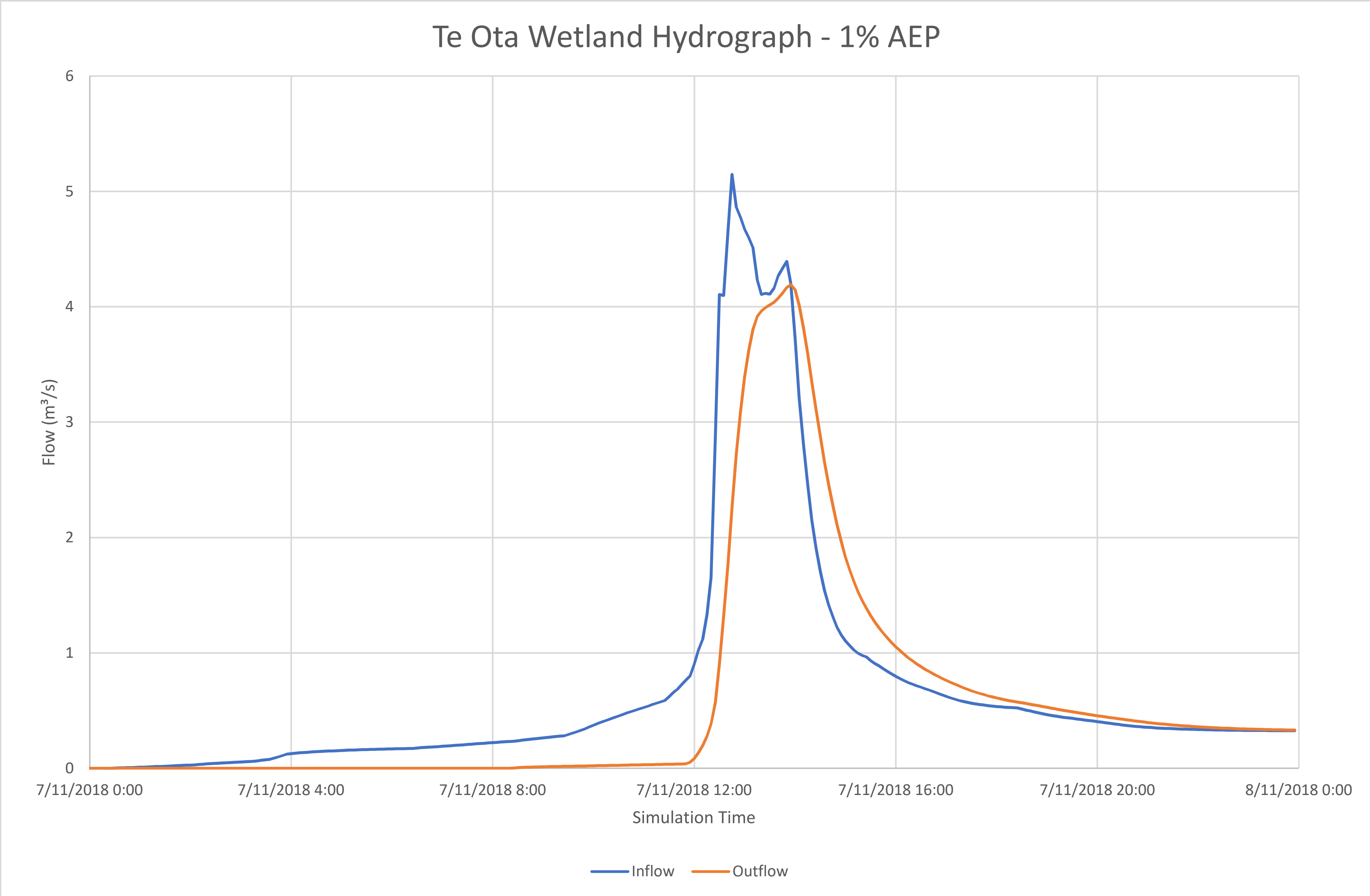
Ohote A Wetland Hydrograph - 1% AEP
4
3.5
3
2.5
2
1.5
1
0.5
0
Flow (m³/s)
7/11/2018 0:00
7/11/2018 4:00
7/11/2018 8:00
7/11/2018 12:00
7/11/2018 16:00
7/11/2018 20:00
8/11/2018 0:00
Simulation Time
Inflow
Outflow



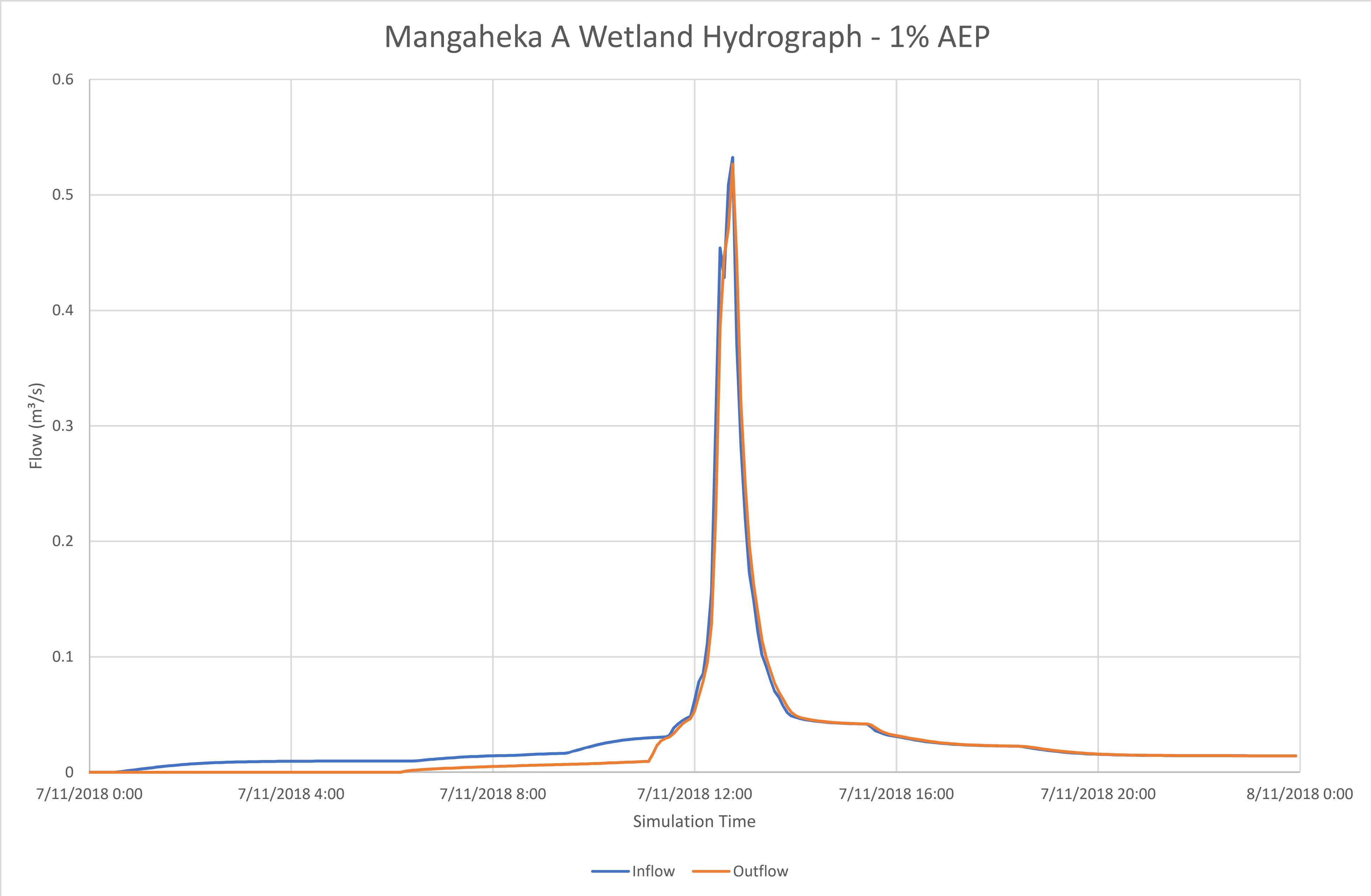
Ohote B Wetland Hydrograph - 1% AEP
Flow (m³/s)
3.5
3
2.5
2
1.5
1
0.5
0
7/11/2018 0:00
7/11/2018 4:00
7/11/2018 8:00
7/11/2018 12:00
7/11/2018 16:00
7/11/2018 20:00
8/11/2018 0:00
Simulation Time
Inflow
Outflow


Ohote D Wetland Hydrograph - 1% AEP
Flow (m³/s)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
7/11/2018 0:00
7/11/2018 4:00
7/11/2018 8:00
7/11/2018 12:00
7/11/2018 16:00
7/11/2018 20:00
8/11/2018 0:00
Simulation Time
Inflow
Outflow

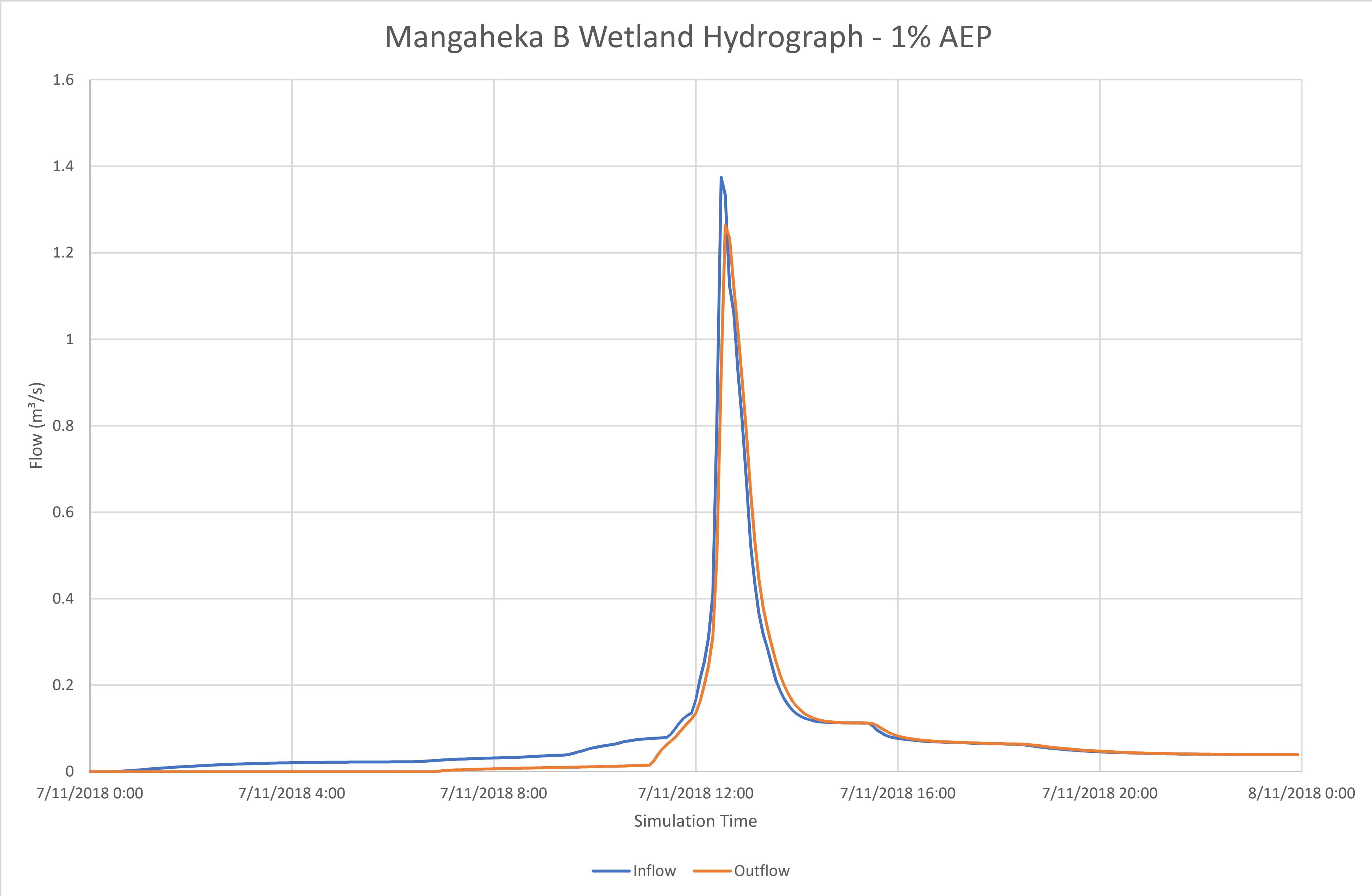

Ohote E Wetland Hydrograph - 1% AEP
Flow (m³/s)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
7/11/2018 0:00
7/11/2018 4:00
7/11/2018 8:00
7/11/2018 12:00
7/11/2018 16:00
7/11/2018 20:00
8/11/2018 0:00
Simulation Time
Inflow
Outflow



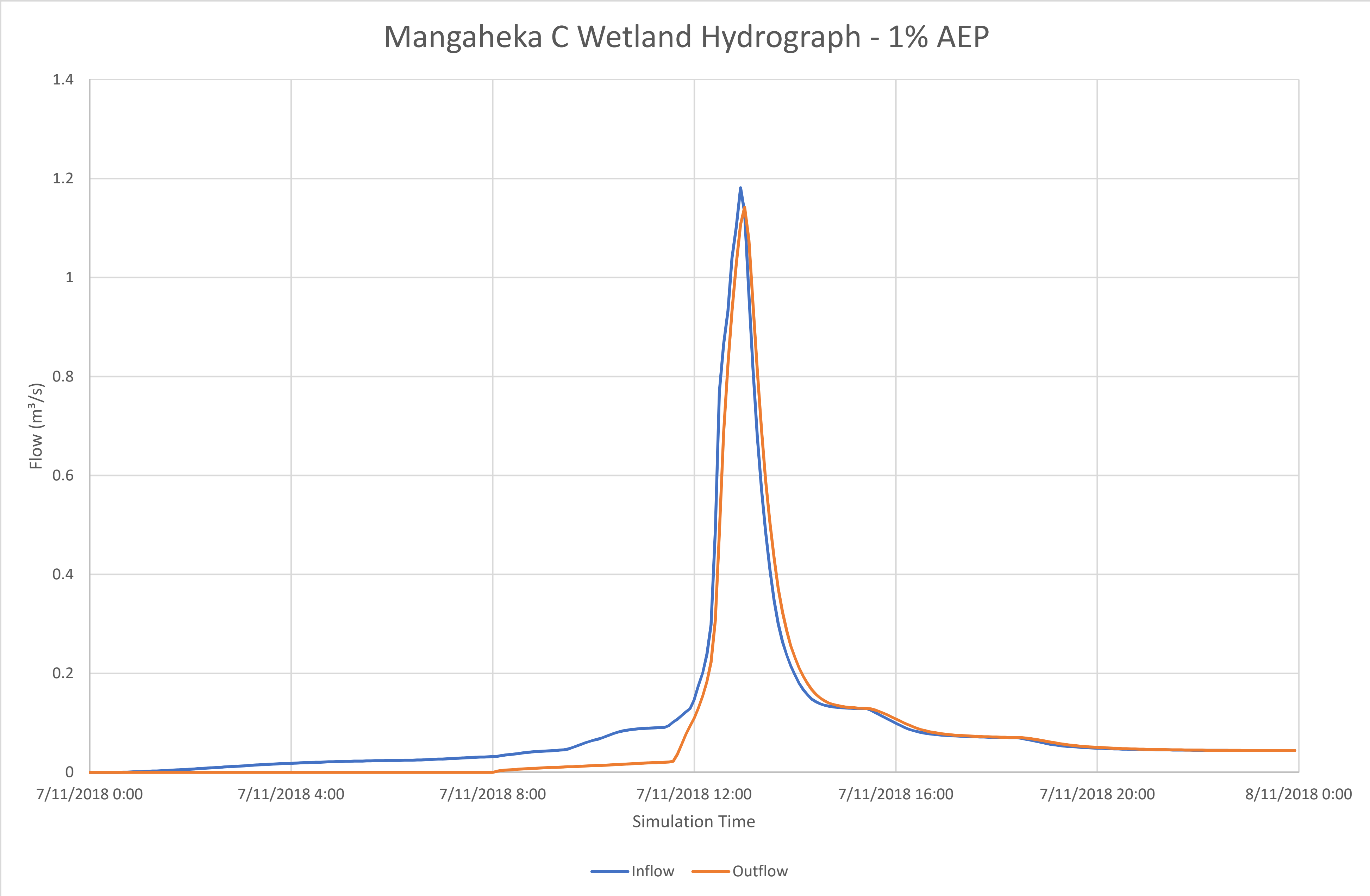
Te Ota Wetland Hydrograph - 1% AEP
Flow (m³/s)
0
1
2
3
4
5
6
7/11/2018 0:00
7/11/2018 4:00
7/11/2018 8:00
7/11/2018 12:00
7/11/2018 16:00
7/11/2018 20:00
8/11/2018 0:00
Simulation Time
Inflow
Outflow

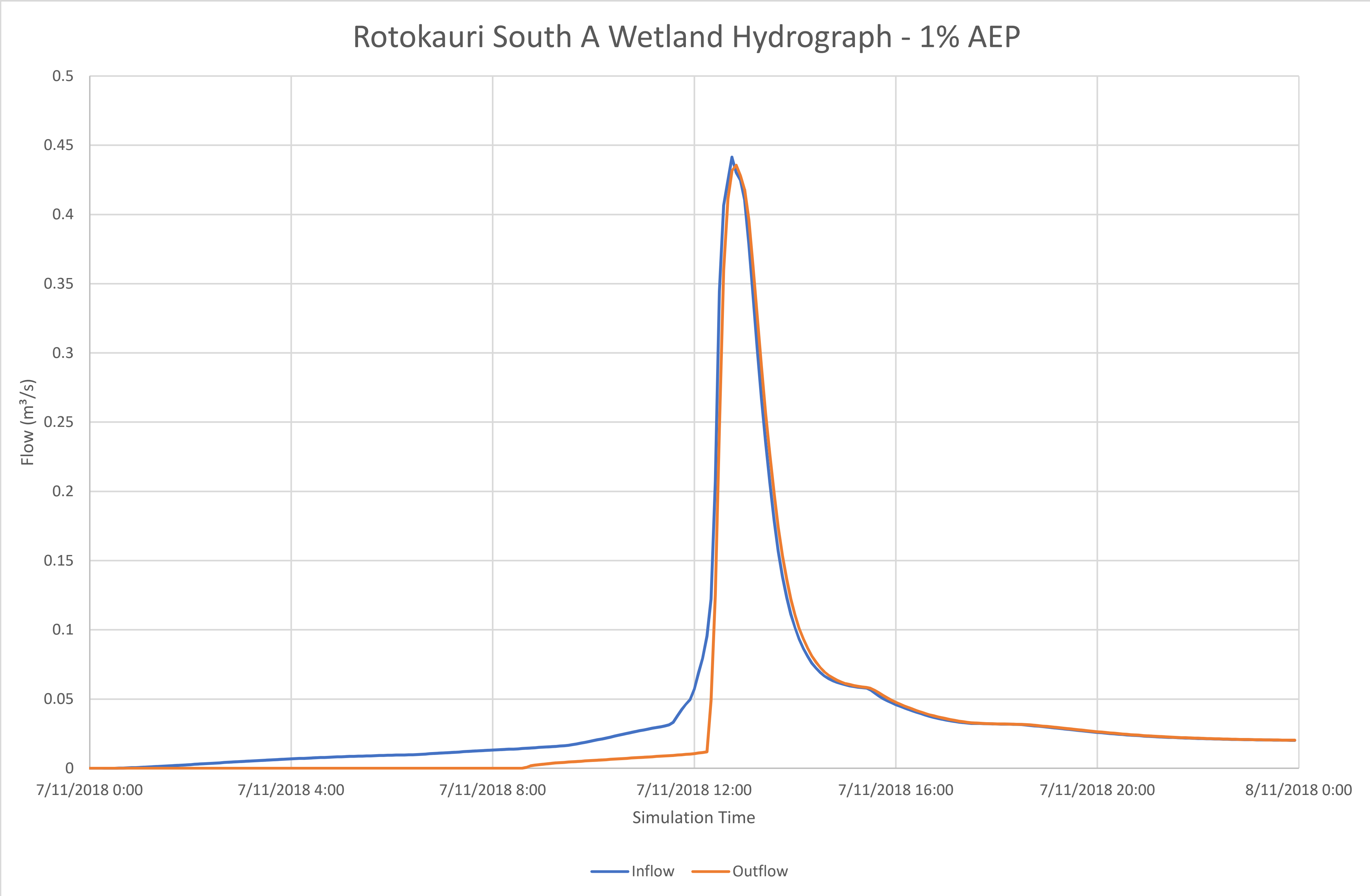


Mangaheka A Wetland Hydrograph - 1% AEP
0.6
0.5
0.4
0.3
0.2
0.1
0
Flow (m³/s)
7/11/2018 0:00
7/11/2018 4:00
7/11/2018 8:00
7/11/2018 12:00
7/11/2018 16:00
7/11/2018 20:00
8/11/2018 0:00
Simulation Time
Inflow
Outflow

