SYDNEY WATER PLANNING PARTNER
Level 5, 116 Military Road
Neutral Bay, NSW 2089

TECHNICAL MEMORANDUM

To	Emma James	From	Amelia Basson, Eli Tavakol
Copy	Tashya Miranda, Galilee Semblante, Sally Spedding, Viji Augustus	Reference	505018
Date	24/05/2021	Pages (including this page)	47
Subject	Picton WRP LVA – Hydrological Impact Study (Final)		

1 Introduction

1.1 Project Background

Sydney Water is developing a strategy to expand the Picton Wastewater Scheme to service new connections and growth in the area.

The existing recycled water management system includes recycled water storage, irrigation at Picton Farm and precautionary discharges to Stonequarry Creek. Picton Water Recycling Plant (WRP) currently has an average dry weather flow (ADWF) treatment capacity of 4 ML/d (secondary and tertiary treatment trains).

Recycled water is used to irrigate up to 119 hectares of pastureland at Picton Farm. Precautionary discharges occur when excess recycled water is discharged to Stonequarry Creek via the Western Dam in accordance with flow and volume limits in EPL 10555 (known as the precautionary discharge rules). Discharges follow a drainage channel, which flows to Stonequarry Creek at a location about 1.5km upstream of the Nepean River.

Increased development in the area has led to a significant rise in wastewater coming into the Picton Water Recycling Plant. This additional wastewater means the options to use or release the water once it's treated are at capacity, that is, the farm is unable to use any more water and the conditions of Sydney Water Environmental Protection Licence prevent discharging more treated water (Sydney Water, 2020).

Aurecon and Arup have been engaged by Sydney Water, through the Planning Partnership, to assess the potential hydrological impacts associated with the scenarios currently proposed. A Hydrology report for the Picton WRP Review of Environmental Factors (REF) was previously completed in November 2020 (Aurecon Arup, 2020). Information relating to the description of the existing environment (including catchment, available flow monitoring data, fluvial geomorphology and land use) has been detailed in that report.

1.2 Project Setting and Assessment Locations

Flow and water quality modelling for Stonequarry Creek in the broader Nepean River catchment has been undertaken. The model was developed using the eWater Source software and was calibrated to observed data, prior to being used to model potential future scenarios, as documented in *Picton Addendum Modelling Report, Stonequarry Creek and Nepean River – Flow and Water Quality* (Sydney Water and Alluvium, 2021).

Simulated flow data for locations up and downstream of the discharge point, as generated by the model, have been used to inform the hydrological assessment. These locations are shown in Figure 1 and additional metadata for each location provided in Table 1.

Figure 1 Locations of the modelled flow

Table 1 Modelled flow locations

Location ID	Description	Catchment area (ha)	Data period assessed
N911B	Stonequarry (SQ) Creek directly upstream of the discharge location	9,560	2010-2018
N911	Stonequarry (SQ) Creek downstream of the discharge location (SWC Gauge location)	9,600	
N91	Nepean River downstream of Stonequarry Creek	27,080	

1.3 Scenarios

Five scenarios have been assessed; these are detailed in Table 3. Scenarios C1, C2 and C3 are the three future scenarios which are currently being considered and have been compared, from a hydrological perspective, to provide recommendations as to which discharge regime will result in the least impact on the existing downstream environment. Additional details pertaining to each of the scenarios are included in Table 2 and Table 3 with further information provided in the *Picton Addendum Modelling Report* (Sydney Water and Alluvium, 2021).