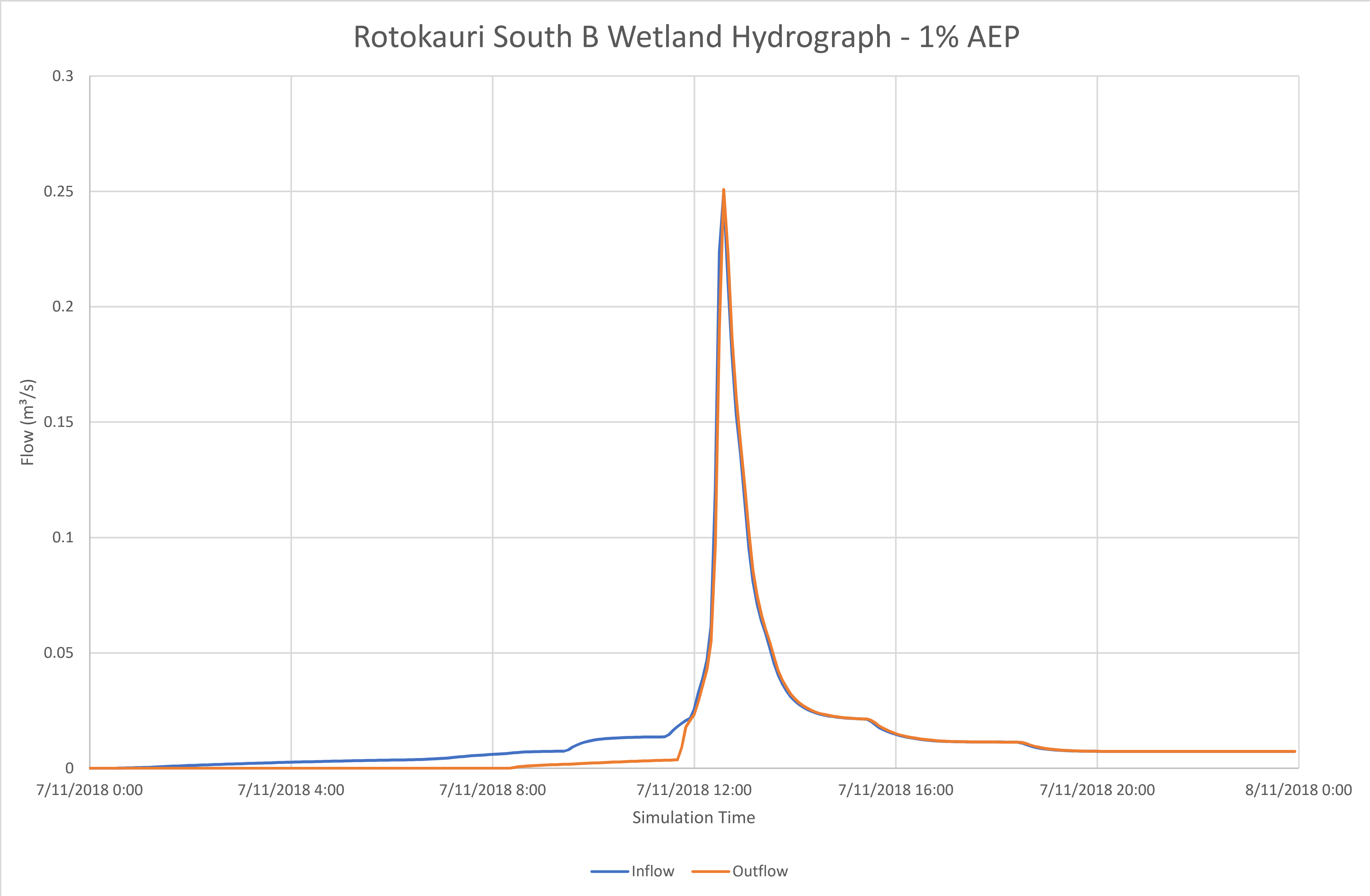


Mangaheka B Wetland Hydrograph - 1% AEP
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Flow (m3/s)
7/11/2018 0:00
7/11/2018 4:00
7/11/2018 8:00
7/11/2018 12:00
7/11/2018 16:00
7/11/2018 20:00
8/11/2018 0:00
Simulation Time
Inflow
Outflow

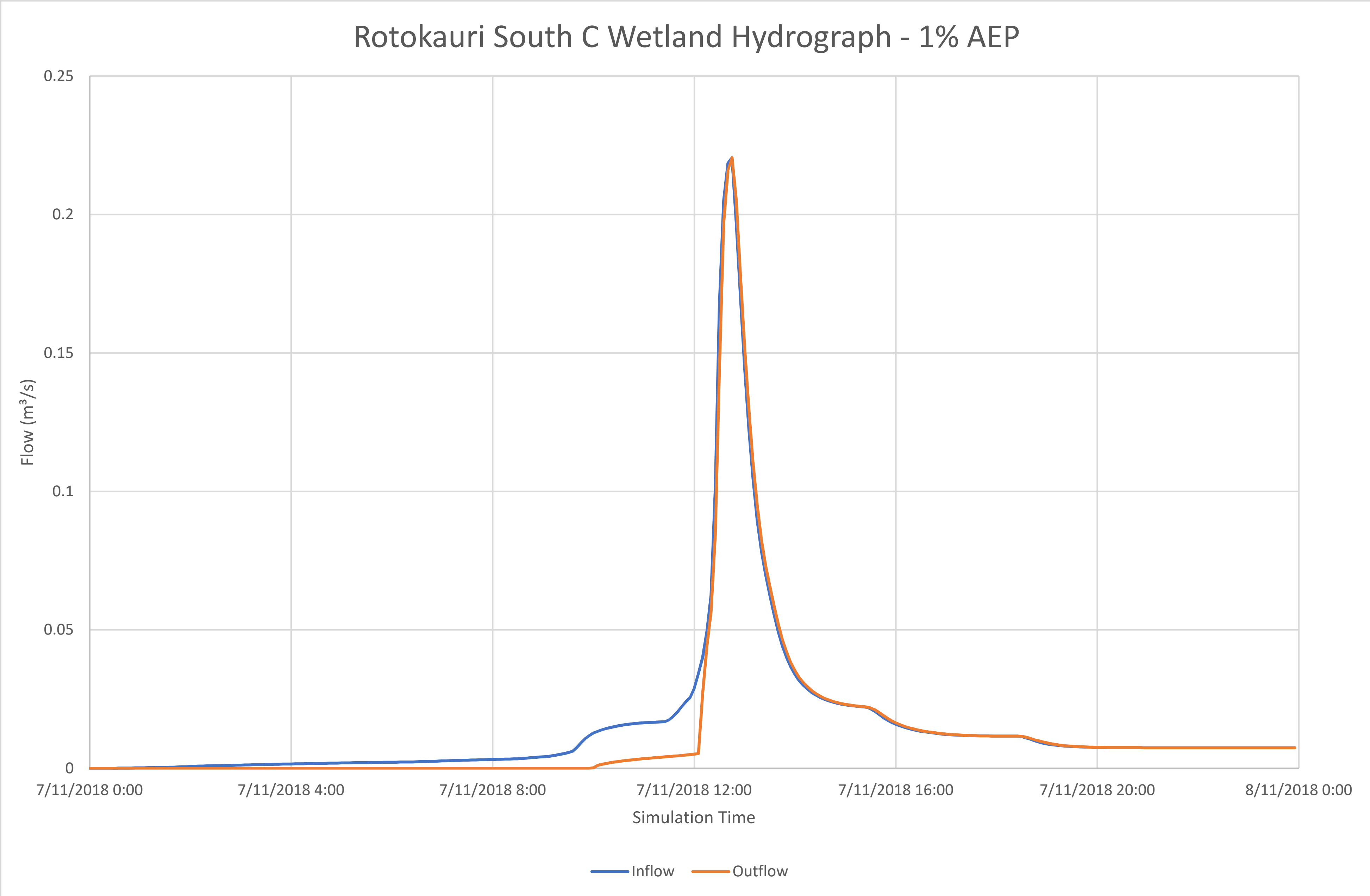

Mangaheka C Wetland Hydrograph - 1% AEP
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Flow (m³/s)
7/11/2018 0:00
7/11/2018 4:00
7/11/2018 8:00
7/11/2018 12:00
7/11/2018 16:00
7/11/2018 20:00
8/11/2018 0:00
Simulation Time
Inflow
Outflow



Rotokauri South A Wetland Hydrograph - 1% AEP
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Flow (m³/s)
7/11/2018 0:00
7/11/2018 4:00
7/11/2018 8:00
7/11/2018 12:00
7/11/2018 16:00
7/11/2018 20:00
8/11/2018 0:00
Simulation Time
Inflow
Outflow



Rotokauri South B Wetland Hydrograph - 1% AEP
0.3
0.25
0.2
0.15
0.1
0.05
0
Flow (m³/s)
7/11/2018 0:00
7/11/2018 4:00
7/11/2018 8:00
7/11/2018 12:00
7/11/2018 16:00
7/11/2018 20:00
8/11/2018 0:00
Simulation Time
Inflow
Outflow


Rotokauri South C Wetland Hydrograph - 1% AEP
0.25
0.2
0.15
0.1
0.05
0
Flow (m³/s)
7/11/2018 0:00
7/11/2018 4:00
7/11/2018 8:00
7/11/2018 12:00
7/11/2018 16:00
7/11/2018 20:00
8/11/2018 0:00
Simulation Time
Inflow
Outflow

APPENDIX G –SWALE HYDRAULIC RESULTS

1% AEP_{cc} Hydraulic Results

Ohote A Catchment

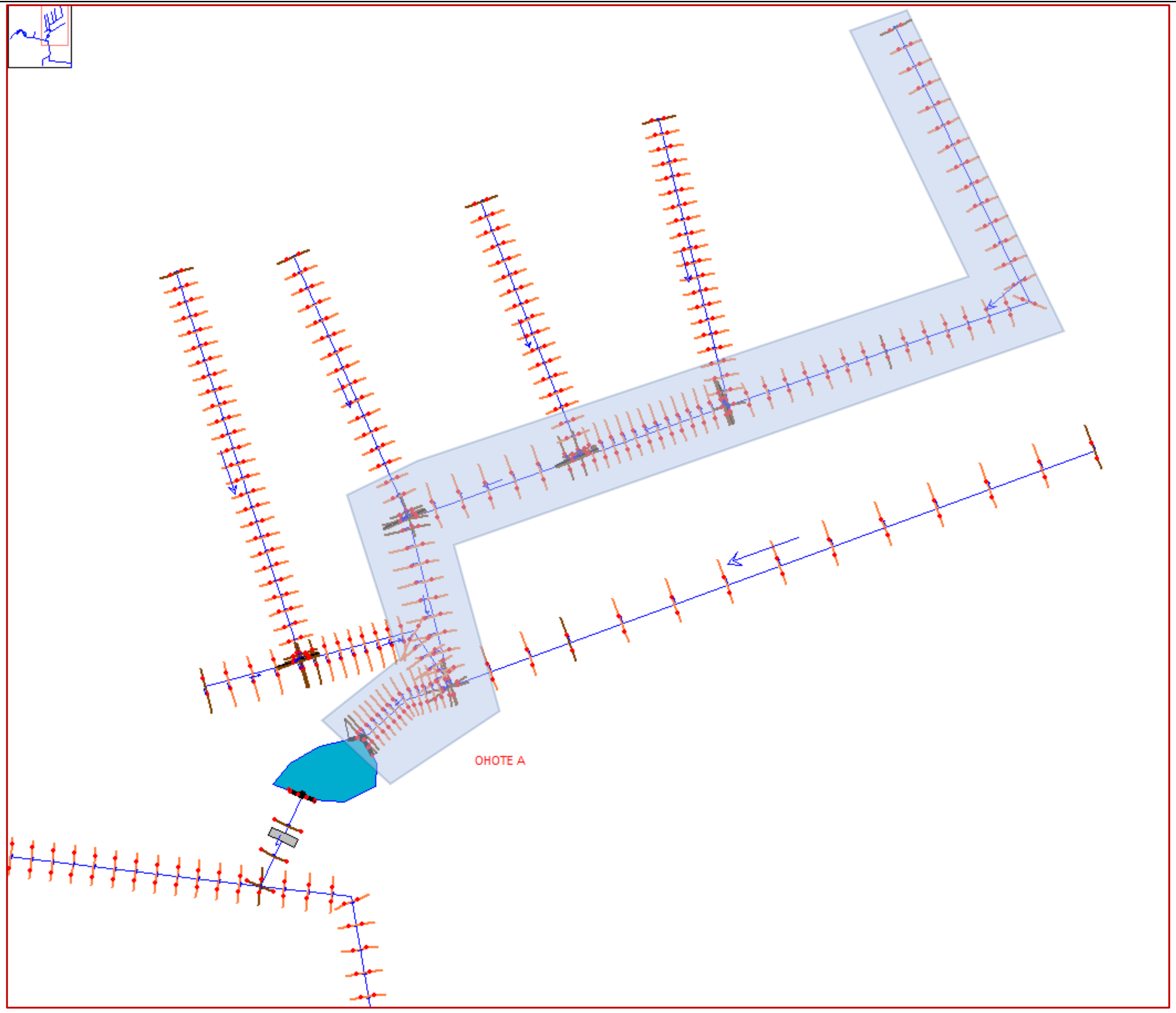


Figure 1 – Schematic Arrangement of Swale Network of Ohote A Wetland Contributing Area (Qualifying Development)

Critical hydraulic section shaded as per above.

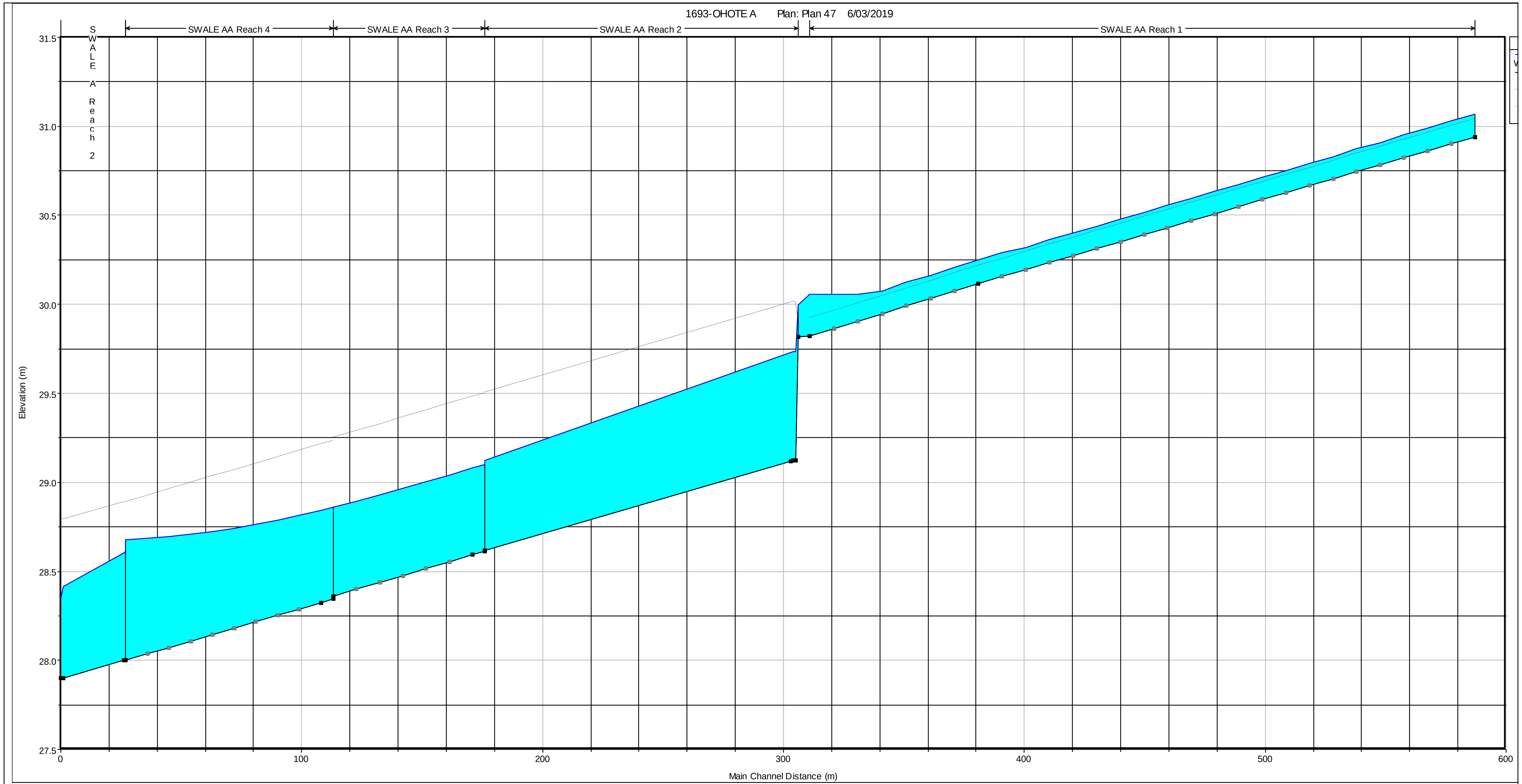


Figure 2 – Water Depth along Critical hydraulic section.

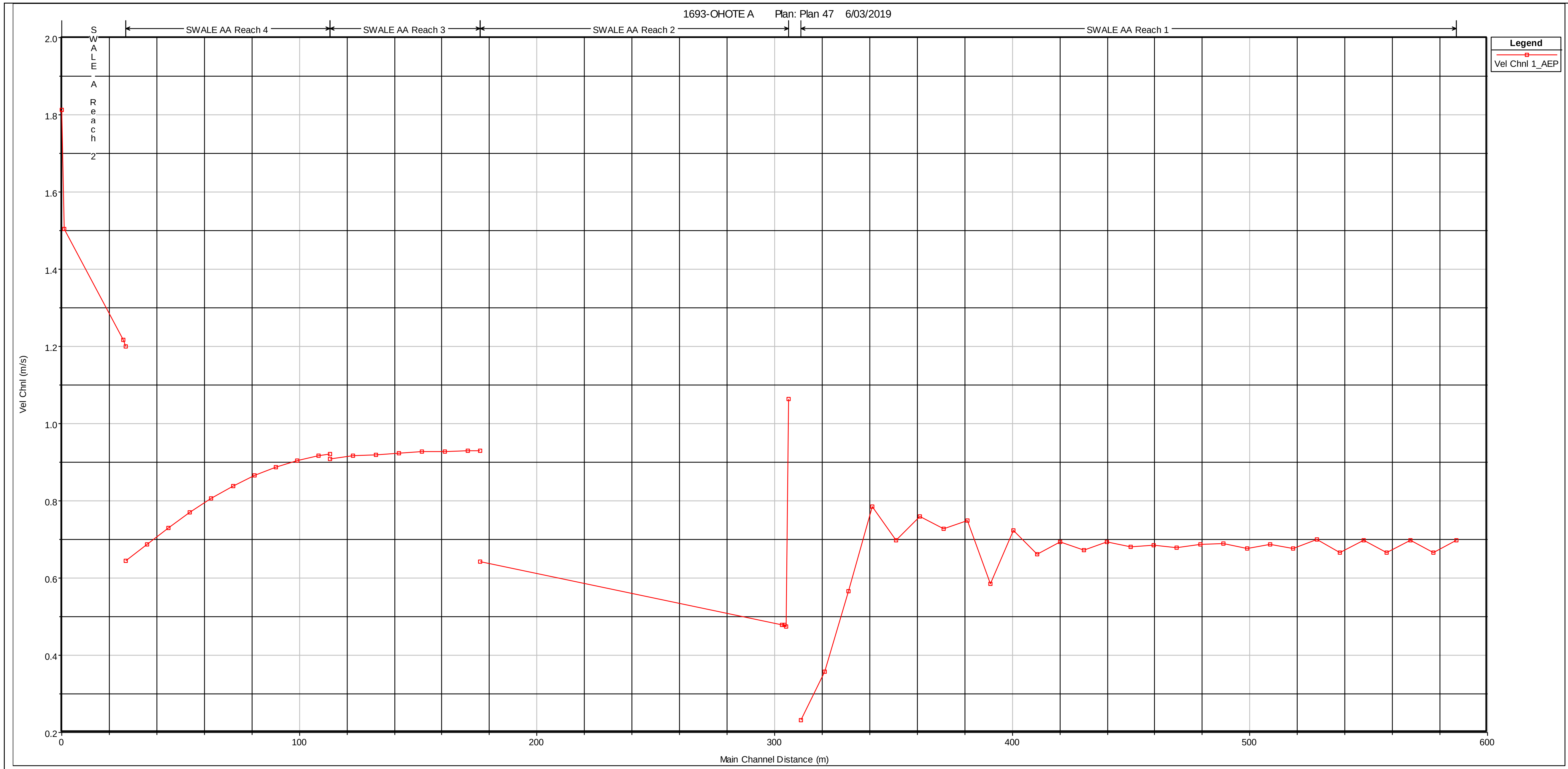


Figure 3 – Velocity Profile along Critical hydraulic section.