Table 2 Description of model scenarios

<table>
<tr><th colspan="2">Scenario name & rationale</th><th>Scenario description</th></tr>
<tr><td colspan="2">Scenario A
‘existing’ baseline</td><td>The ‘existing’ baseline (Scenario A) is the calibration model that uses 2.7 ML/d for the dry weather inflow to the Picton WRP. The calibrated model aimed to reflect the inflows, dam levels, reuse and discharge observed for the period 2014 – 2020 which also corresponds to the period that has regular water quality data available in the receiving waterways. Refer to Part A Waterway Assessment of existing conditions (Sydney Water, 2021).</td></tr>
<tr><td colspan="2">Scenario B
‘EPL compliant’ baseline</td><td>‘EPL compliant’ baseline has lower inflow than the ‘current / existing baseline’.
‘EPL compliant’ baseline aims to represent the period prior to discharges from the Picton WRP that breach the requirements of the current EPL (discharge in lower creek flow conditions under an ‘Emergency Operating Protocol’ – EOP). In the modelled timeseries there are some extreme conditions that result in 5% of the time where discharge occurs despite the significantly reduced inflow. Inflow of 2.25 ML/d occurred around the period 2010 – 2014 and did not result in discharge beyond the EPL conditions.</td></tr>
<tr><td colspan="2">C Scenarios</td><td>Future scenarios (for the short to medium term) which consider 4 ML/d inflow. These are the focus of this report and for the Review of Environmental Factors and Licence Variation Application. This is the expected inflow to the Picton WRP in the period from 2024 – 2028 subject to development connections and water usage / volumes discharged to the sewer.</td></tr>
<tr><td rowspan="3">Future Scenarios</td><td>Scenario C1
‘EOP like’</td><td>Similar operational rules to the current Emergency Operating Protocol with discharge from the Western Dam when water levels are too high. Discharge rules: ‘Precautionary’ (up to 25% of the Creek flow when over 8 ML/d) plus ‘EOP’ (3 ML/d when the Creek flow exceeds 3 ML/d, ‘100%’), with additional infrequent excess at higher dam levels to prevent overtopping the dams.</td></tr>
<tr><td>Scenario C2
‘less frequent’</td><td>‘Storm’ discharge only in higher creek flows (above 5 ML/d) as much as possible but limited to 200% of the creek flow (10 ML/d discharge when creek flows at 5 ML/d). Some infrequent discharge at higher dam levels to prevent overtopping the dams.</td></tr>
<tr><td>Scenario C3
‘less proportion of SQ flows’</td><td>‘Regular’ discharge across almost all creek flow categories (except the lowest creek flows less than 0.5 ML/d). Discharge rule for up to 50% of the creek flow when creek flows are above 0.5 ML/d). Some infrequent discharge at higher dam levels to prevent overtopping the dams.</td></tr>
</table>

The source model uses time series climate data from 2010 to 2018 to represent a wide range of wet and dry weather conditions. The statistics in Table 3 refer to average discharge volumes over this 9-year period. Some years have higher or lower discharge rates than the average due to variation in inflow, irrigation demands, and creek flow conditions that allow for discharge.

Table 3 Discharge scenarios

Metric	Units	Scenario A Existing	Scenario B Compliant	Scenario C1 'EOP-like'	Scenario C2 Less frequent	Scenario C3 Less proportion of SQ flows
Inflow to WRP	ML/d	2.7	2.25	4	4	4
Storm discharges		25% at 8 ML/D	25% at 8 MLD	25% at 8 ML/D	200% at 5 ML/D	50% at 5 ML/D
'Excess' discharges		100% at 2.5 ML/D	NIL	100% at 3 ML/D	NIL	50% at 0.5 M/LD
Total discharge to SQ	ML/yr ML/d	451 1.2	395 1.1	915 2.5	932 2.6	926 2.5
Annual discharge frequency	% of time	42%	30%	70%	50%	87%
'Excess' discharge	ML/yr	96	0	172	0	132
Spill prevention discharge*	ML/yr	40	13	119	79	60
*Preventative discharges taking place outside stated discharge operating rules (i.e. below lowest indicated allowable limit for storm or 'excess' discharging)						

1.4 Assessment Methodology

The hydrological impact assessment work conducted to support the *Review of Environmental Factors (REF) for the Picton WRP license variation application* (Aurecon Arup, 2020), has been further refined and targeted to assess the current proposed discharge scenarios, as documented in this memorandum. This assessment evaluated expected changes to the following key hydrological characteristics and metrics:

1. Flow durations / exceedances (described in Section 1.4.1)
2. Basic Urban Streamflow Impact Assessment (USIA) metrics (described in Section 1.4.2)
3. Ecological threshold exceedances (described in Section 1.4.3)

Metrics 1 and 2 were assessed by considering the proportional changes due to the proposed activity (i.e. increase in discharge of recycle water). The following generic impact classes have been defined based on the percentage of change from the compliant discharge condition (Scenario B) and the corresponding risk of changes to typical urban hydrological metrics:

- Low risk: <20% change
- Moderate risk: 20-50% change
- High risk: >50% change

These risk ratings have been applied to identify features, time periods or conditions at greater risk of being adversely affected. However, the additional works completed, identifying the local specific ecological threshold values (as indicated below), brings additional relevant focus to the assessment.