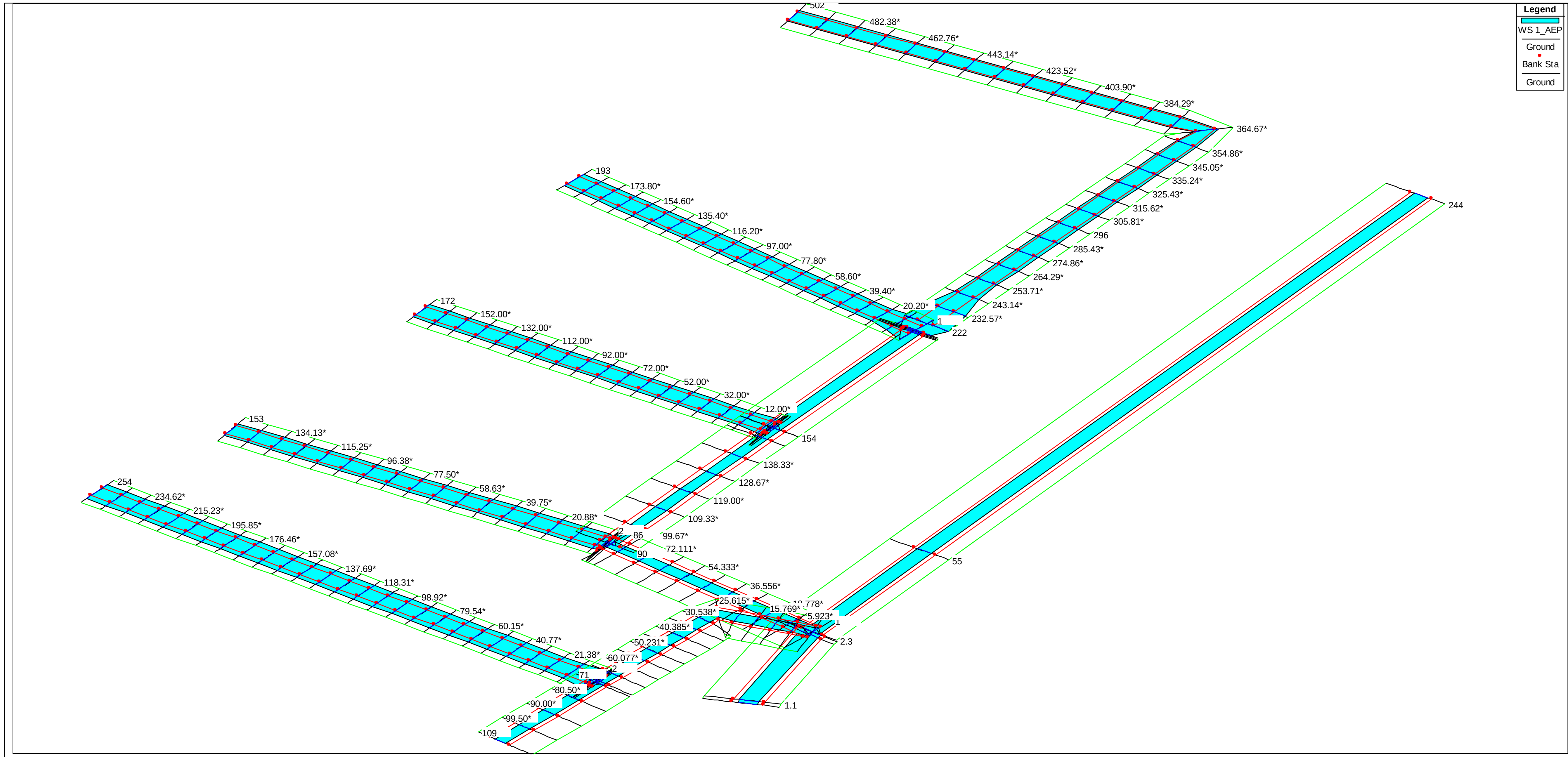


Figure 4 – 3D Water Depth Plot Ohote Swale and Channel Network

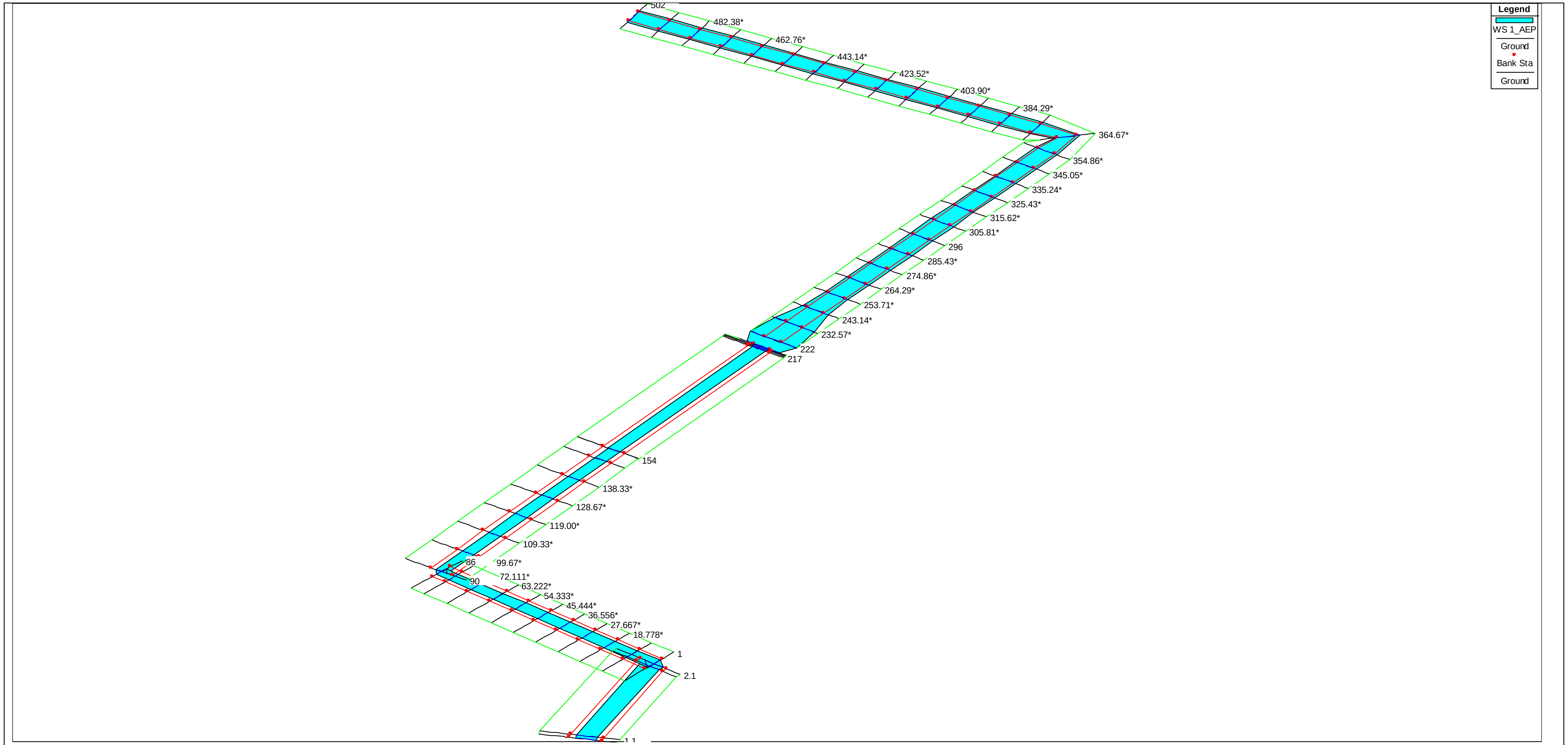


Figure 5 – 3D Water Depth Plot along critical hydraulic section.

Te Otamanui Catchment

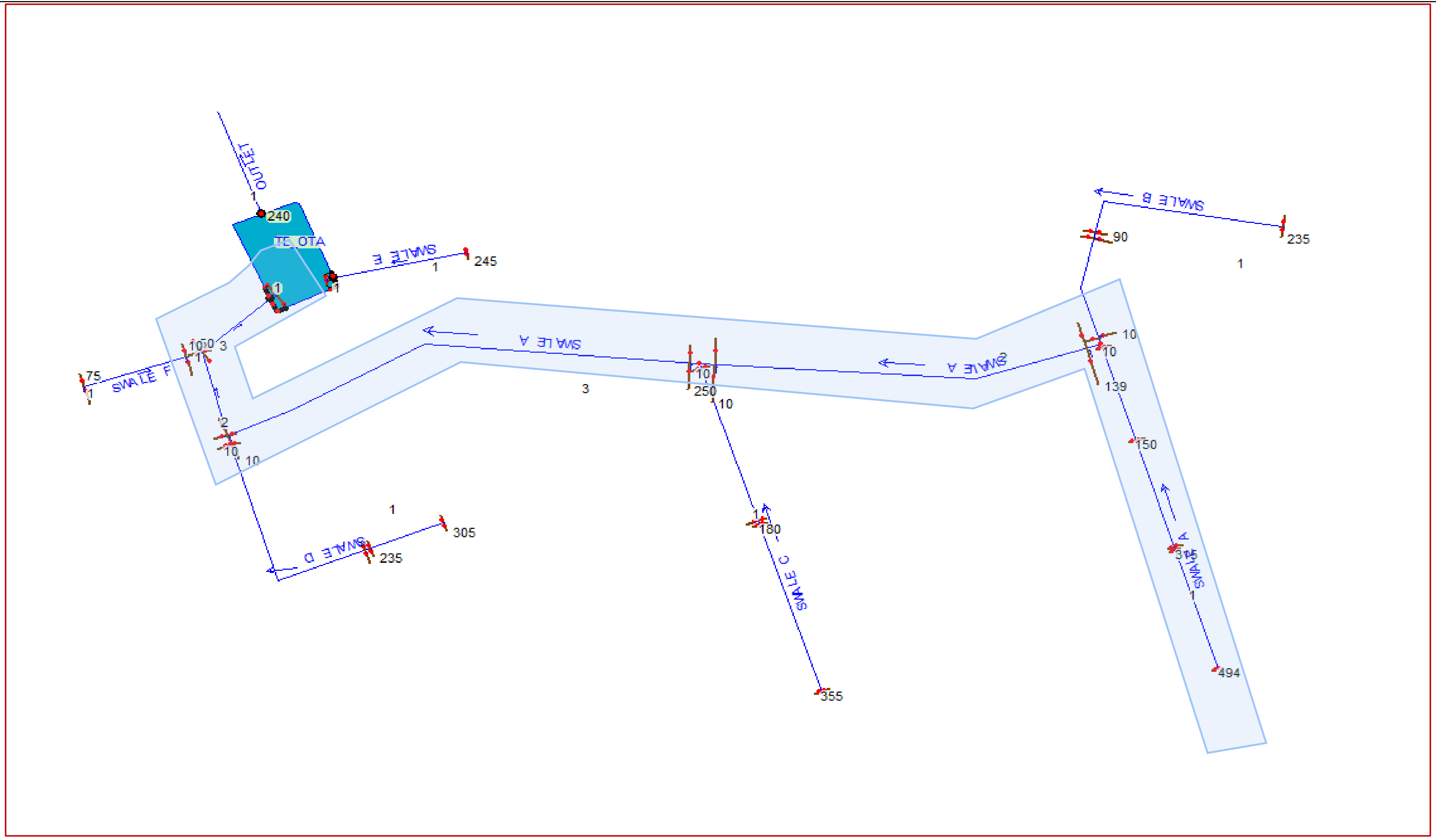


Figure 1 – Schematic Arrangement of Swale Network of Ohote A Wetland Contributing Area (Qualifying Development)

Critical hydraulic section shaded as per above.

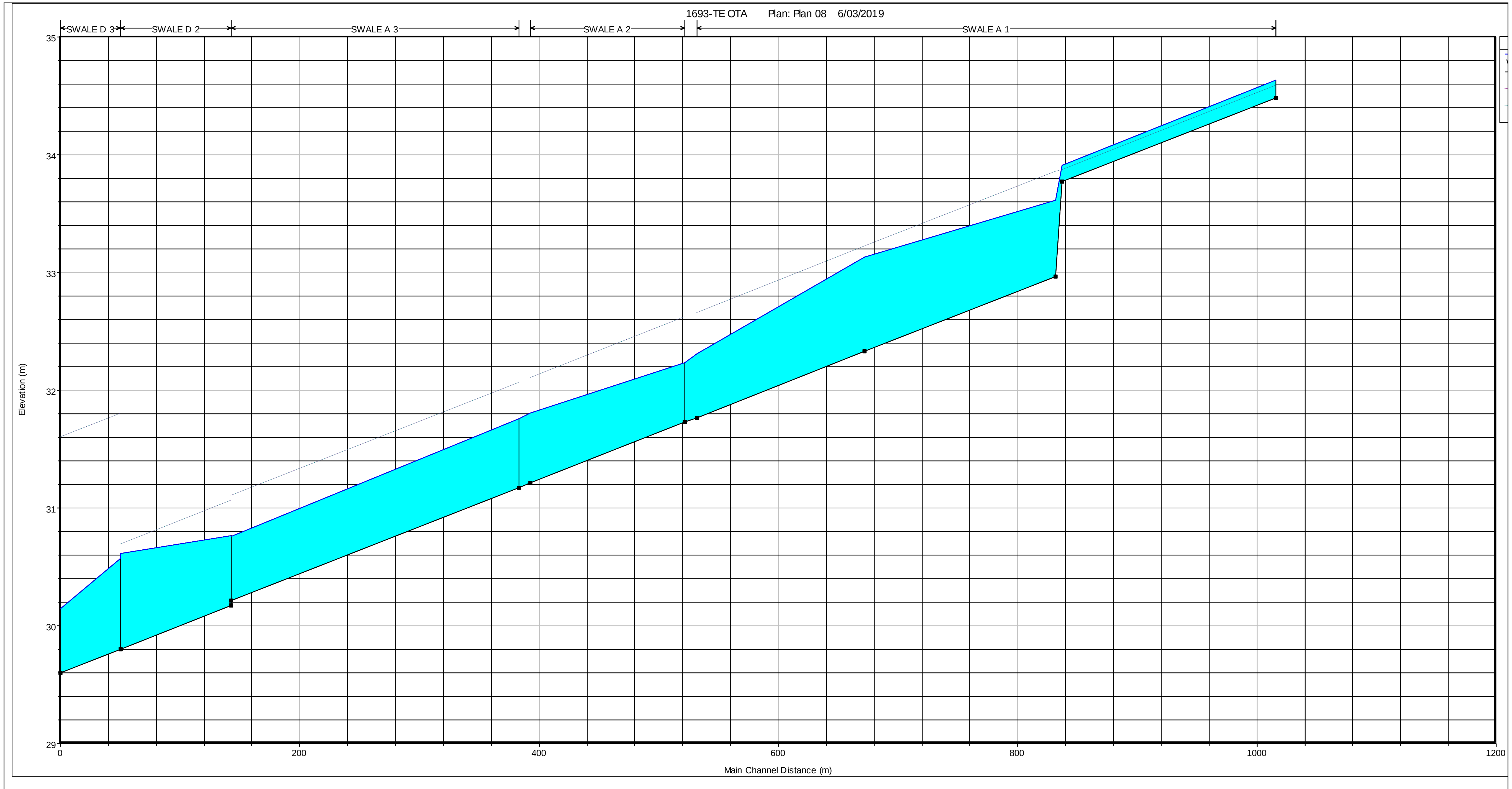


Figure 2 – Water Depth along Critical hydraulic section.

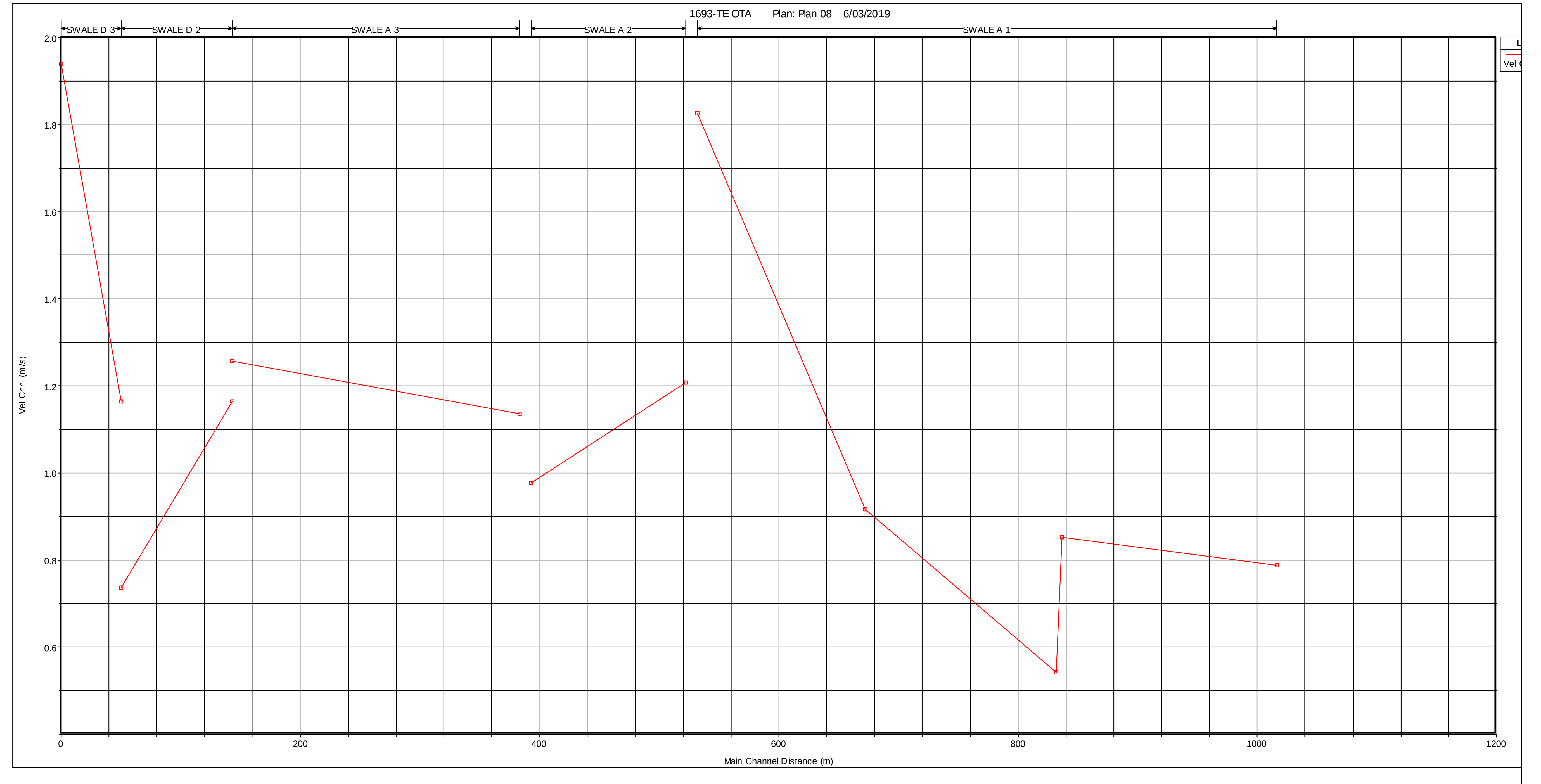


Figure 3 – Velocity Profile along Critical hydraulic section.

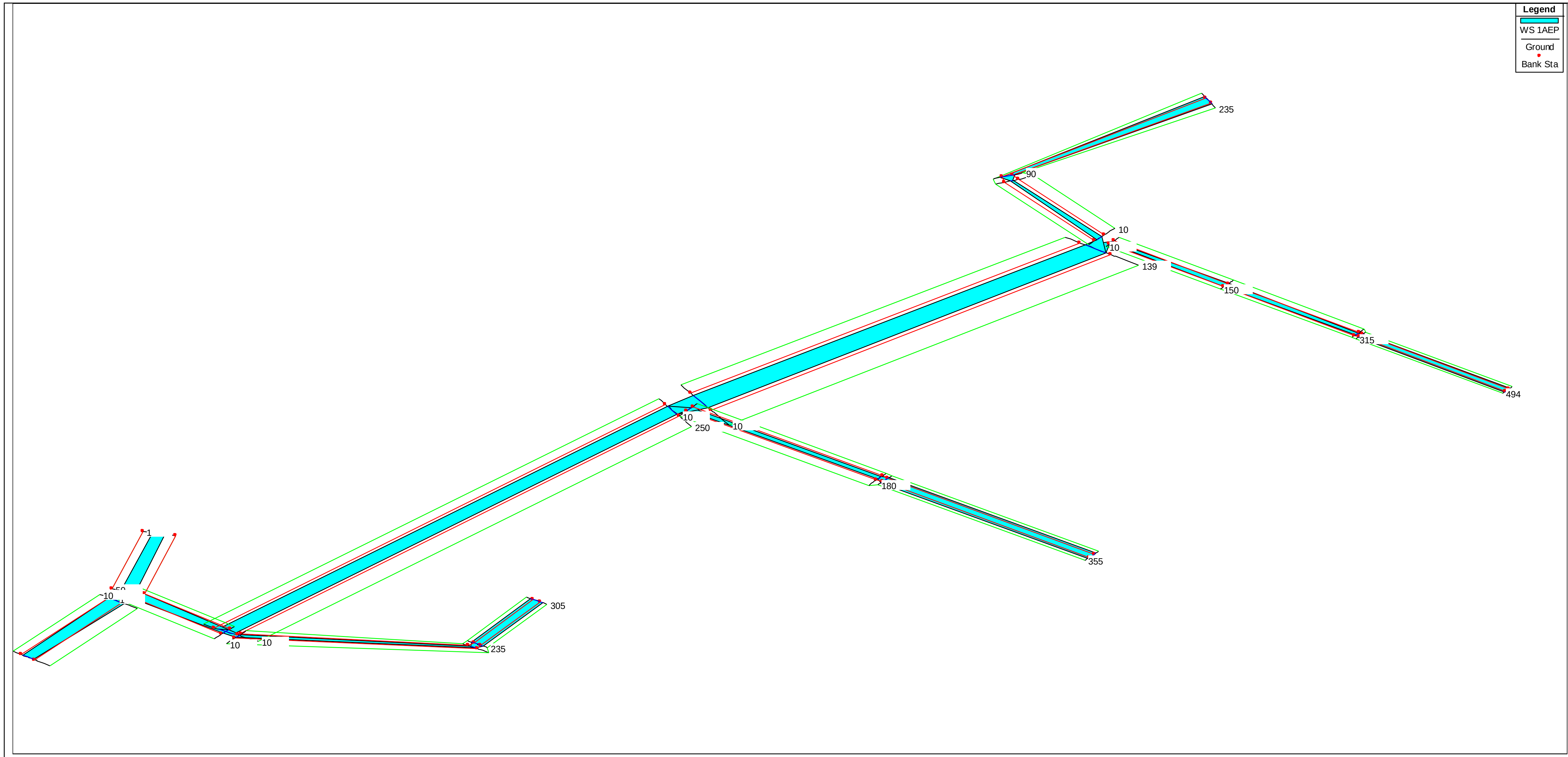


Figure 4 – 3D Water Depth Plot Te Otamanui Swale and Channel Network

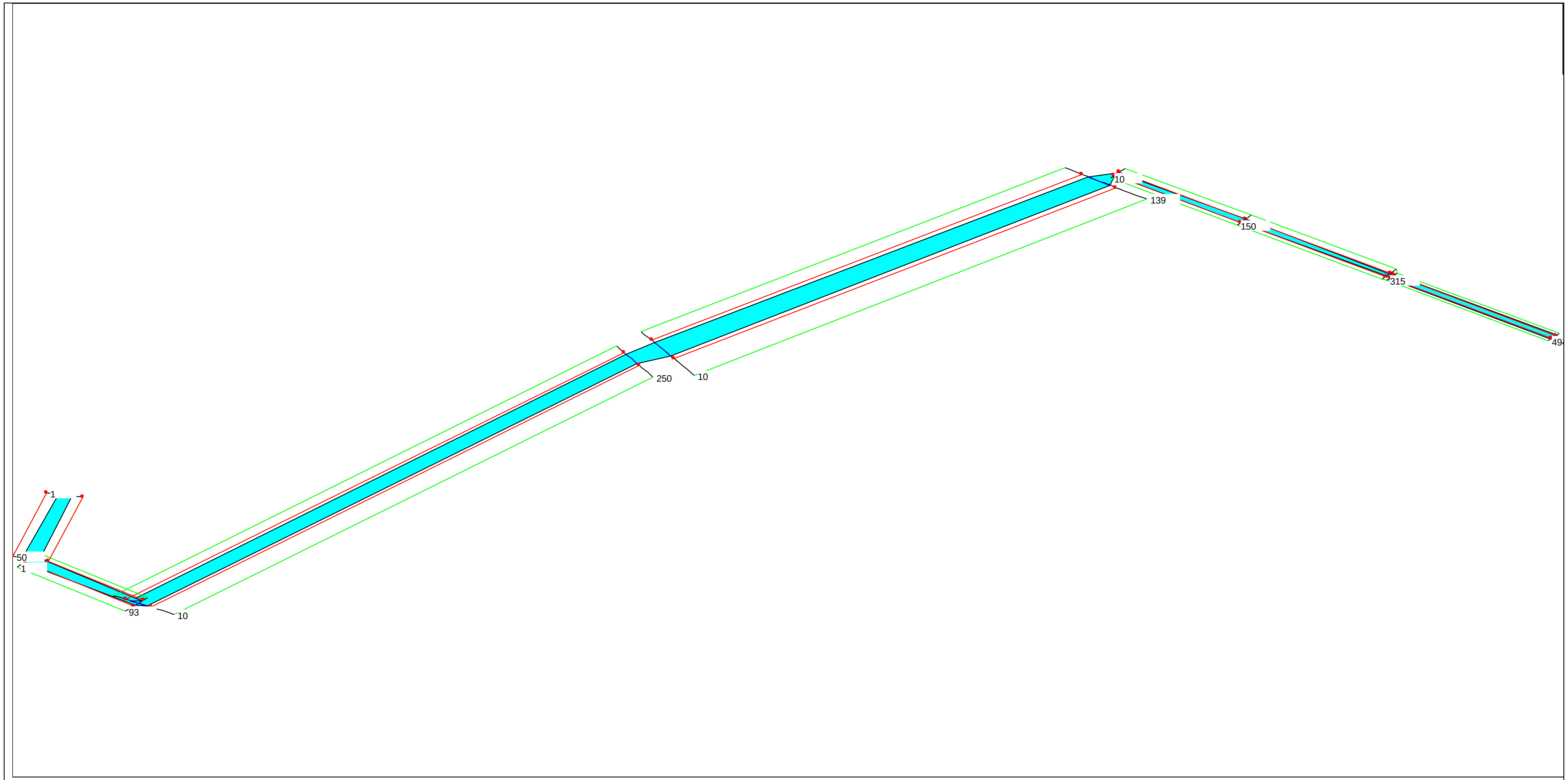


Figure 5 – 3D Water Depth Plot along critical hydraulic section.

APPENDIX H –OHOTE STREAM MODEL FIGURE

Legend

- Rotokauri North PPC Area
- WRC/HCC TA Boundary
- Ohote Stream Approximate Centre Line

Modeled Sections

- Sensitive
- Not Sensitive

Data License:
Data by Hamilton City Council and Land Information New Zealand is licensed under CC BY 4.0 NZ.

Map Projection:
NZGD2000 / Mount Eden 2000 (EPSG: 2105)

Drawn By:	FW	Date:	14/02/2019	Signed:	
Checked By:		Date:		Signed:	
Approved By:		Date:		Signed:	
Plot Date:	14/02/2019				

Project:
Rotokauri North
Private Plan Change (PPC)
Greenseed Consultants Ltd

Title:
Sensitivity Analysis
Ohote Stream

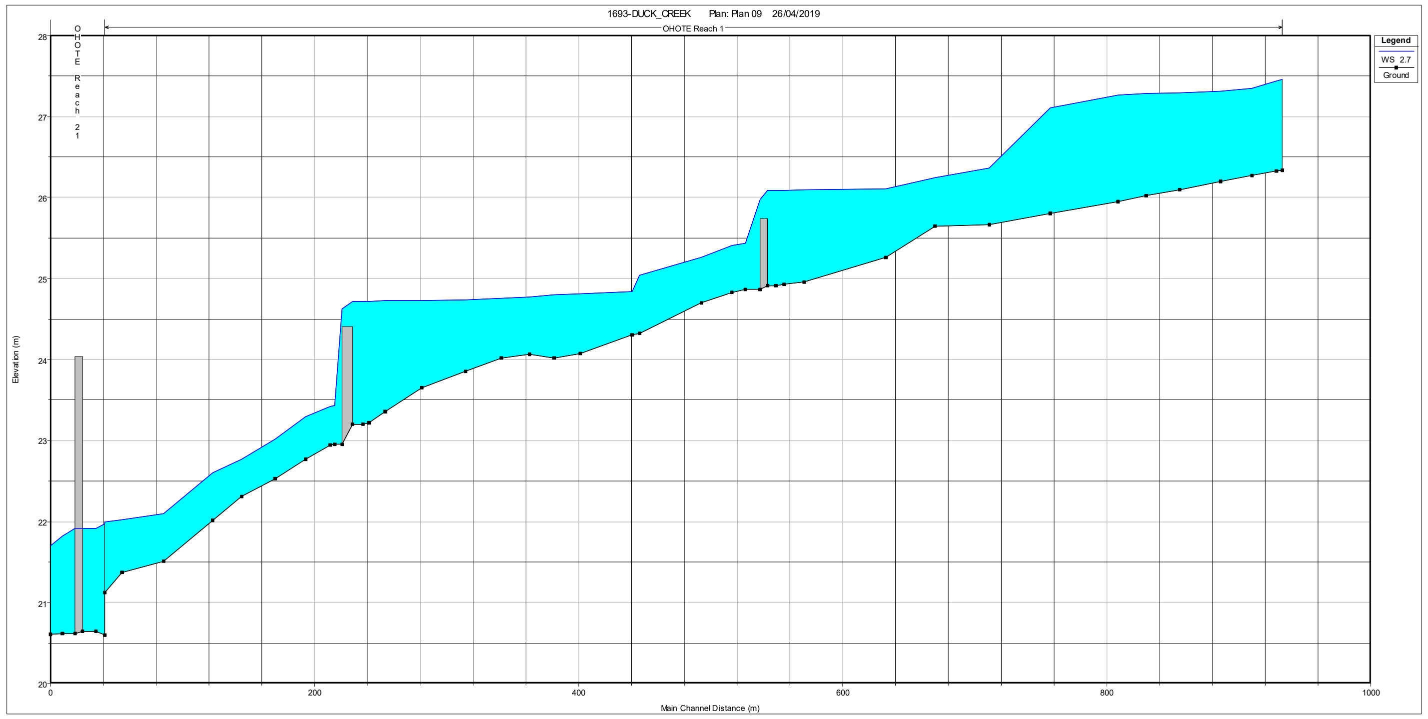
McKenzie&Co Consultants Ltd

Issue Status:	For Information
Project Number:	1693
Drawing Number:	340
Revision:	A
A3 Scale:	1:3500

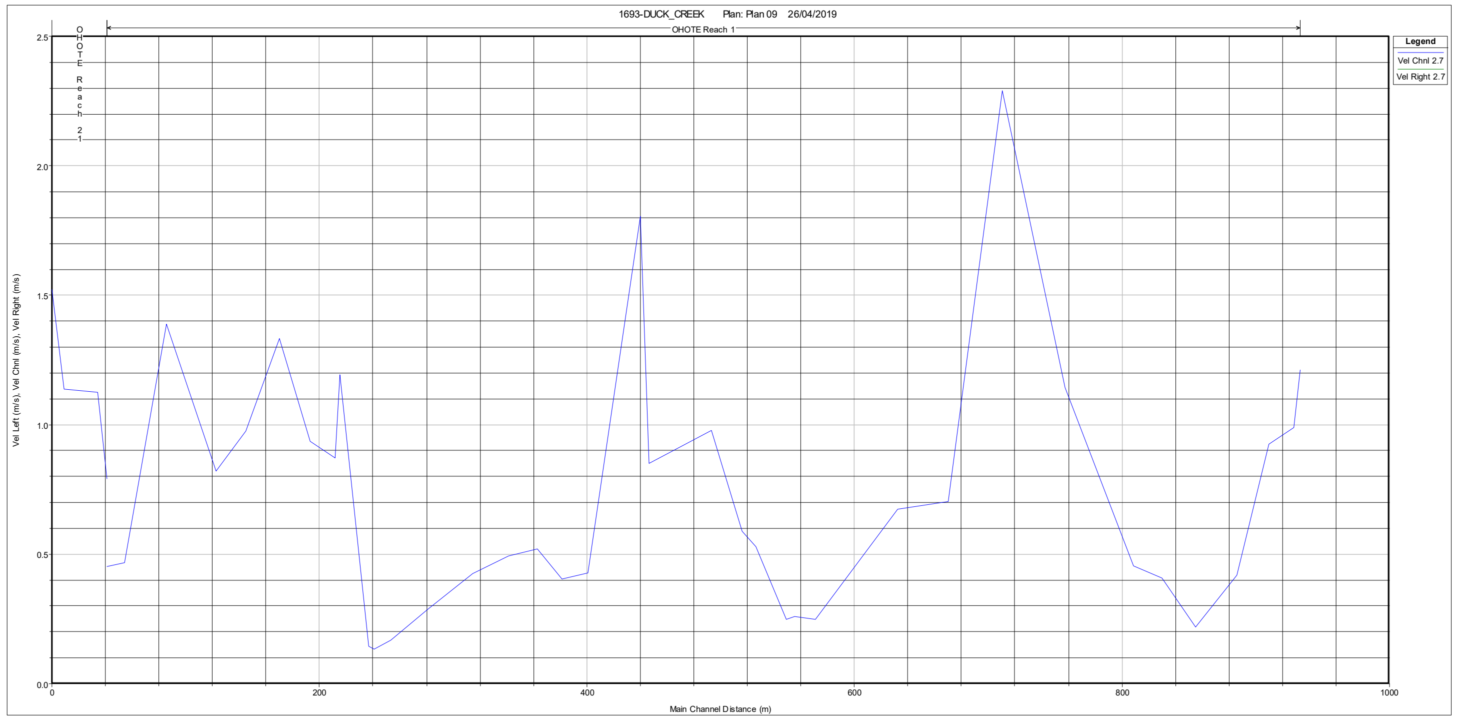
APPENDIX I – EXISTING OHOTE STREAM HYDRAULICS

BASE CASE (2.7 m³/s)