Assessment of the third metric (3. Ecological threshold exceedances) was informed by in-field survey works completed to identifying the local relevant ecological threshold values (as described in the *Assessment of Potential Hydraulic Driven Impacts to Ecological Values of Stonequarry Creek* (CTEnvironmental, 2021)). The assessment compared the modelling results to the identified ecologically driven threshold values to predict the change in impact to the waterway ecological values for each of the proposed future scenarios.

1.4.1 Stonequarry Creek flow categories

To assess impacts within various flow categories, daily flow values were grouped based on pre-selected flowrate thresholds. These thresholds were informed by step-changes in the discharge operating rules associated with the proposed scenarios.

The categories, their associated ranges, the probability of exceedance (PoE) associated with the modelled time period as well as the stated operating rules for each scenario are indicated in Table 4. Instances where “Spill prevention discharge” is indicated refers to emergency discharge conditions, required when the dam storage facilities have exceeded their normal operating levels and discharge is required to prevent a spill. Where a range is indicated, i.e. 25-100% of Creek flow, the lower value refers to normal operation whereas the upper value refers to the discharge rate under emergency conditions (EOP).

These complex configurations are required for a treatment plant without a constant discharge or licenced bypass in wet weather. Extreme inflows present a complex challenge for the operation of the plant (and representation in a computer model). Equally the extremes with reuse can result in extended periods with no discharge to waterways from the treatment plant.

Table 4 Probability of daily flow within stated bracket

Category	Flow bracket lower bound (ML/d)	No discharge PoE on lower bound	Flow bracket upper bound (ML/d)	Scenario A	Scenario B	Scenario C1	Scenario C2	Scenario C3
Very low	0	100%	0.5	EOP + Spill prevention discharge	Spill prevention discharge	Spill prevention discharge	Spill prevention discharge	Spill prevention discharge
Low	0.5	75%	3	EOP + Spill prevention discharge	Spill prevention discharge	Spill prevention discharge	Spill prevention discharge	50% of Creek flow (only EOP)
Medium	3	45%	5	EOP + Spill prevention discharge	Spill prevention discharge	100% of Creek flow (only EOP)	Spill prevention discharge	50% of Creek flow (only EOP)
High	5	35%	8	EOP + Spill prevention discharge	Spill prevention discharge	25-100% of Creek flow	200% of Creek flow	50% of Creek flow
Very High	8	25%	∞	25-100% of Creek flow	25% of Creek flow	25-100% of Creek flow	200% of Creek flow	50% of Creek flow

Year-on-year the flow in Stonequarry Creek varies significantly and thus, on an annual basis, the portion of time spent within any of these categories also varies as indicated in Figure 2, for the 9 modelled years. This variance influences the volume of water that can be released in specific flow categories as well as the probability of compliant discharge being feasible or an emergency discharge needing to take place.

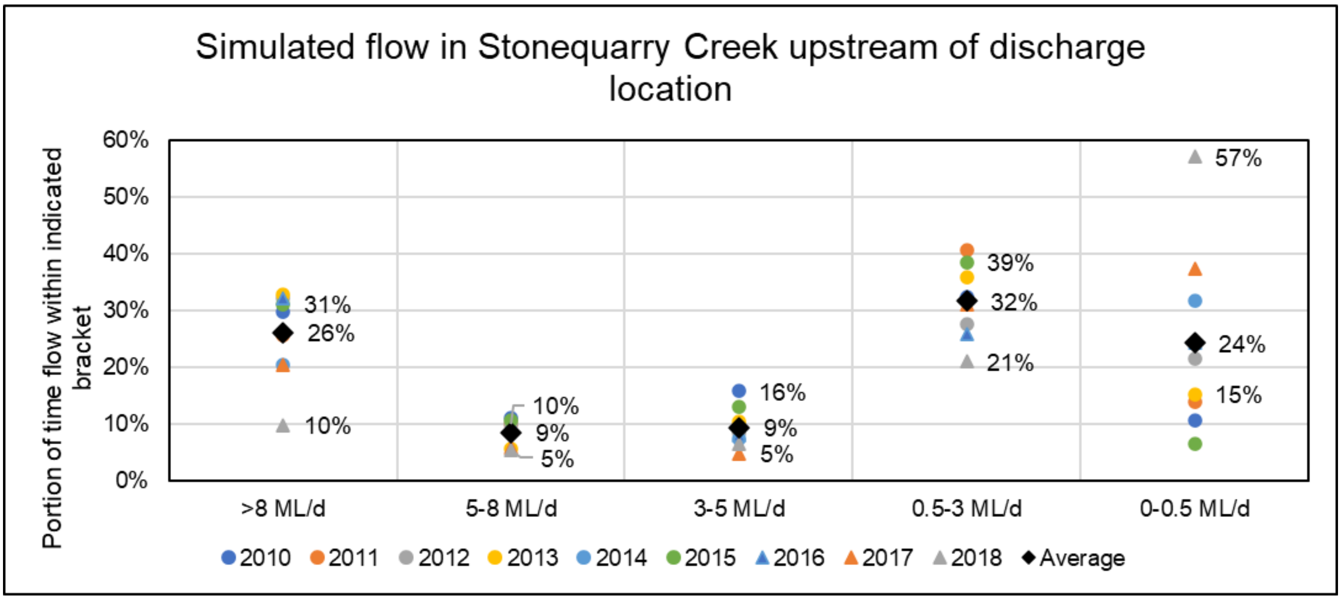

Figure 2 Portion of time within indicated flow category

As per the Picton Addendum Modelling Report (Sydney Water and Alluvium, 2021), model calibration for flows below 0.5 ML/d was less accurate due to gauge limitations, model structure limitations and complexity of groundwater interactions. Simulated flows below 0.5 ML/d (and particularly below 0,2 ML/d) should be considered carefully, mindful of the potential for flows to be underestimated (and likely over estimation of concentration impacts from the WRP).

1.4.2 USIA

To inform the waterway health assessment several of the hydrologic metrics relevant to urban settings as recommended in the *Stormwater and Outflow Planning Controls for Waterway Health: Applying the Urban Streamflow Impact Assessment* (USIA) (Streamology *et al*., 2019) were considered, these included:

- USIA1 Mean annual flow volume
- USIA2 Mean duration of zero flow periods (average over all zero flow events) *
- USIA3 Total duration of zero flow periods (as a portion of the total flow period assessed) *
- USIA4 Baseflow index (ratio of baseflow to total flow volume) (flows < top 20th percentile) **

* Zero flows have been classified as any average daily flow rates less than 0.005 ML/d

** The USIA4 metric (Baseflow index) was replaced with a more comprehensive analysis, the Lyne and Hollick (1979) method, as described in the REF report (Aurecon Arup, 2020).

1.4.3 Ecological threshold exceedances

Hydrologic changes become important when they impact the local aquatic ecology and biodiversity. A valuable component when assessing impacts, is identifying value thresholds and being able to tie them back to a probability of any proposed changes disrupting the existing environment.

Subsequent to the *publishing of the REF report (Aurecon Arup, 2020)* a more detailed ecological assessment of the Stonequarry Creek and Nepean River sites was conducted (CTEnvironmental, 2021). This assessment defined specifically applicable thresholds for parameters/metrics where supporting information is available or a generic trigger value has been identified. These indicators and the threshold values linked to hydrologic changes are listed in Table 5.

Several sediment samples were collected to allow erosion risk to be quantified. Threshold flows could result in bed and bank erosion occurring. Sediment samples comprised mainly of clay (43%) and silt (40%), with gravel (10%) and sand (7%) accounting for the remainder. Using the Hjulström curve the range of minimum velocity rates that could lead to erosive conditions were determined.

Table 5 Indicators and threshold values

Indicator	Biodiversity affected	Threatened Species	Threshold values
Maximum flow velocities	Native fish, e.g. < 1-2 m/s for Bass migration Platypus Water & riparian birds Other, e.g. ~0.2 m/s sand & silt mobilisation, ~0.4 m/s clay, organic detritus and macroinvertebrate mobilisation	Macquarie Perch, burst swimming speed is > 0.8 m/s for adults, < 0.2 m/s for juveniles	0.2 m/s 0.4 m/s 0.8 m/s 1.0 m/s Erosion: 0.2-1.0 m/s
Pool depths & permanency	Native fish Platypus, forage in pools < 5 m deep Water & riparian birds	Macquarie Perch and Sydney Hawk Dragonfly, prefer slow-flowing pools	Minimal change to slow flowing pools 5 m

Representative sensitive reaches and waterway features were identified (see Section 2.1.5), and high-resolution bathymetry and bank elevation profile data was collected. These datasets were amalgamated with the lower resolution digital elevation models (DEM) available for the area, to generate a terrain profile to be used for hydraulic modelling purposes (patched DEM indicated in Figure 3).