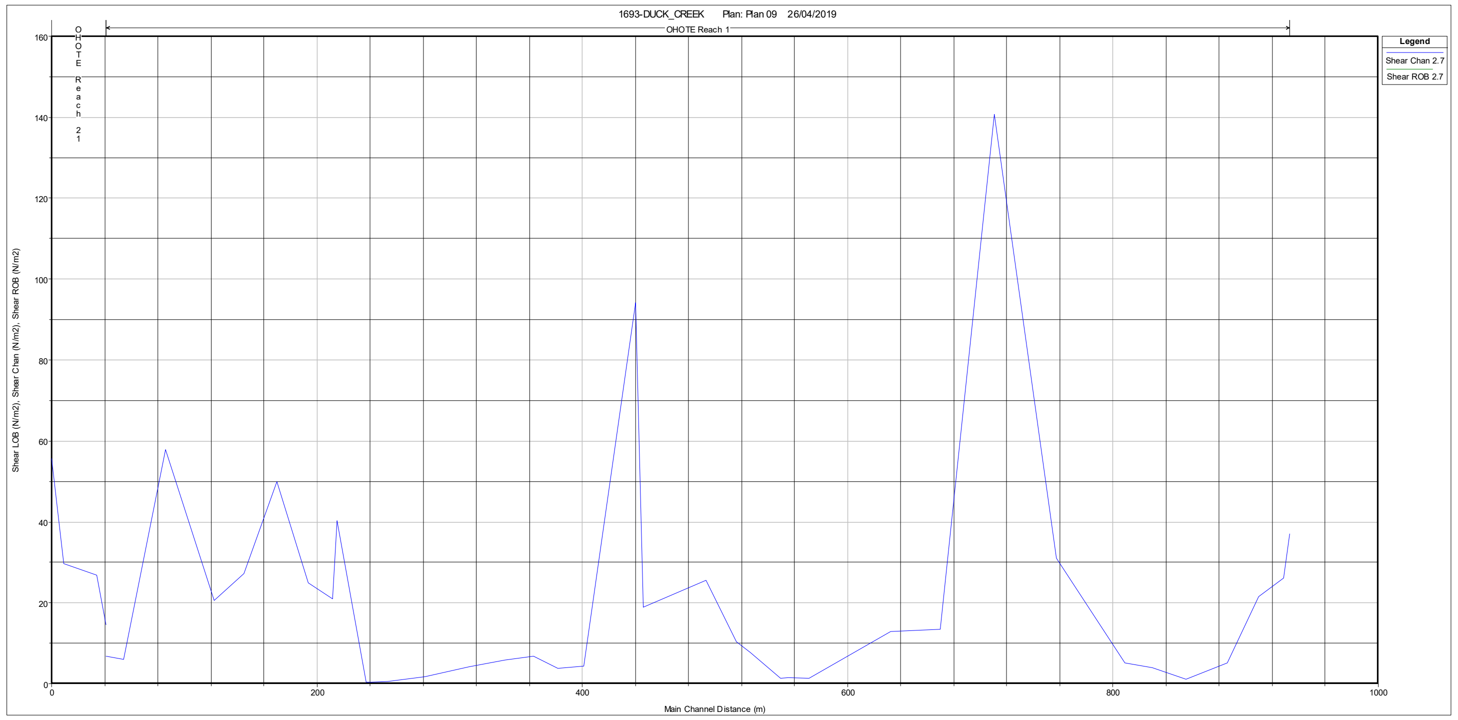
WATER SURFACE PROFILE



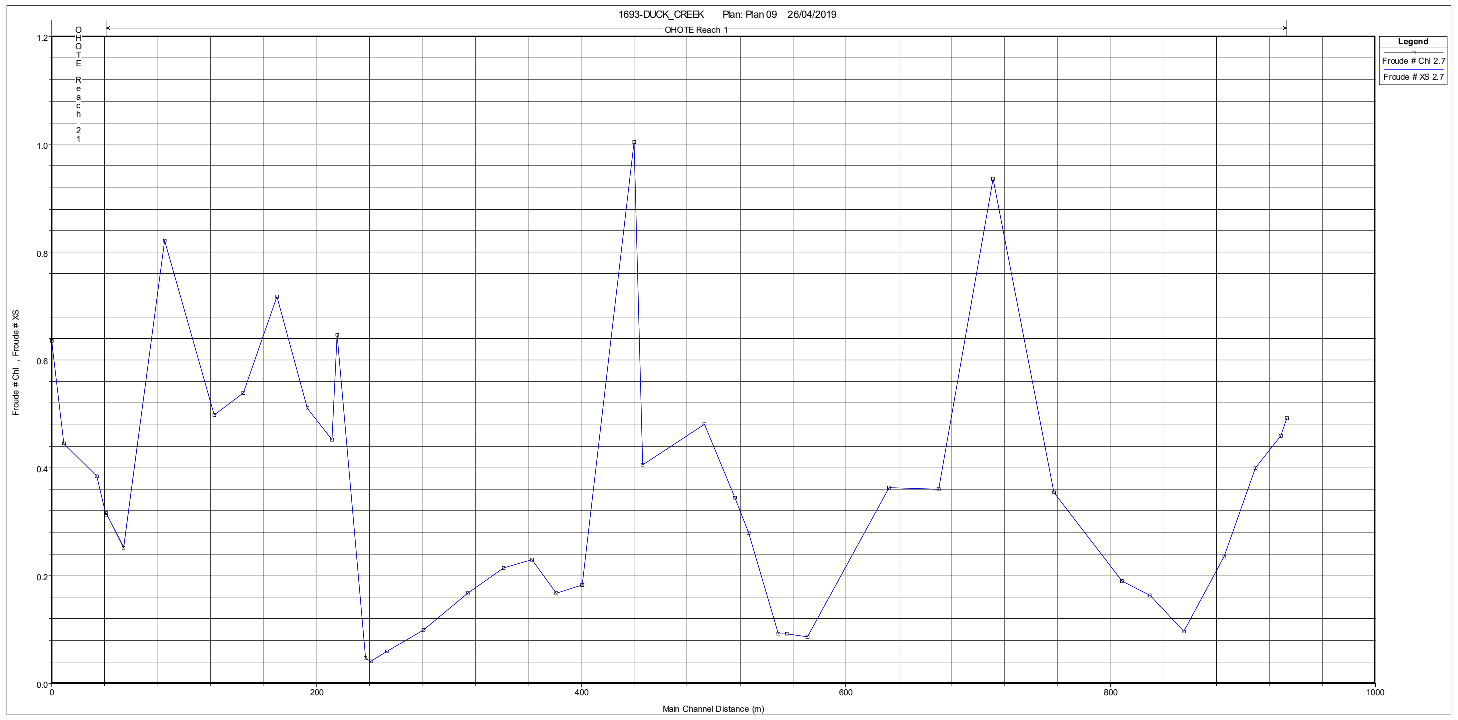
VELOCITY PROFILE



SHEAR STRESS PROFILE

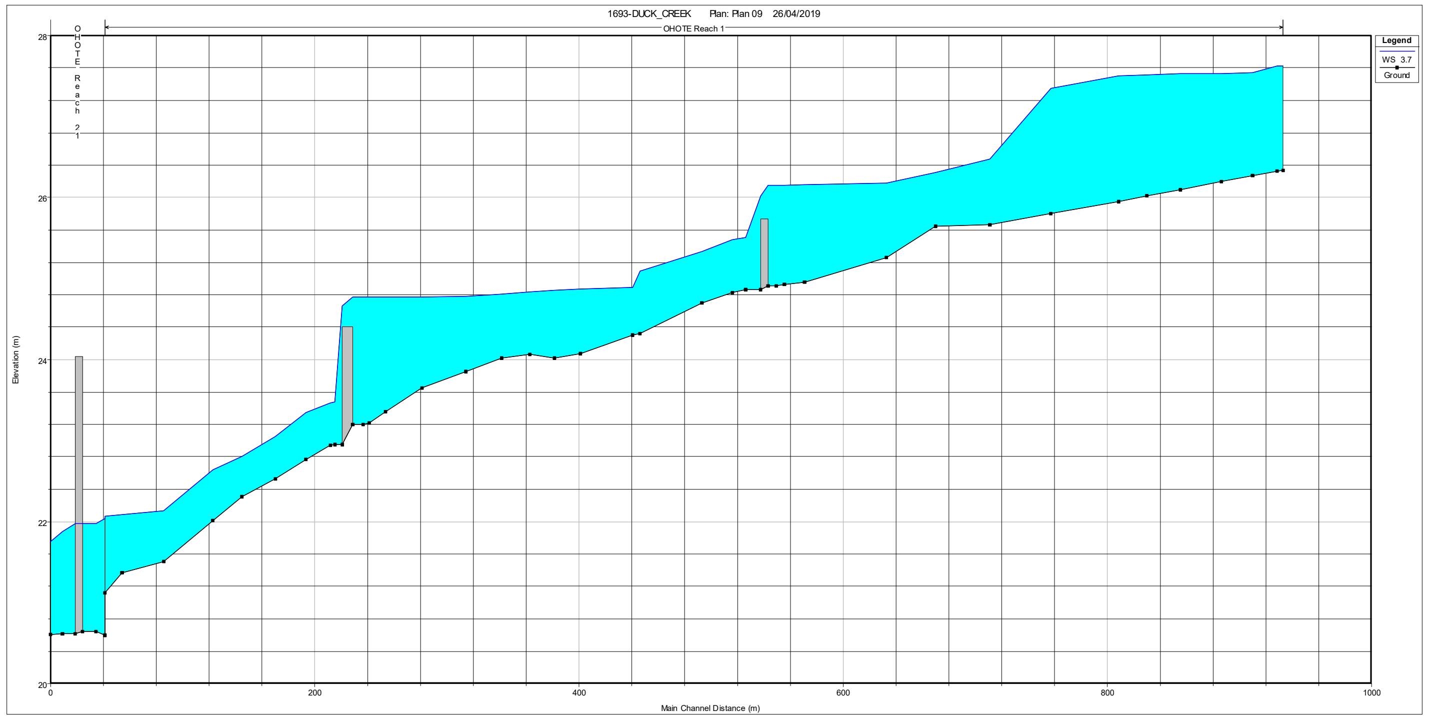


FROUDE NUMBER PROFILE

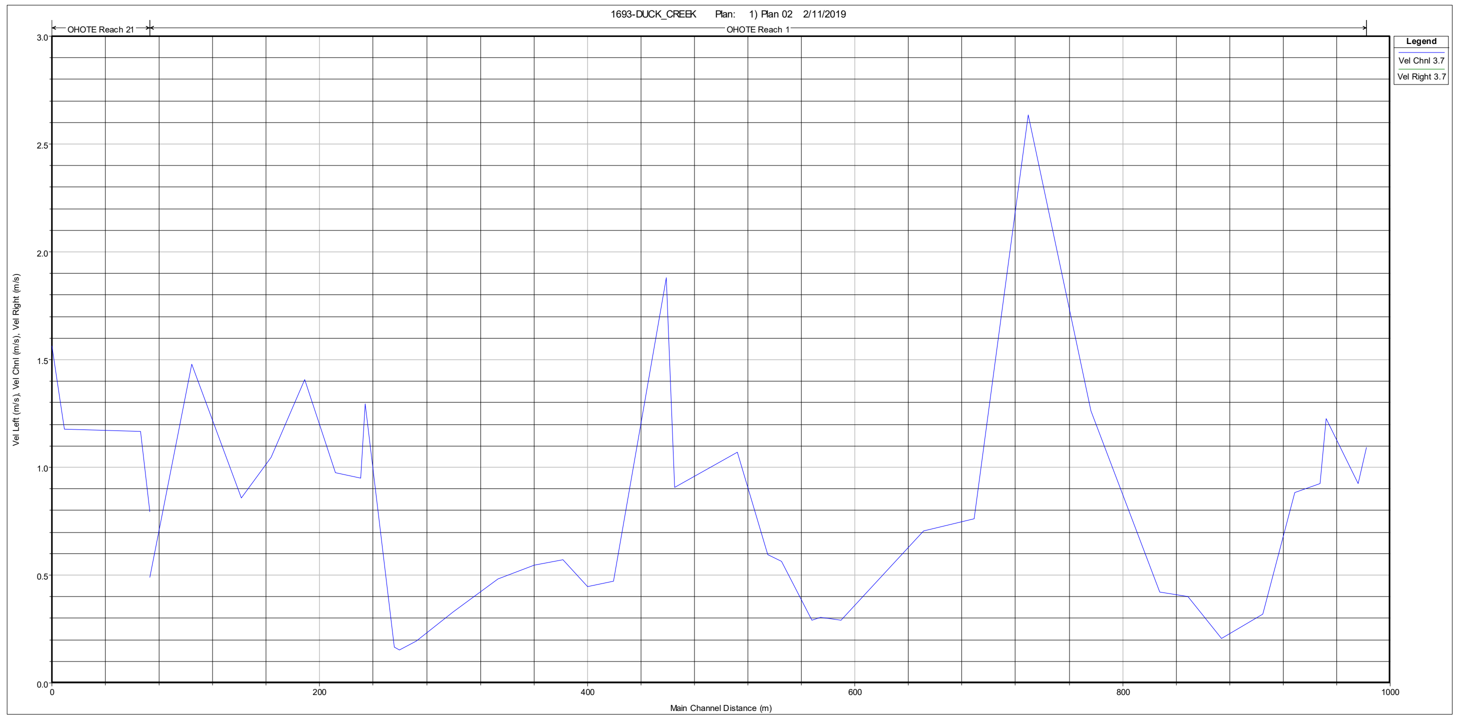


INTERMEDIATE CASE (3.7 m³/s)

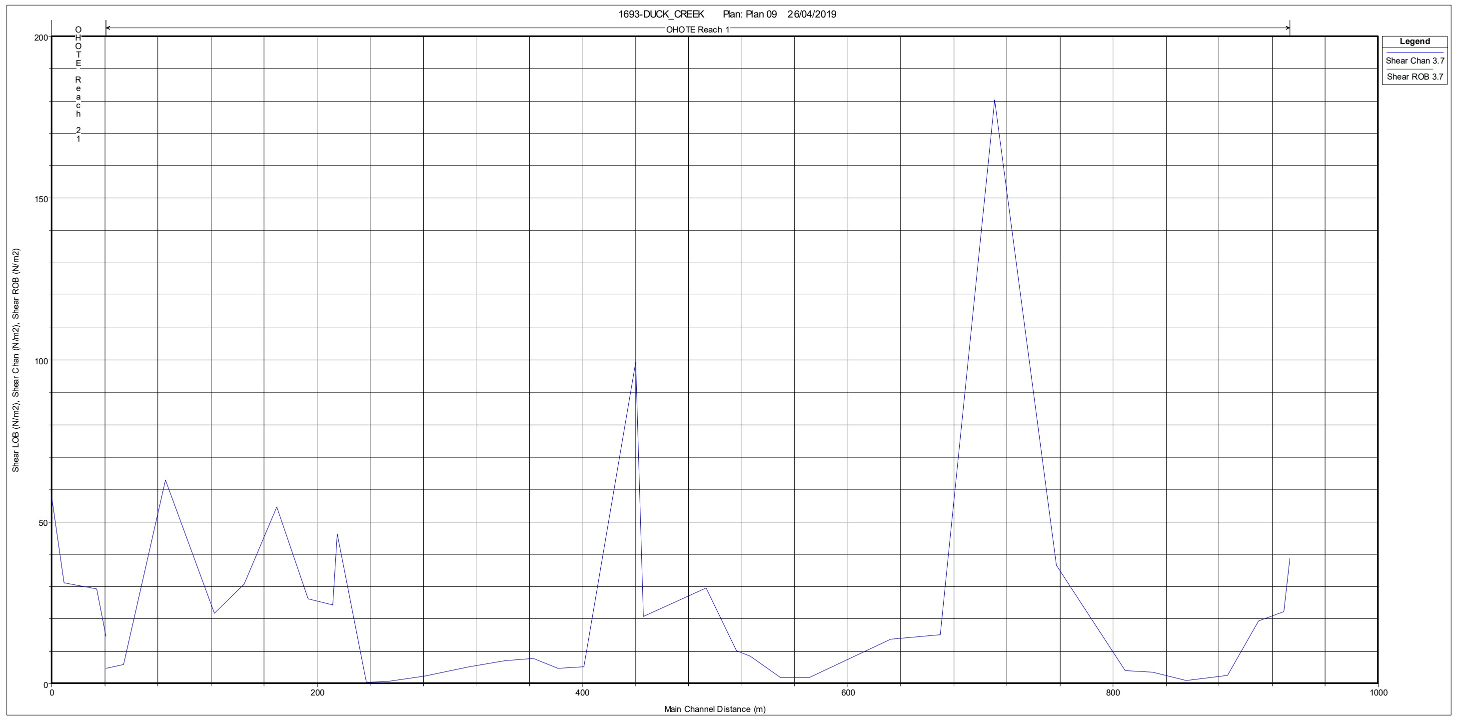
WATER SURFACE PROFILE



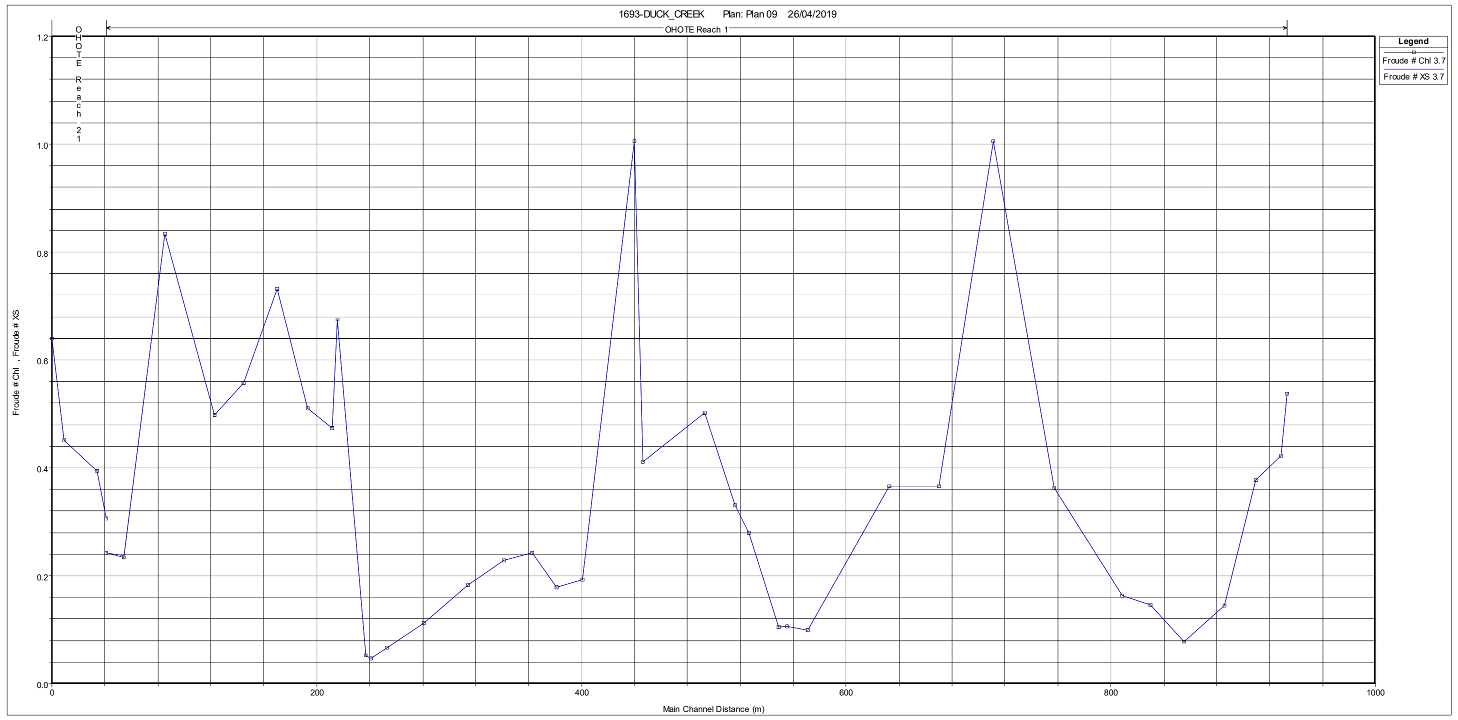
VELOCITY PROFILE



SHEAR STRESS PROFILE

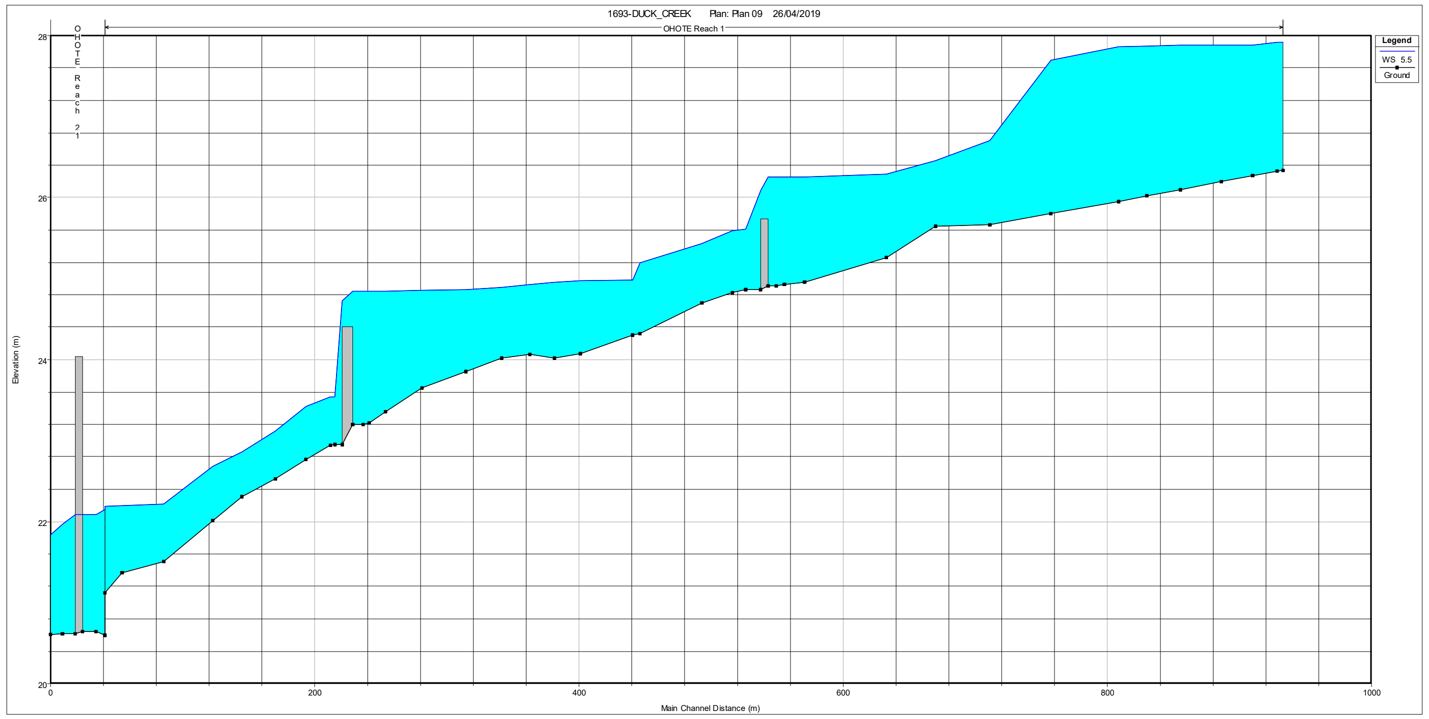


FROUDE NUMBER PROFILE

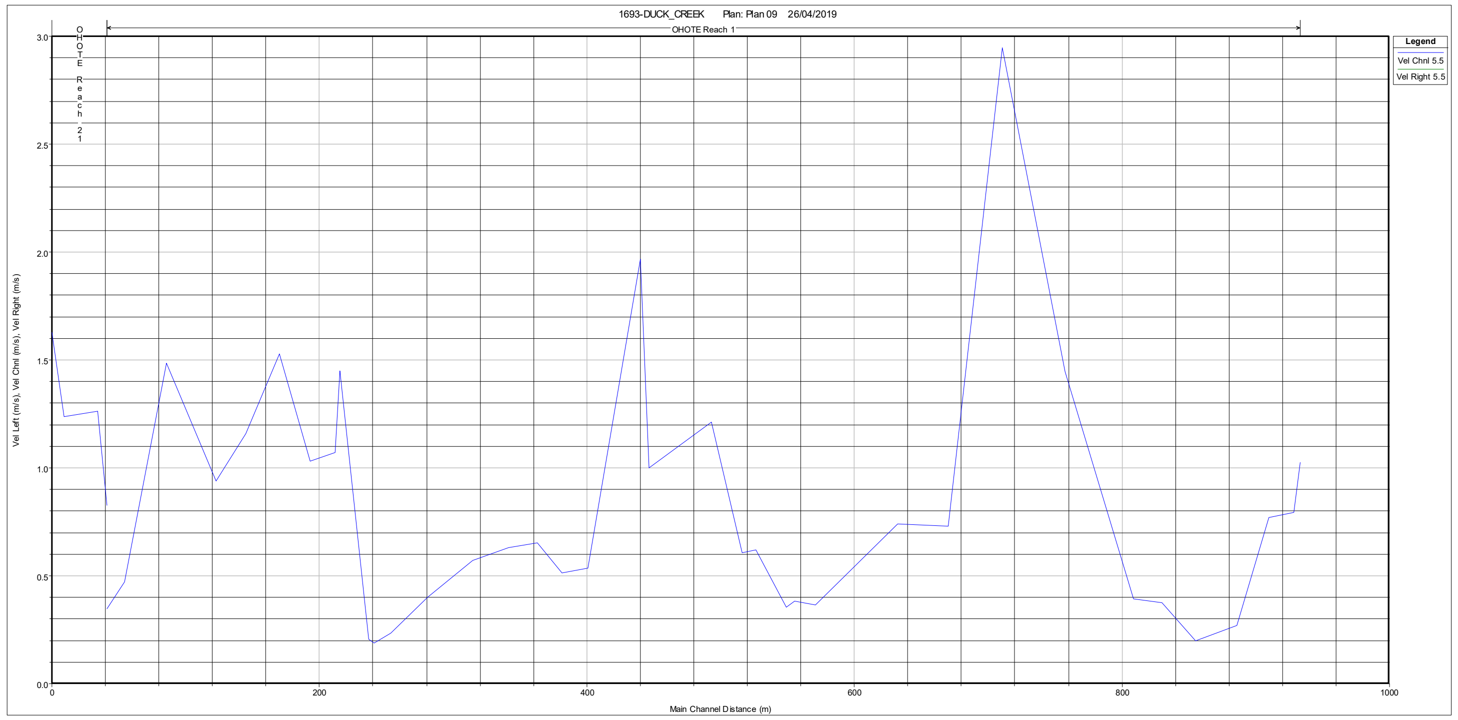


UPPER CASE (5.5 m³/s)