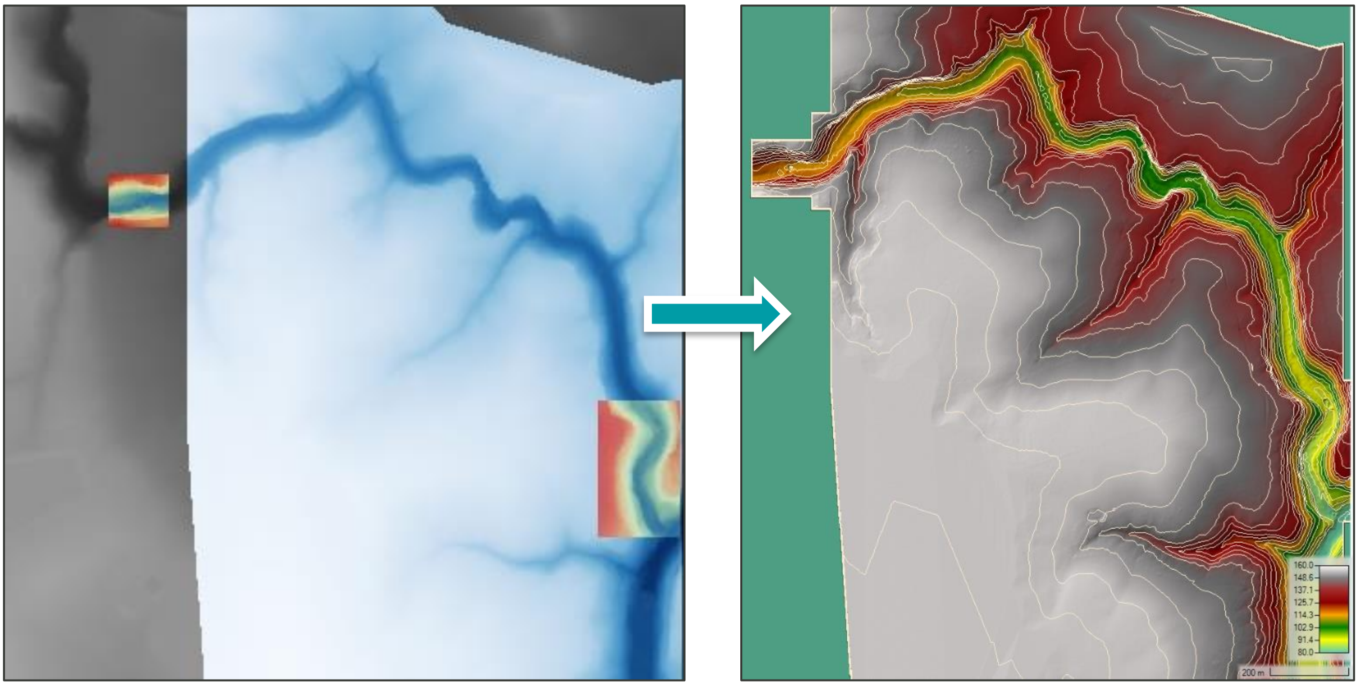

Figure 3 Amalgamated digital elevation model (DEM)

Three independent hydraulic models were then developed for the three reaches using the US Army Corps of Engineers' Hydrologic Engineering Center River Analysis System (HEC-RAS) (version 6.0). Universal roughness coefficients (Manning's "n") values were applied, 0.06 in-channel and 0.1 for the overbank areas (Chow, 1959). The flowrate time series datasets for each of the scenarios were then applied to these reaches using the 1-D unsteady modelling method, and the results for key identified cross-sections were evaluated.

Sensitivity analyses were conducted to assess the impact on outcomes for lower roughness coefficients (down to 0.04 in-channel) as well as several other parameters with varying degrees of uncertainty associated (i.e. upstream and downstream energy gradients). The variation in the results (when testing input values within the likely range) was less than 10% with insignificant impact on the resultant comparative changes between the scenarios.

2 Impact Assessment

2.1 Stonequarry Creek

2.1.1 Volume of discharge

The modelled annual average discharge rates for each scenario, grouped based on the upstream flowrate categories (as listed in Table 4), are indicated in Figure 4.

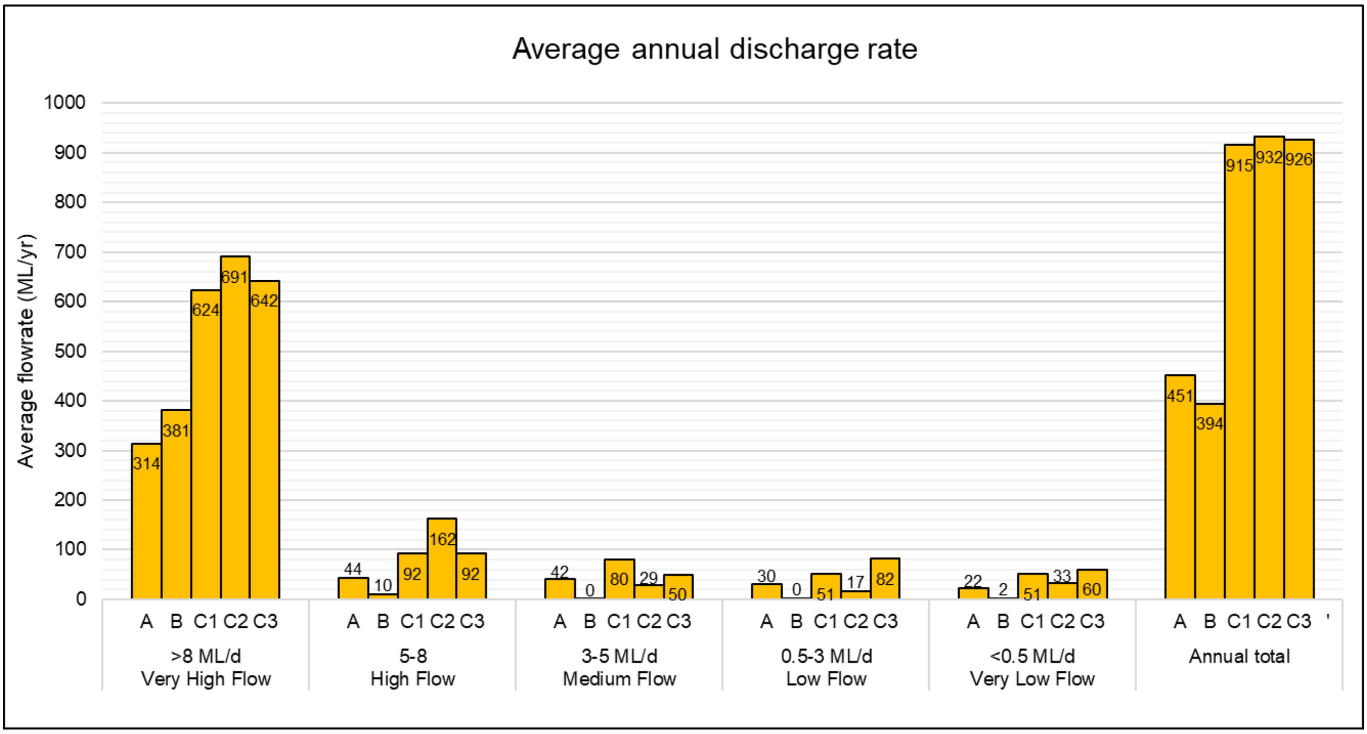

Figure 4 Portion of time within indicated flow category

The annual total volumes indicate the significant shift in total discharge associated with the future scenarios, and the bulk of this occurring during “Very high flow” conditions. Scenario C2 indicates a greater increase for very high and high flow conditions and less of a change for flows below 5 ML/d (medium, low and very low) when compared to C1 and C3.

The total annual discharge rates are compared to the upstream flow rates (over the same modelled period) in Table 6. Even though the median flow rates in Stonequarry over this modelled period is 2.2 ML/d, the average flow rate is significantly higher due to infrequent high flows and flooding events. The comparative total discharge rates are all below 20% of the upstream flow.

Table 6 Total discharge rates versus upstream flow rates

Metric	Scenario A	Scenario B	Scenario C1	Scenario C2	Scenario C3
Average flow in SQ upstream of the discharge location (ML/yr) / (ML/d)	4,849 / 13.3				
Total average discharge to SQ (ML/yr) / (ML/d)	451 / 1.2	395 / 1.1	915 / 2.5	932 / 2.6	926 / 2.5

2.1.2 Discharge as a proportion of creek flows

The **proportion of discharge relative to the upstream flow in Stonequarry Creek** at a point downstream of the discharge location was calculated for each of the scenarios and split into the five indicated flow categories (based on the upstream flowrates) as shown in Figure 5. I.e an indicated 80% blue vs 20% yellow split, could represent 8 ML/d entering from upstream and 2 ML/d added as WRP discharge. The very low flow category is shaded, as modelled flows within this range are less reliable.

Elevated water quality concentrations and greater exceedance of guideline values occurs as the proportion of discharge increases, particularly in the lower flow categories (Part A report, Sydney Water 2021).