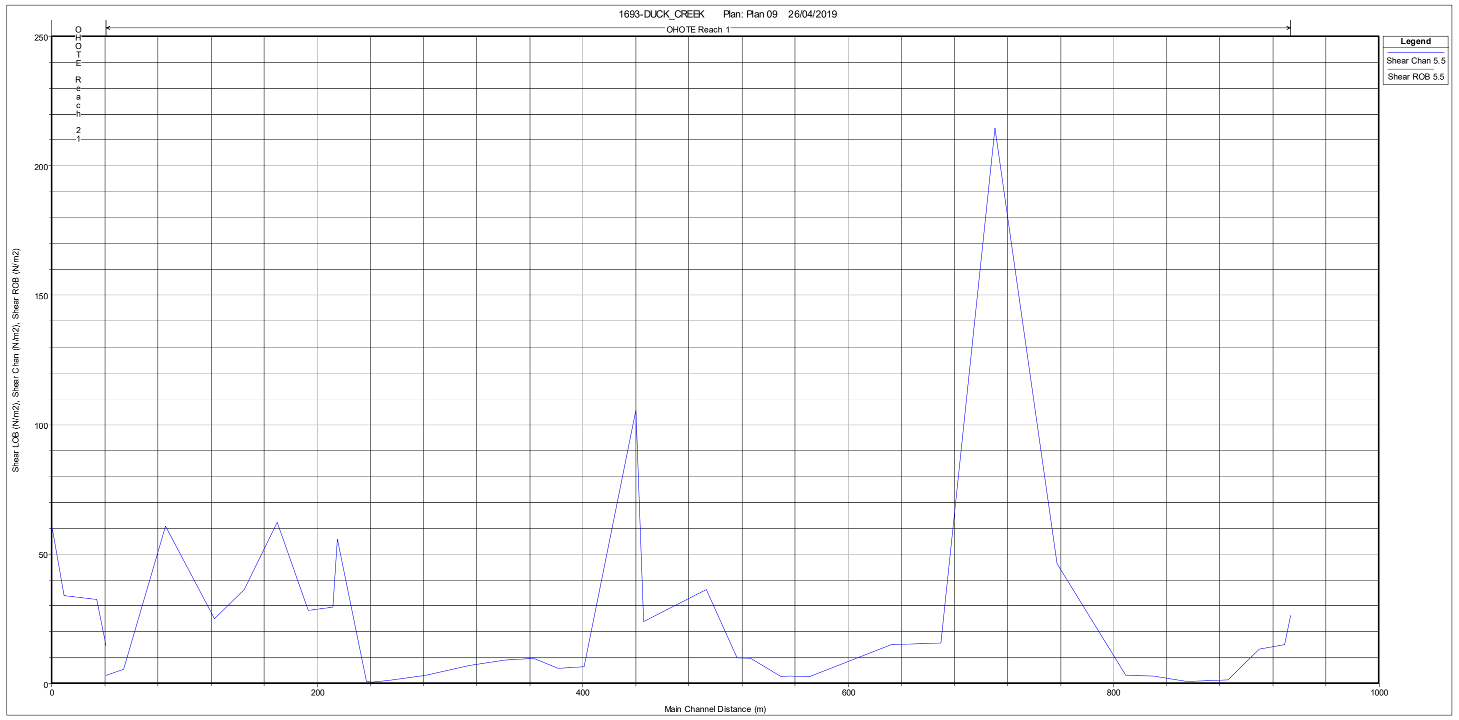
WATER SURFACE PROFILE



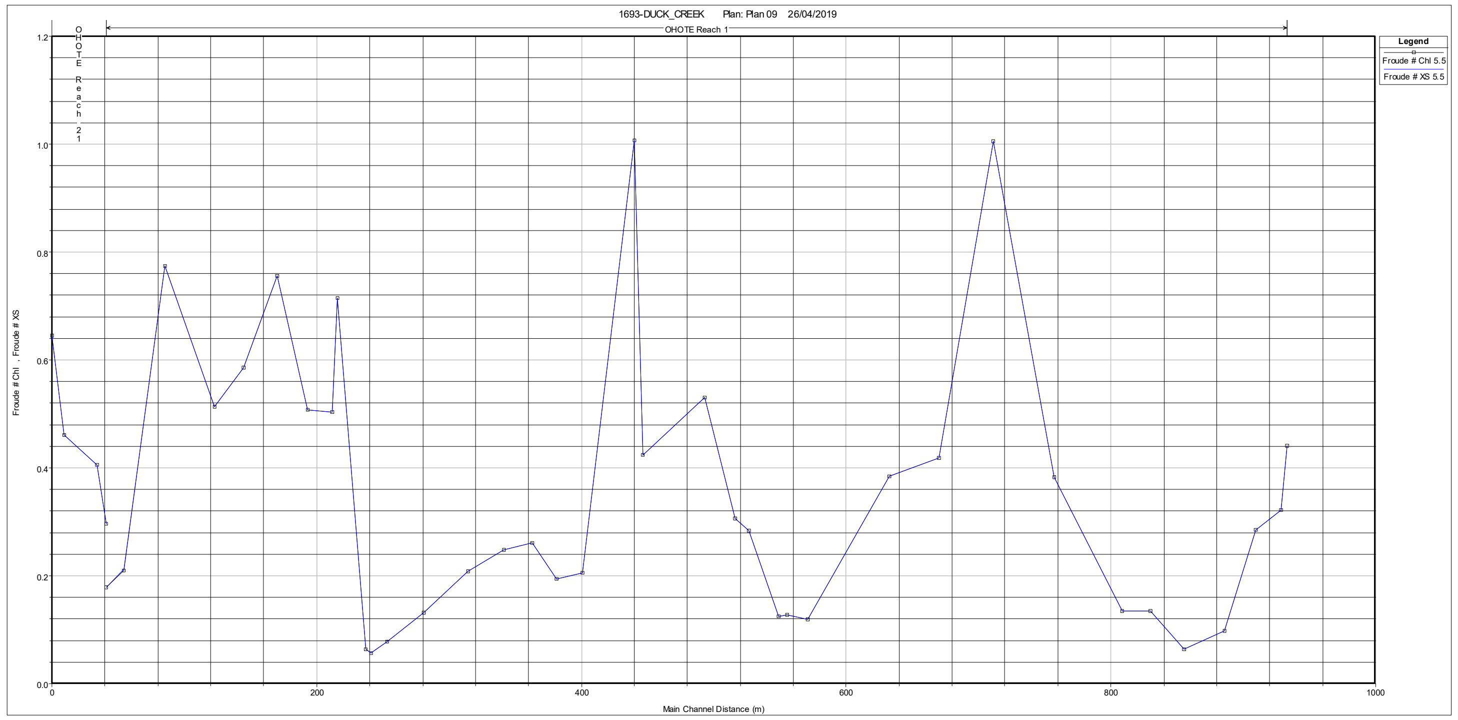
VELOCITY PROFILE



SHEAR STRESS PROFILE



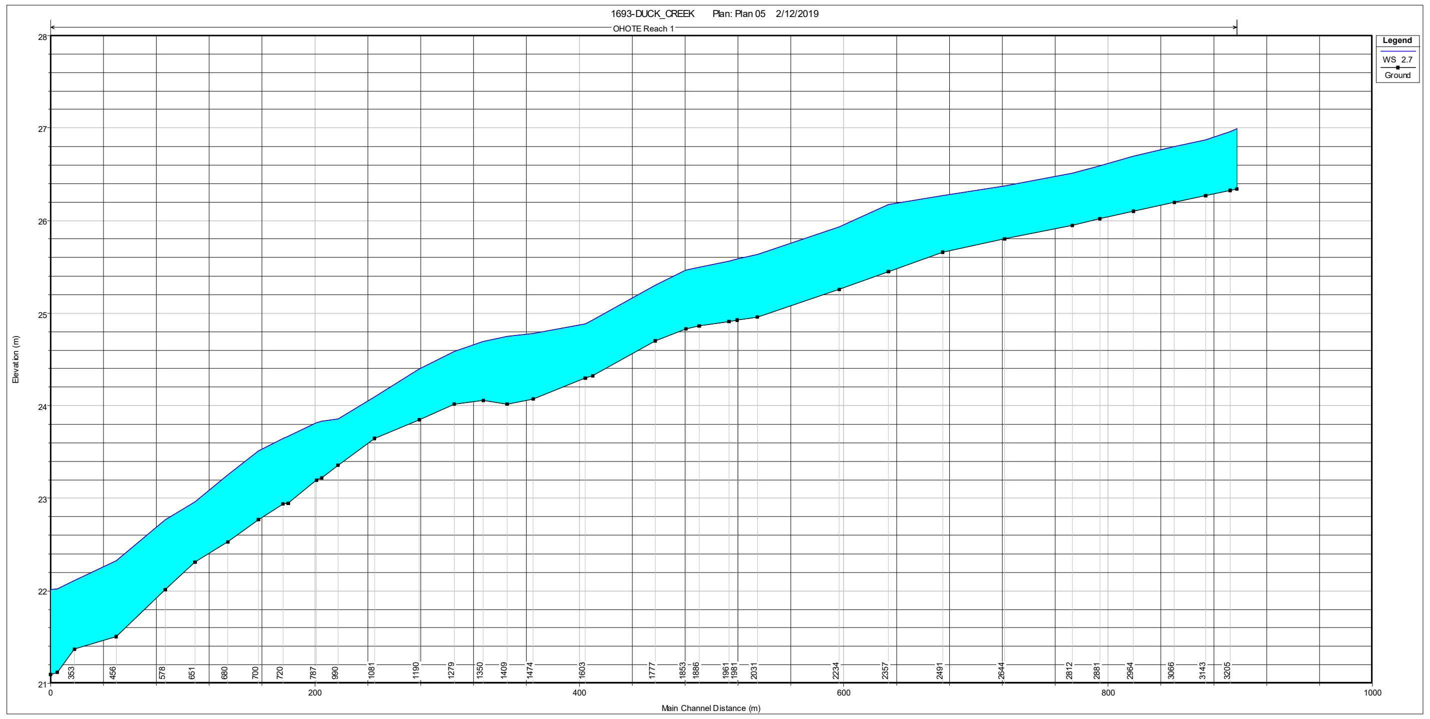
FROUDE NUMBER PROFILE



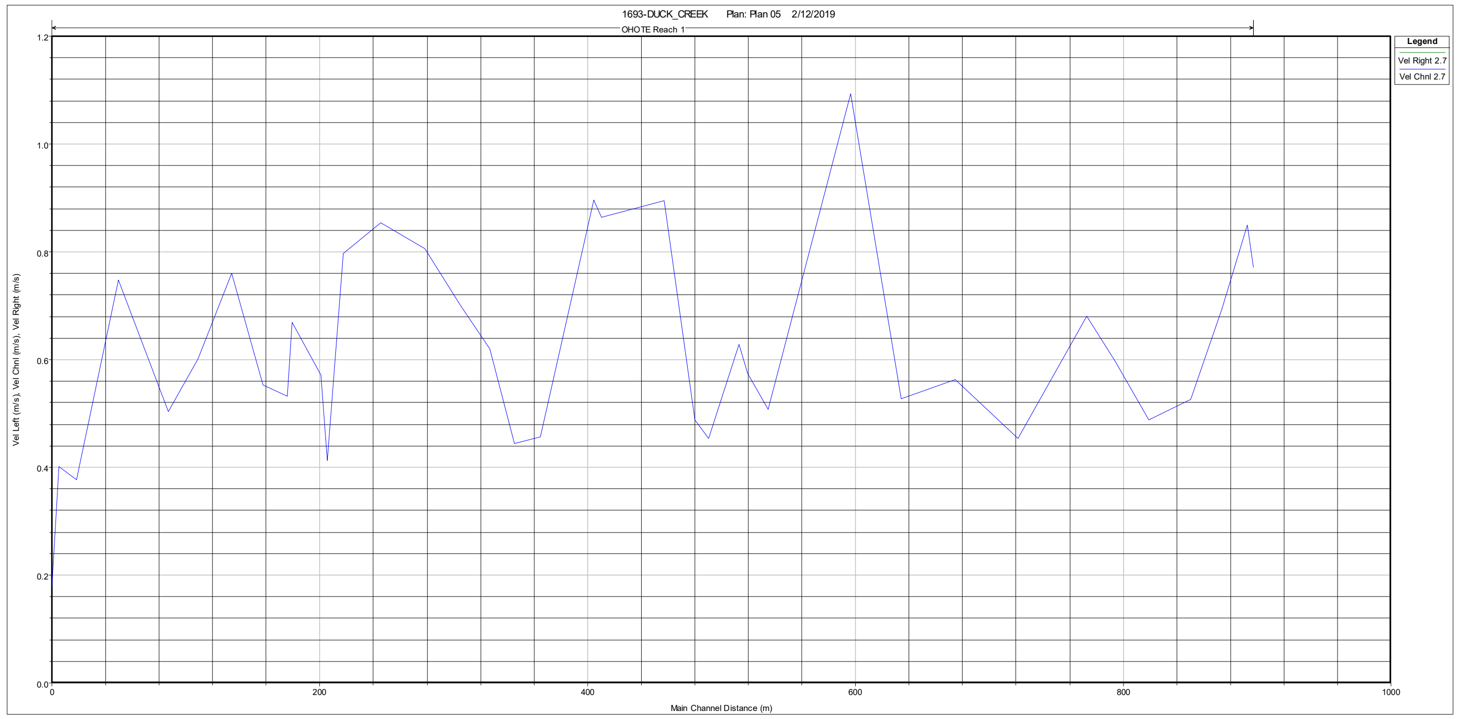
APPENDIX J – DOWNSTREAM WORKS OHOTE STREAM HYDRAULICS

BASE CASE (2.7 m³/s)