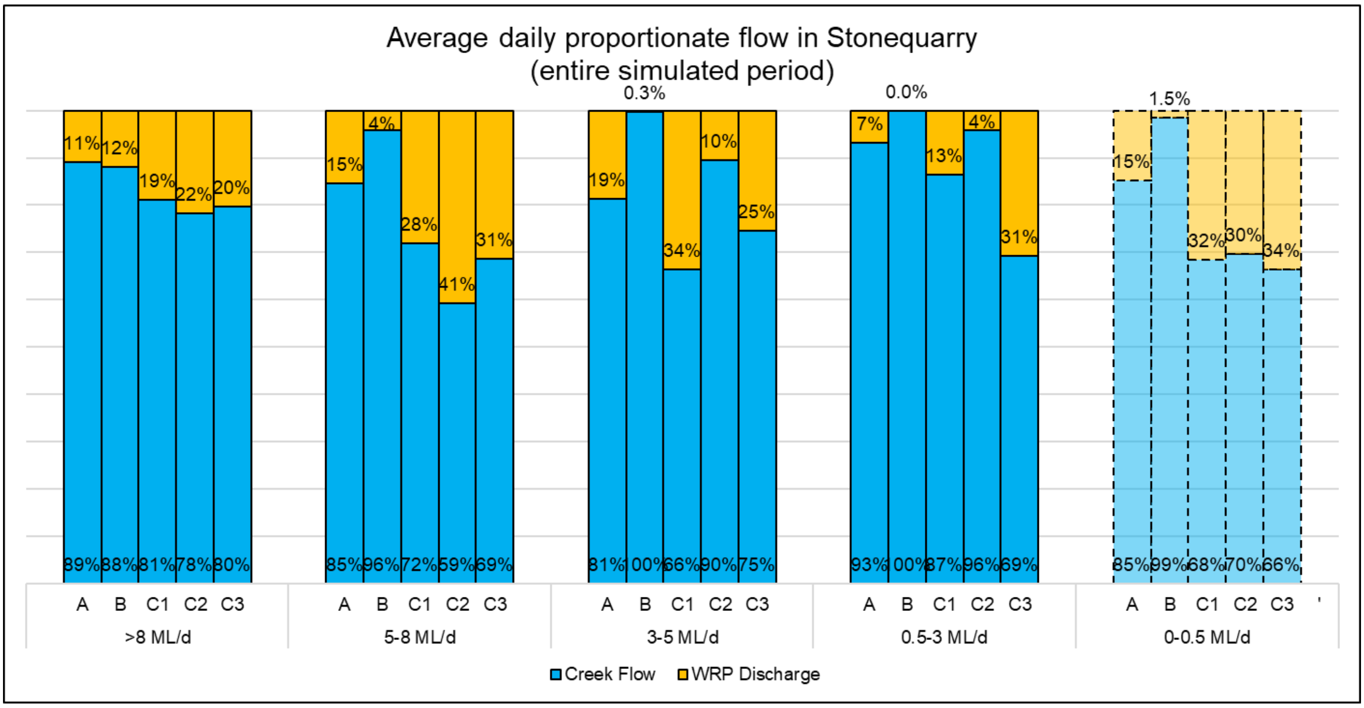

Figure 5 Average daily proportionate flow in Stonequarry Creek (entire simulated record)

From the graph the following interpretations can be made:

- As expected, Scenario B (the compliant scenario) results in the lowest proportionate discharge flows for all conditions except the very high flow category, where Scenario A has a marginally lower discharge proportion. This is due to more discharge taking place sooner, at lower flows, in Scenario A and subsequently ceasing to discharge due to a lack of supply, even though high flow rates in Stonequarry are still occurring.
- When comparing Scenarios C1, C2 and C3 (which are associated with the higher plant inflows of 4ML/ day):
  - All three scenarios perform similarly during very low flow conditions, approximately 70:30 split in contributing flows, and during very high flow conditions, a 80:20 split.
  - During medium (3 - 5ML/ d) and low flow conditions (0.5 - 3ML/ d), the discharge rules for Scenario C2 result in a lower proportion of discharge relative to creek flow than C1 and C3 with discharge flows contributing 10% and 4% respectively of the downstream flow. Scenario C1 has a smaller contribution compared to C3 during lows, and the reverse is true during medium flow conditions
  - During high flow conditions (5 – 8 ML/d), C2 is the least preferable scenario, with a 41% portion of the downstream flow originating from the plant discharge. Whereas C1 and C3 are again similar in contributing portions.