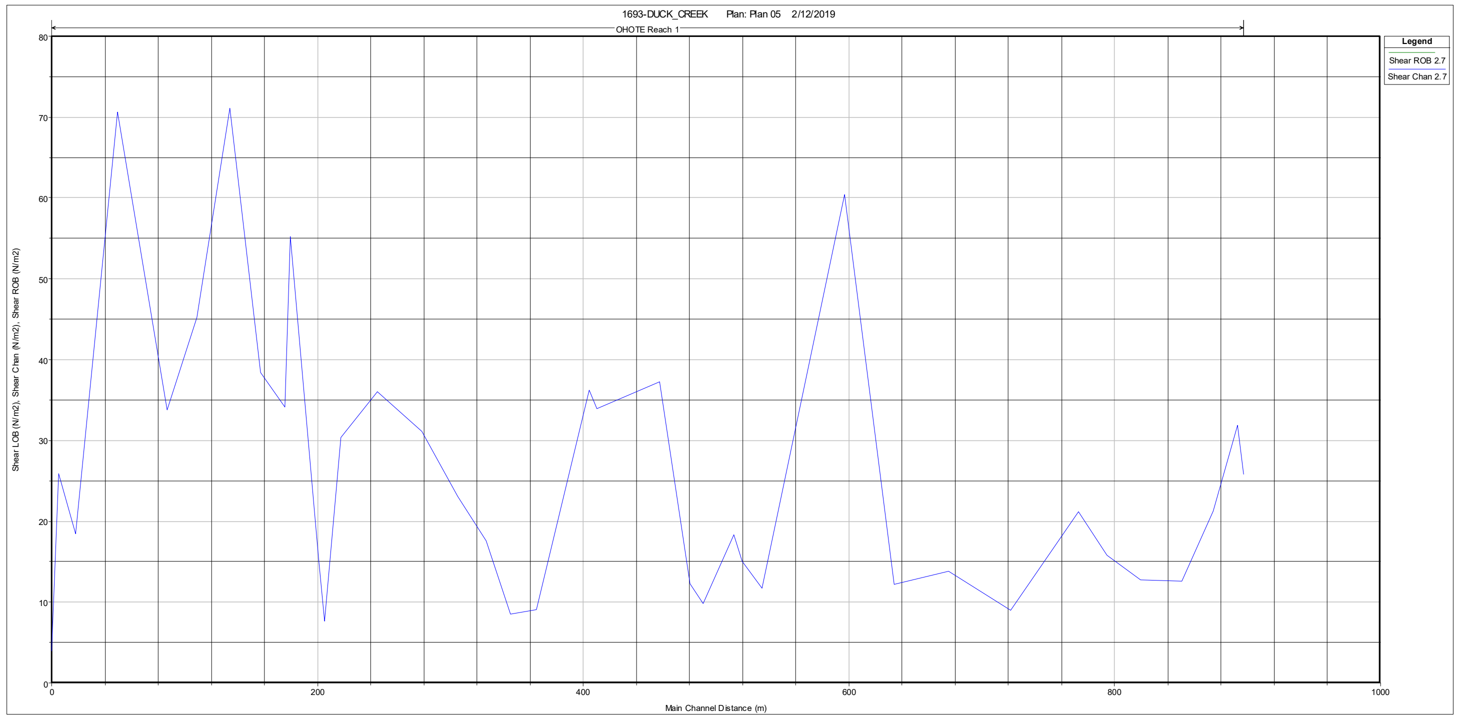
WATER SURFACE PROFILE



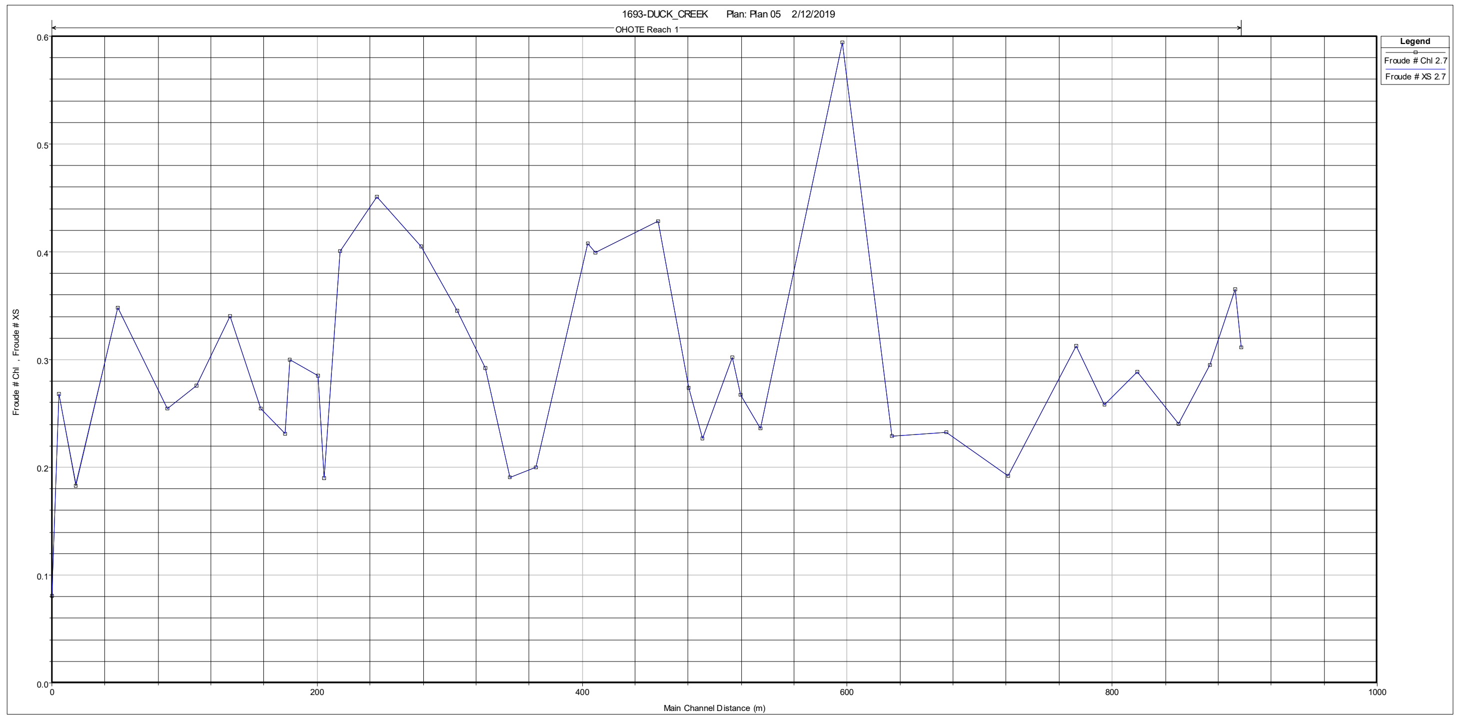
VELOCITY PROFILE



SHEAR STRESS PROFILE

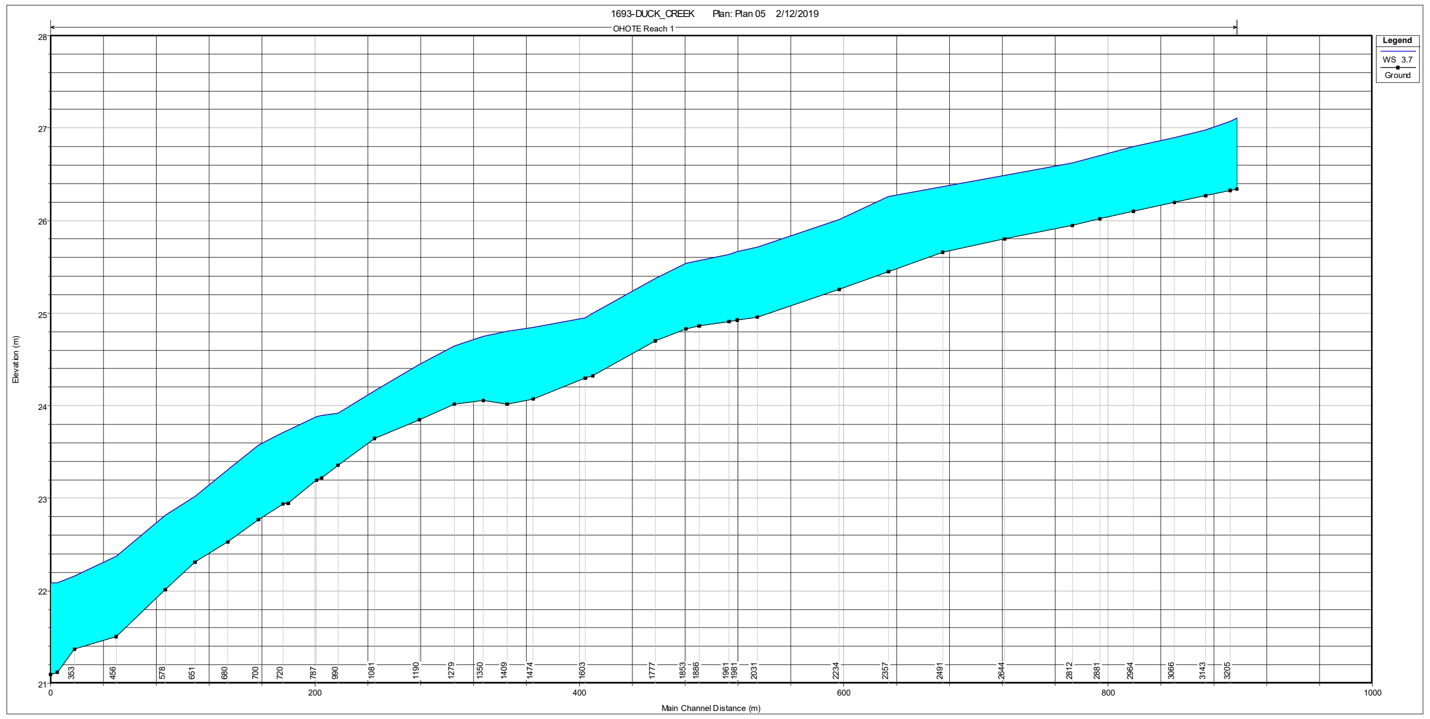


FROUDE NUMBER PROFILE

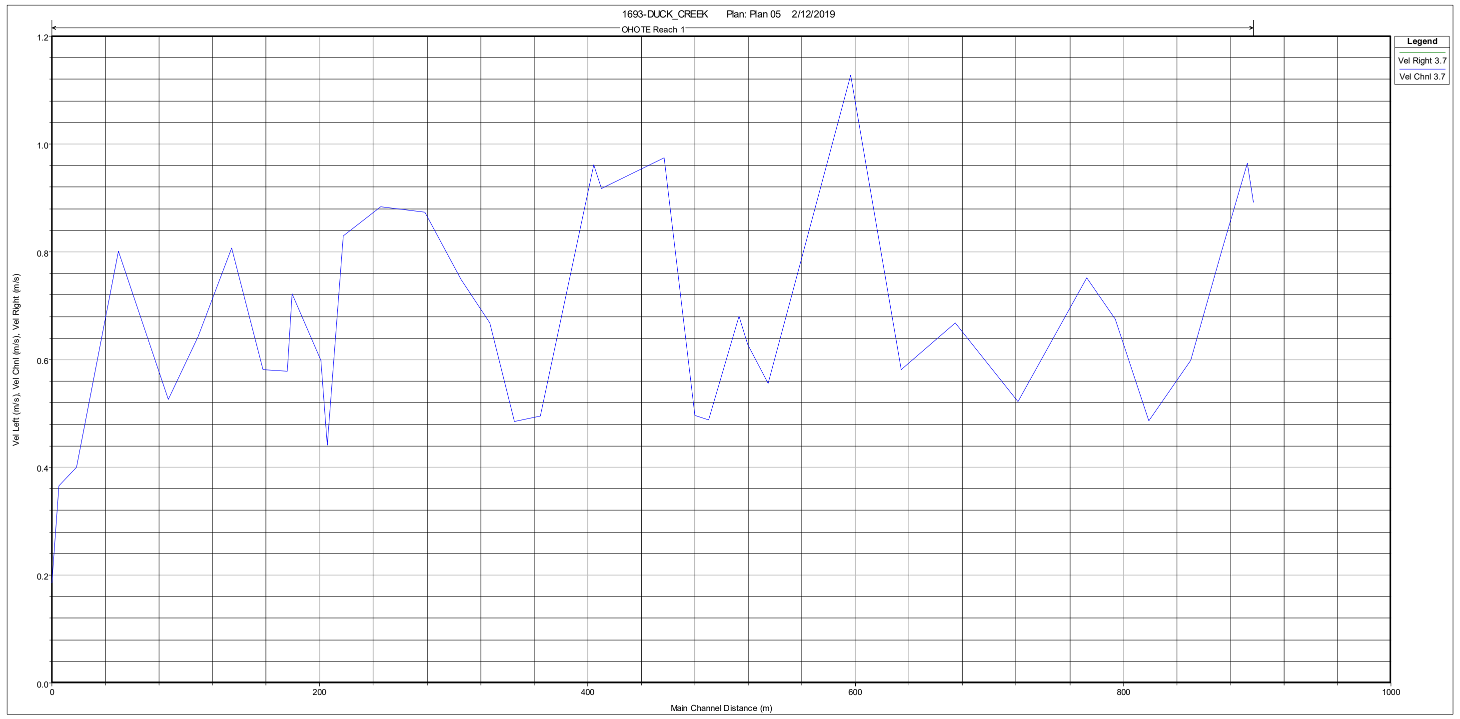


INTERMEDIATE CASE (3.7 m³/s)

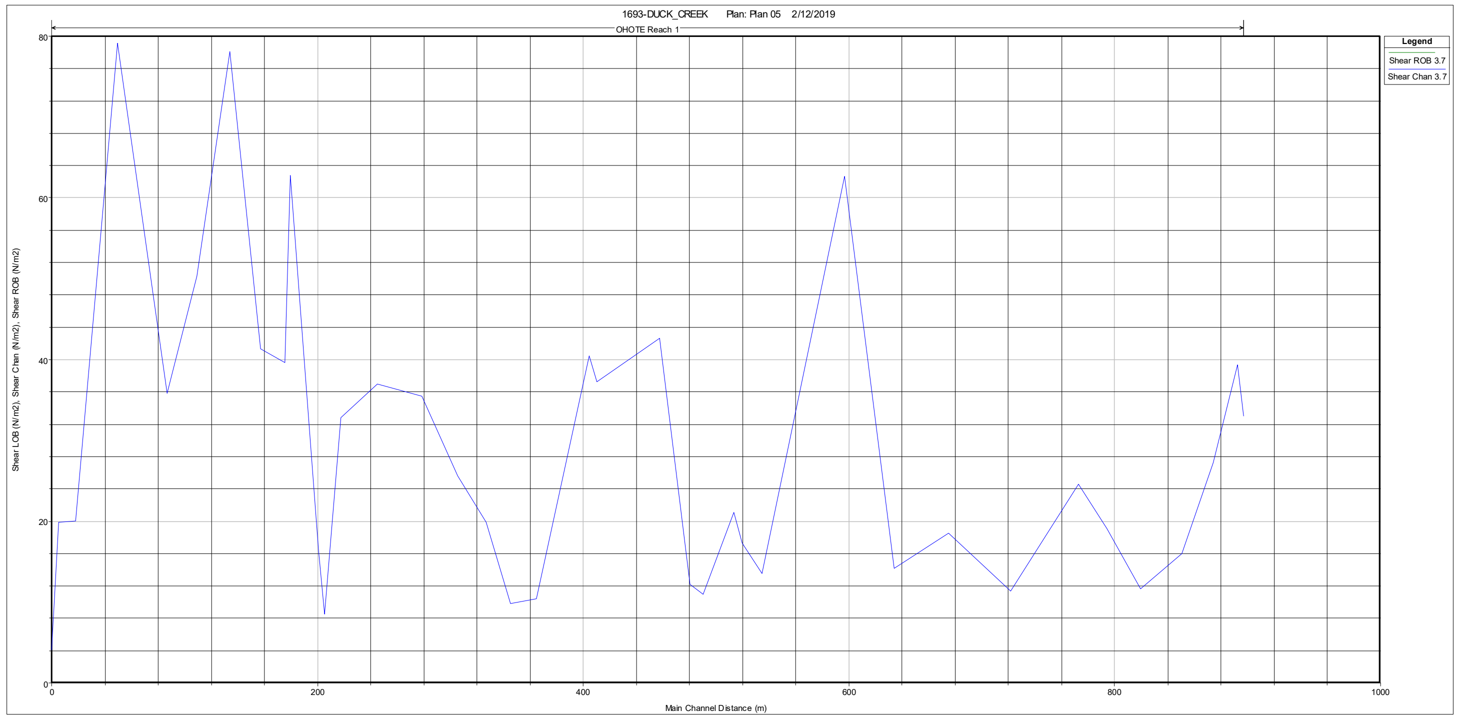
WATER SURFACE PROFILE



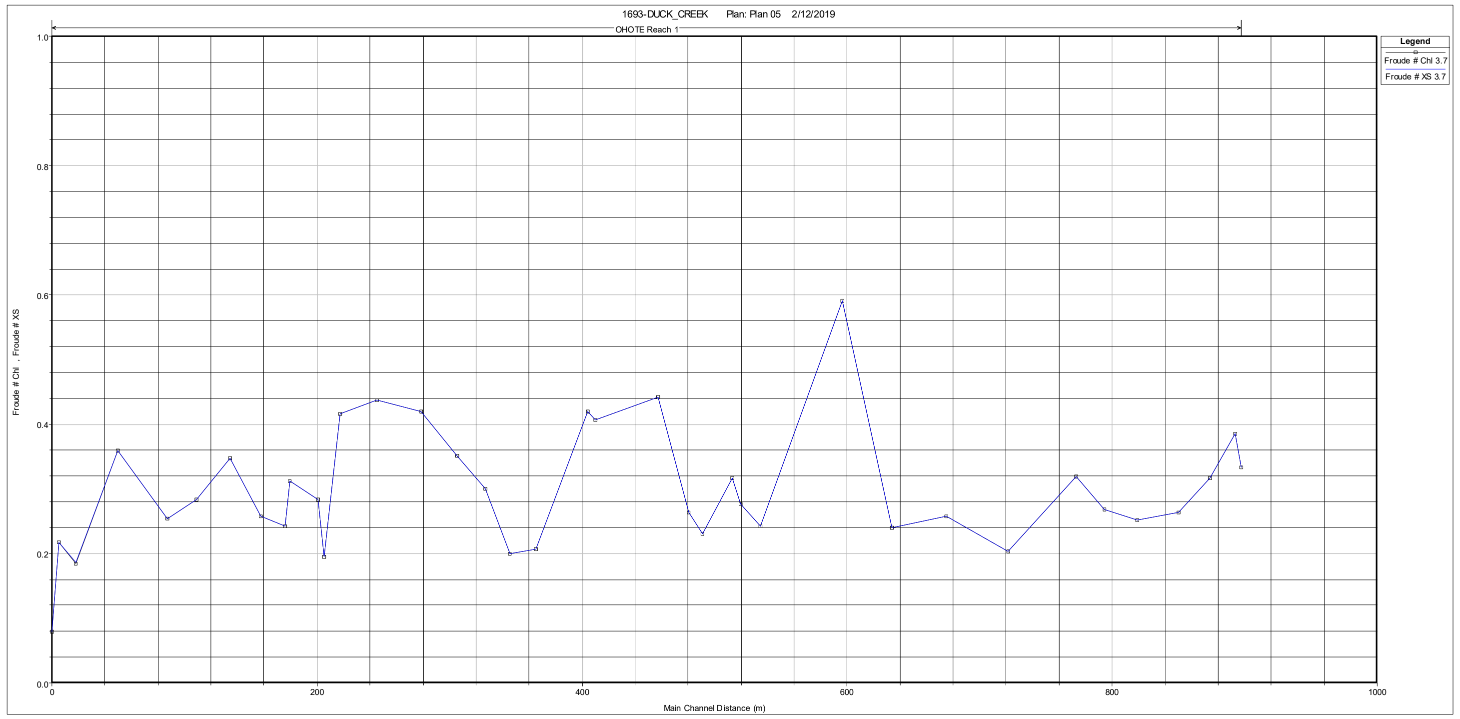
VELOCITY PROFILE



SHEAR STRESS PROFILE

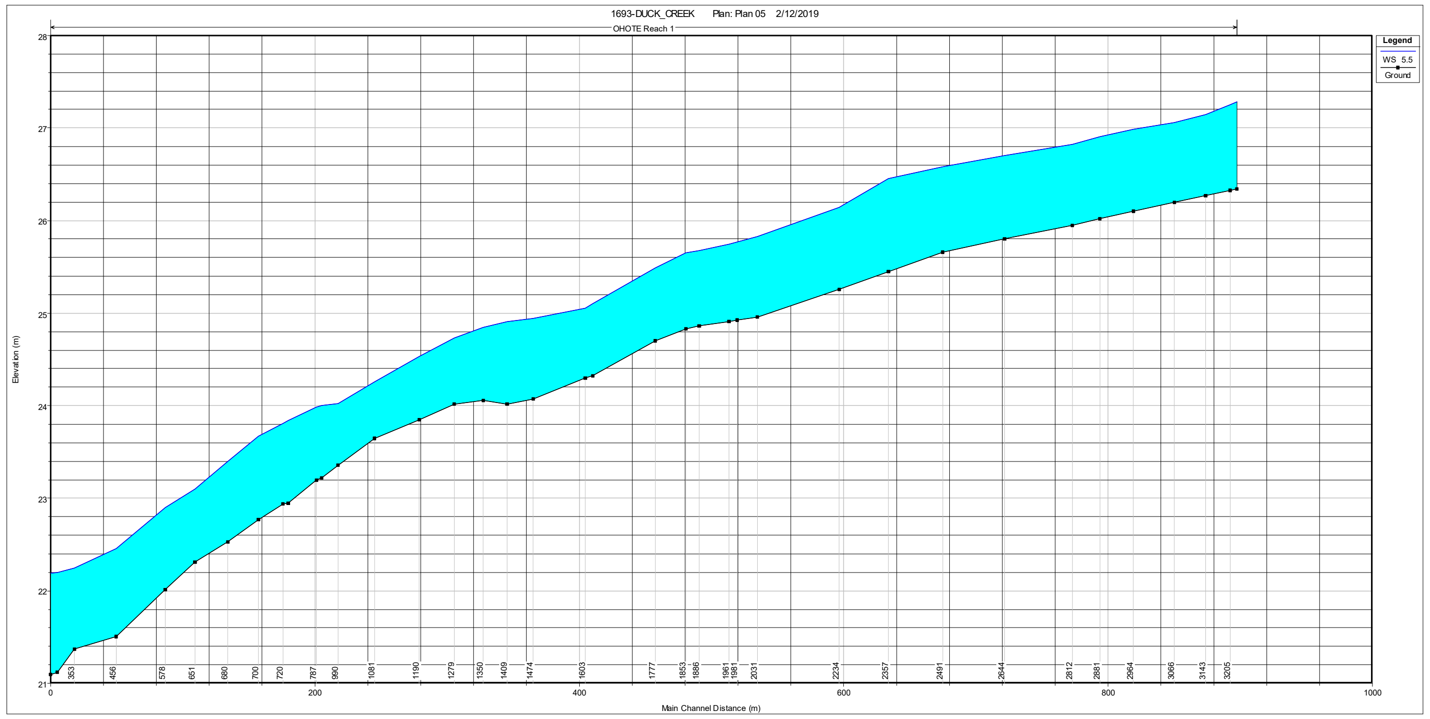


FROUDE NUMBER PROFILE

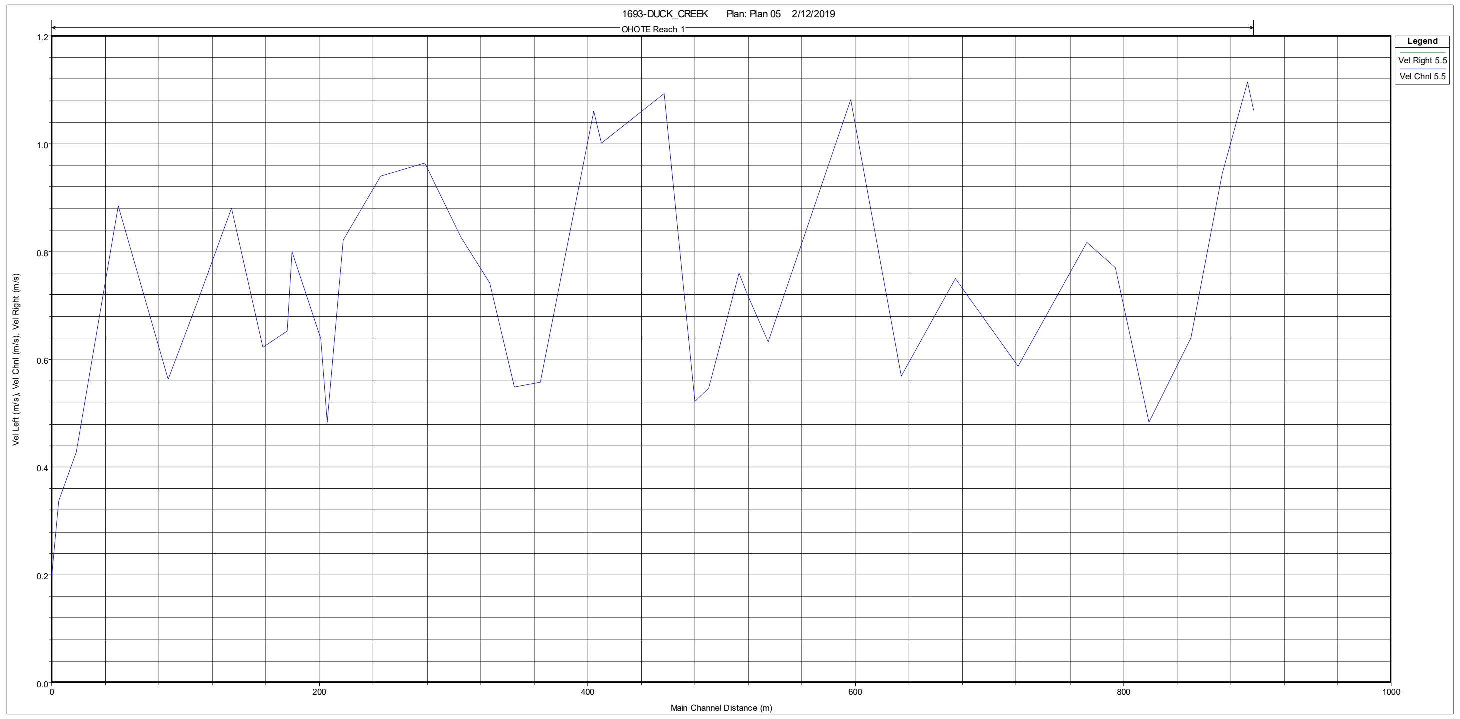


UPPER CASE (5.5 m³/s)

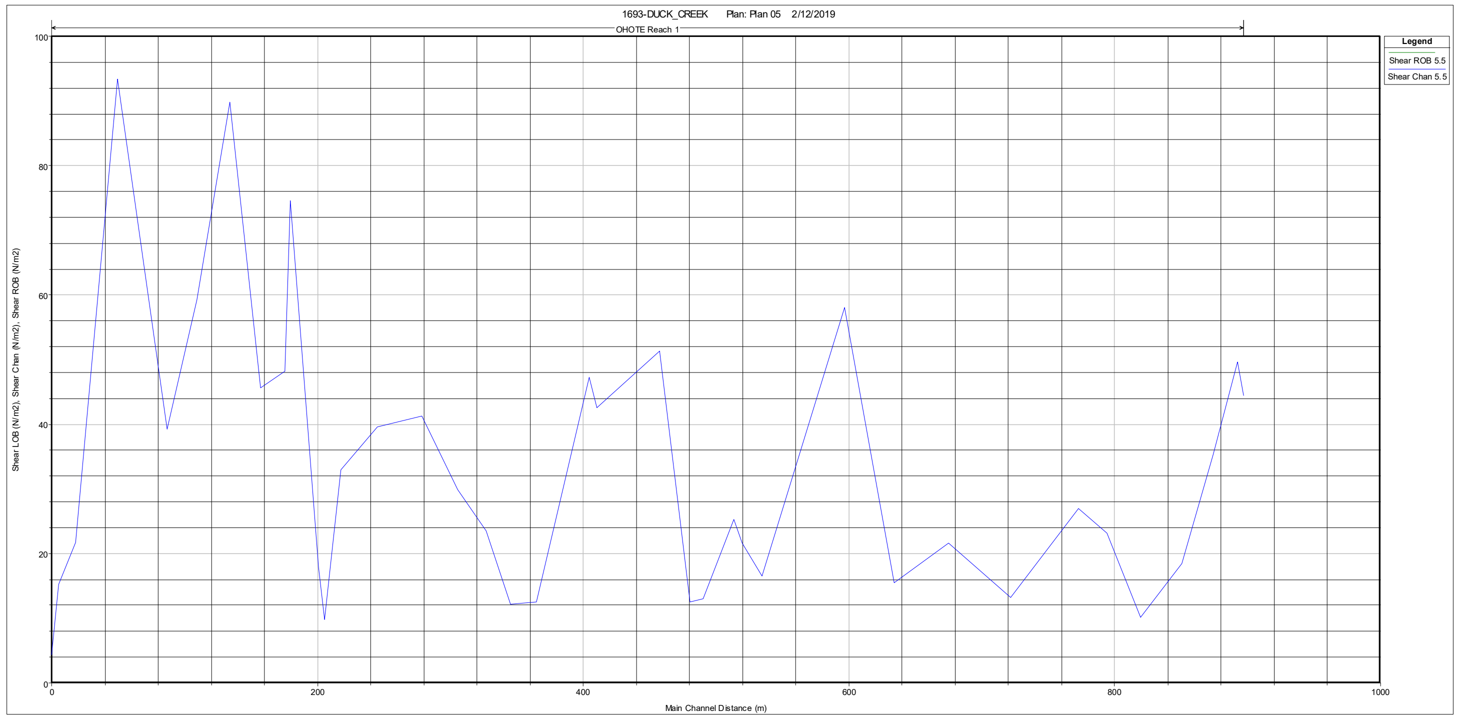
WATER SURFACE PROFILE



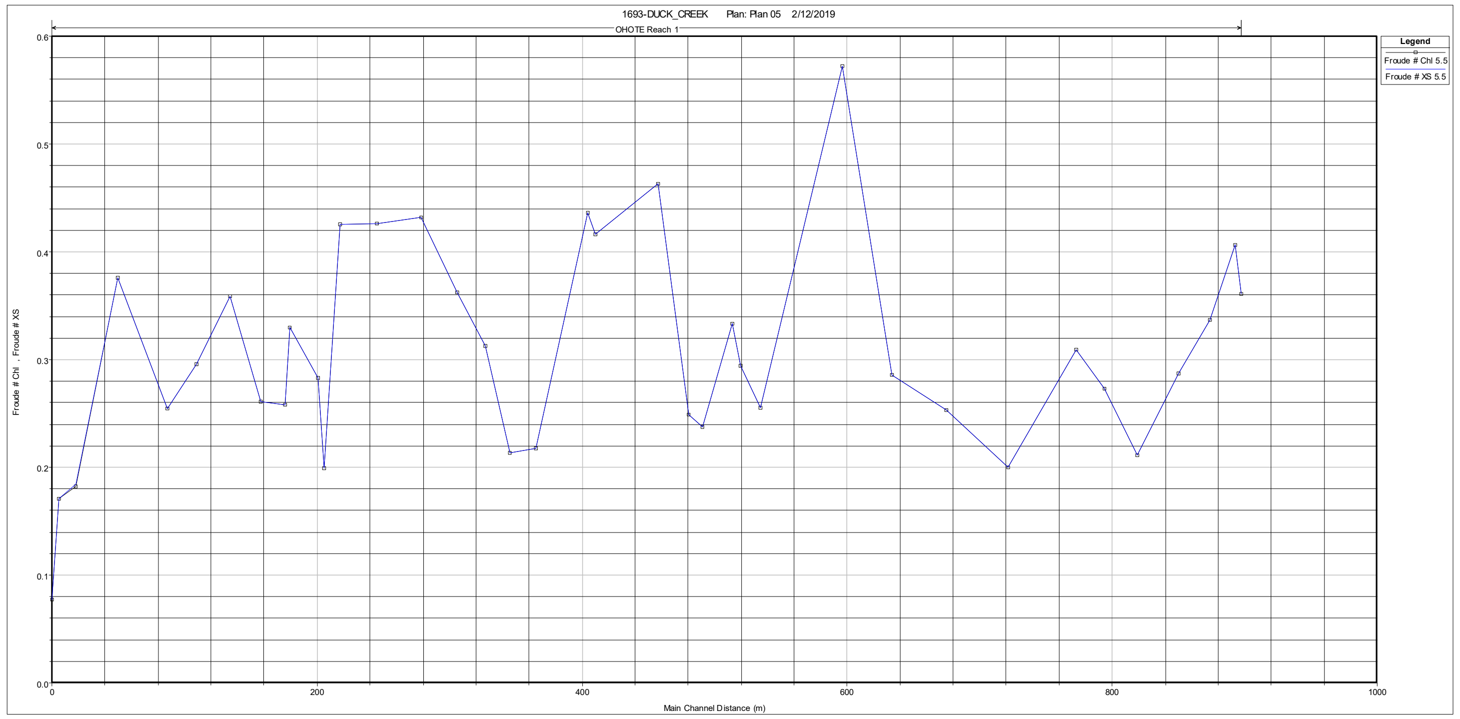
VELOCITY PROFILE

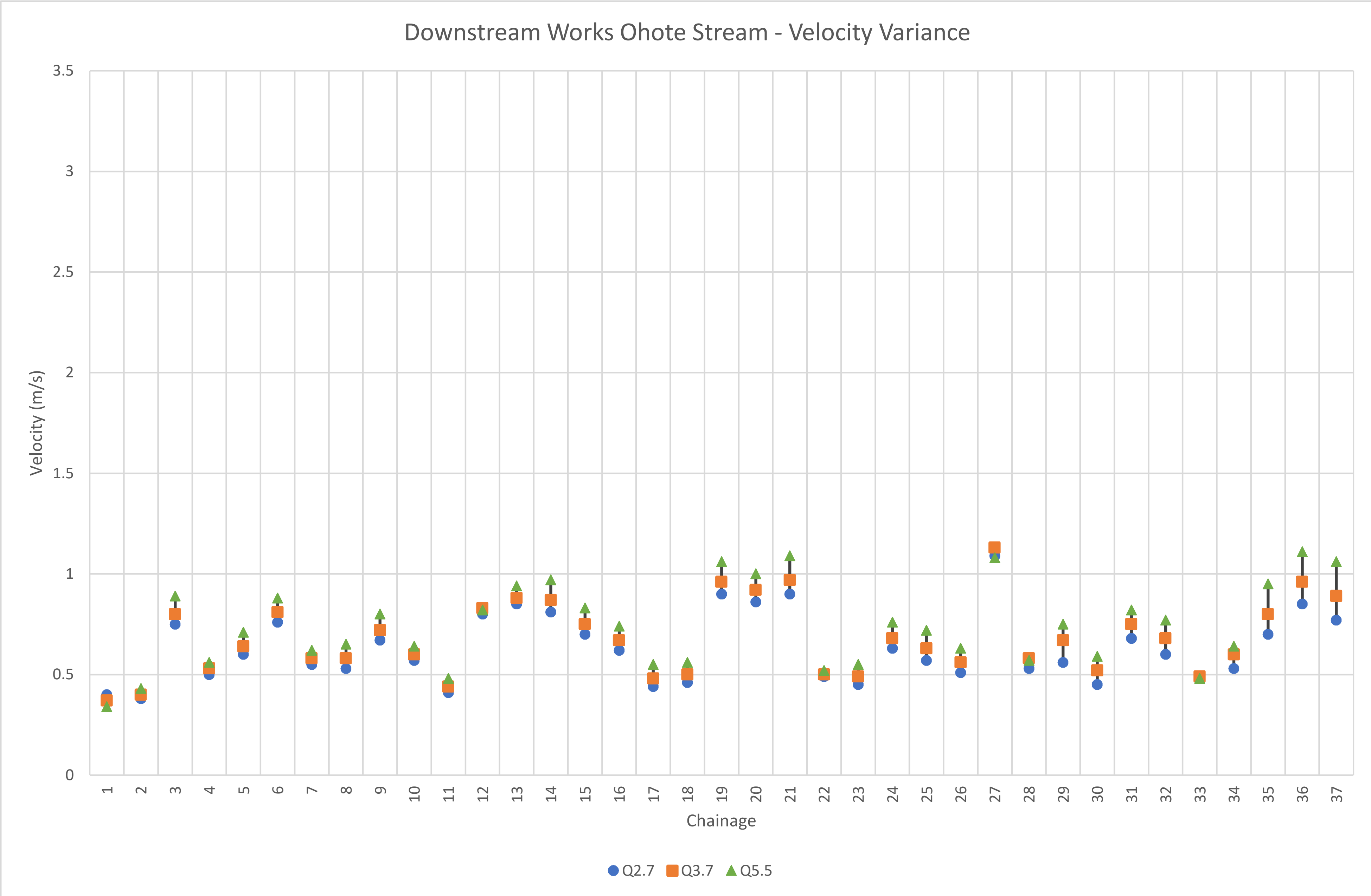


SHEAR STRESS PROFILE

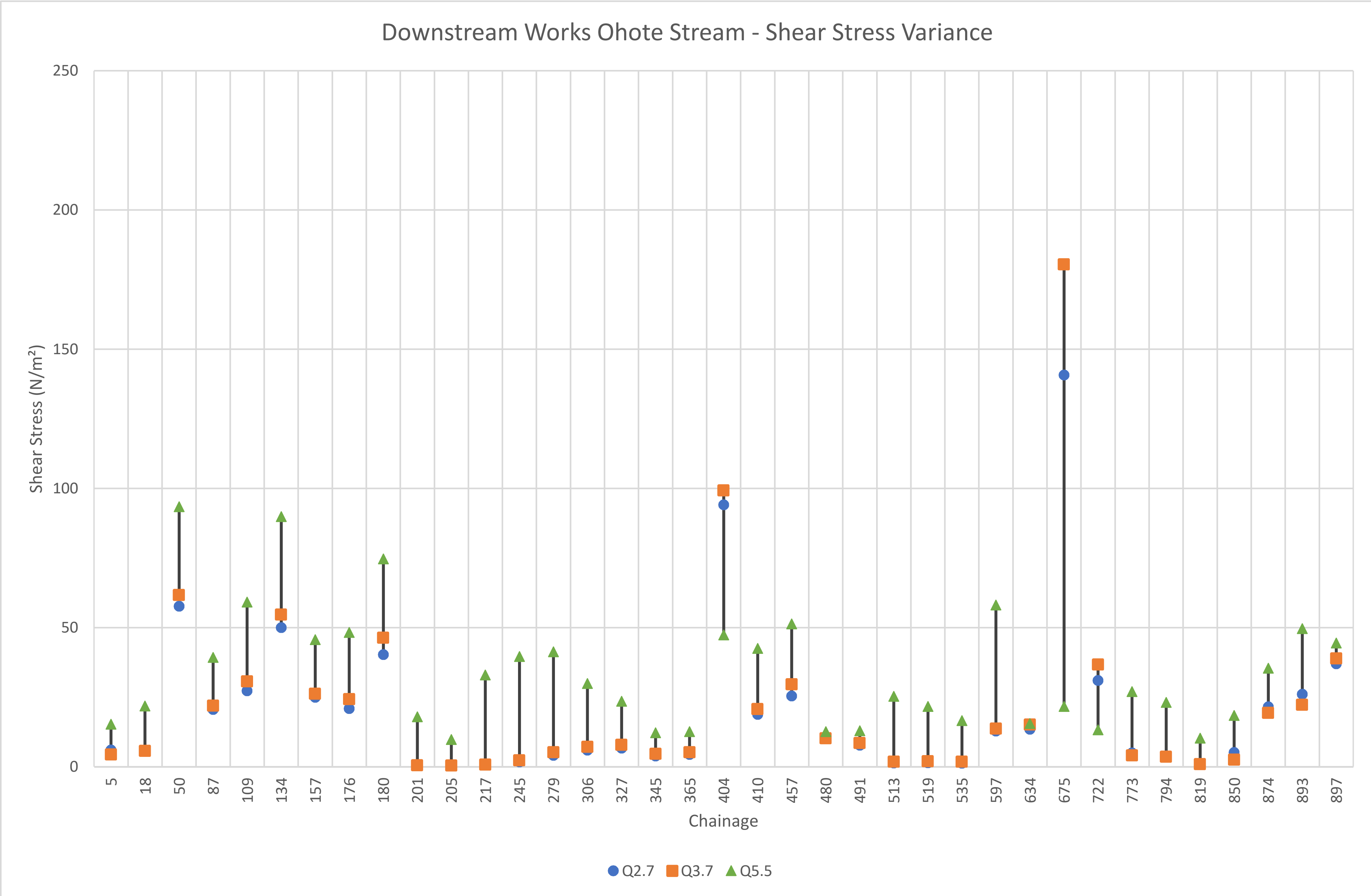


FROUDE NUMBER PROFILE

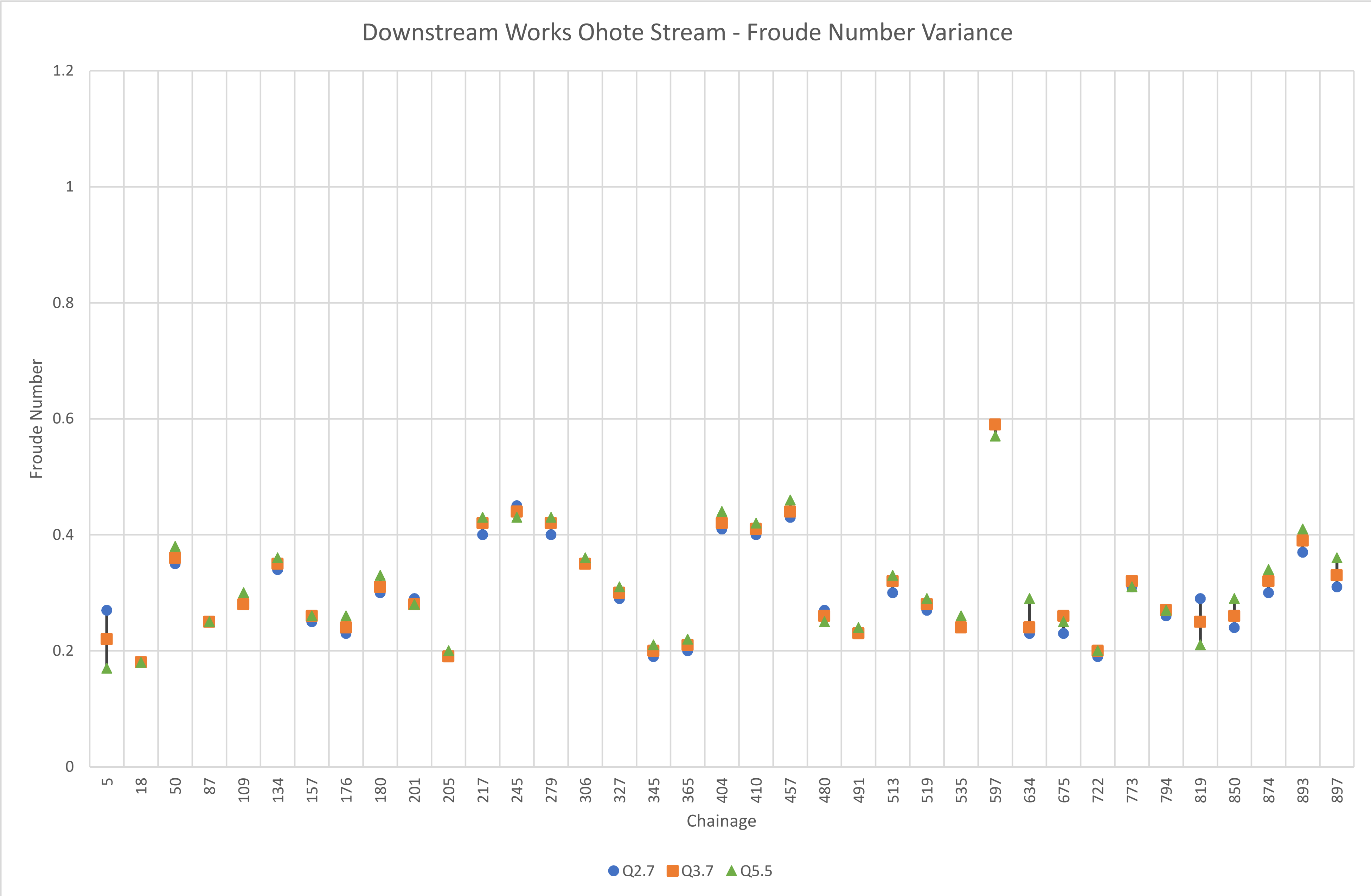


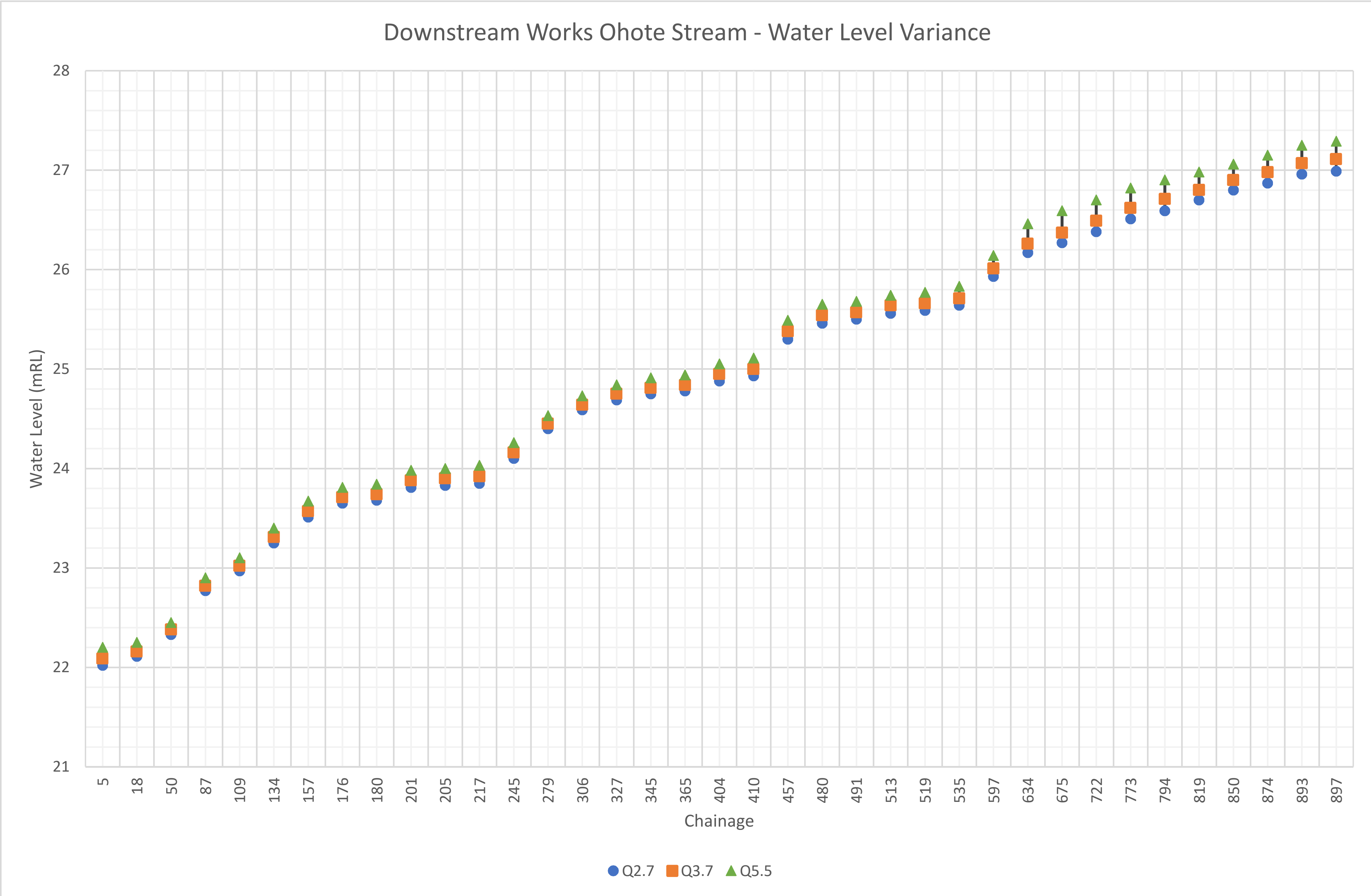


Downstream Works Ohote Stream - Velocity Variance
Velocity (m/s)
3.5
3
2.5
2
1.5
1
0.5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37
Chainage
Q2.7
Q3.7
Q5.5



Downstream Works Ohote Stream - Shear Stress Variance
Shear Stress (N/m²)
250
200
150
100
50
0
5
18
50
87
109
134
157
176
180
201
205
217
245
279
306
327
345
365
404
410
457
480
491
513
519
535
597
634
675
722
773
794
819
850
874
893
897
Chainage
Q2.7
Q3.7
Q5.5


Downstream Works Ohote Stream - Froude Number Variance
Froude Number
1.2
1
0.8
0.6
0.4
0.2
0
5
18
50
87
109
134
157
176
180
201
205
217
245
279
306
327
345
365
404
410
457
480
491
513
519
535
597
634
675
722
773
794
819
850
874
893
897
Chainage
Q2.7
Q3.7
Q5.5



Downstream Works Ohote Stream - Water Level Variance
Water Level (mRL)
28
27
26
25
24
23
22
21
5
18
50
87
109
134
157
176
180
201
205
217
245
279
306
327
345
365
404
410
457
480
491
513
519
535
597
634
675
722
773
794
819
850
874
893
897
Chainage
Q2.7
Q3.7
Q5.5