- Scenario C2 is also preferable to Scenario A (the current discharge regime) during medium and low flows (or approximately 40% of the time)
- Scenario C2 has a higher proportion of the flow originating as discharge during high and very high flows compared to all other scenarios.

The results shown in Figure 6 only consider **the days when discharge is occurring**. The ratios associated with all scenarios and under all conditions are thus equal to or worse than that presented in Figure 5. The frequency (days/yr) of the discharges for each condition and scenario is also indicated at the top of each column, i.e. for the first column on the left of the graph (Scenario A, on days when discharge occurs while the upstream creek flowrate is above 8 ML/d):

- Discharge is 12% of the total creek flow downstream of the discharge (average for discharge days in very high flows)
- There are on average 82 days per year when discharge would occur in these flow conditions for this scenario

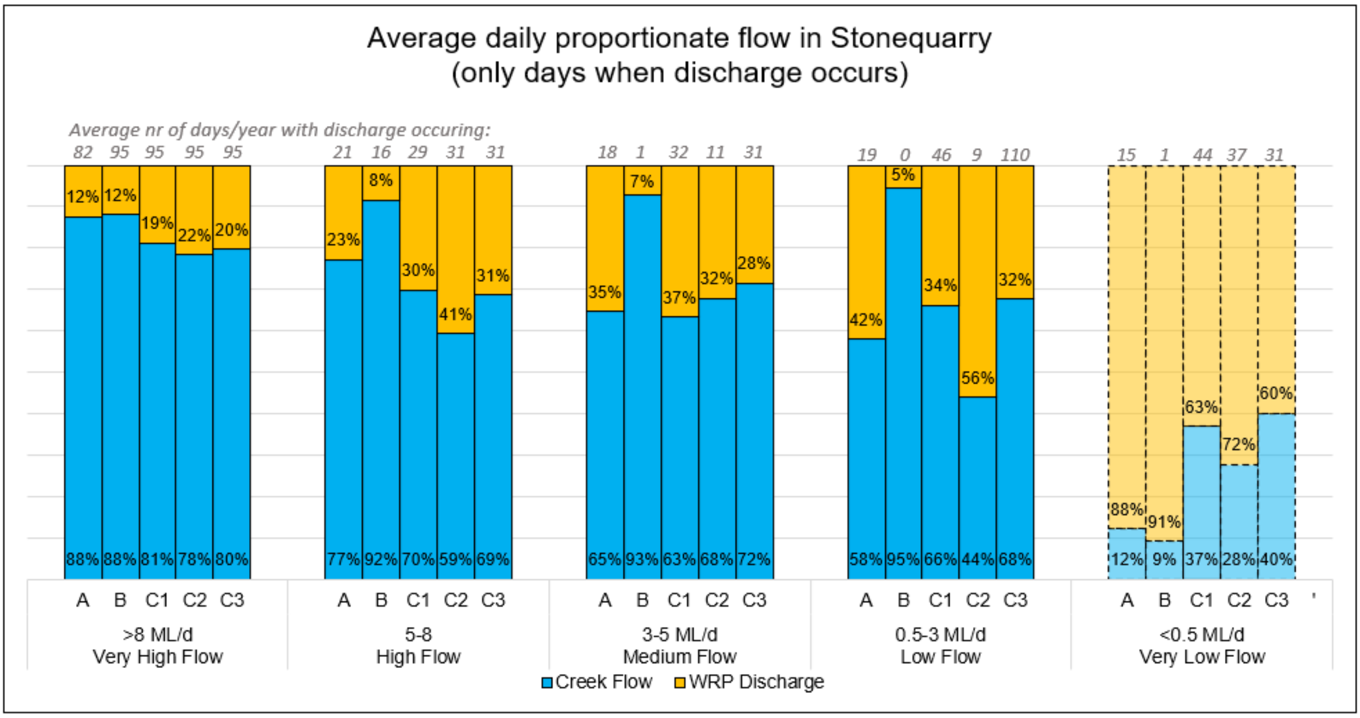

Figure 6 Average daily proportionate flow in Stonequarry Creek (only discharge days)

**Figure note: Direct comparisons of the datasets should be avoided, without taking all factors into account, such as frequency of occurrence*

From the graph the following interpretations can be made:

- As expected, Scenario B (the compliant scenario) still results in the lowest proportionate discharge flows for all conditions, other than the very low flow conditions. However, when considering the frequency of discharge during these conditions, i.e. average of 1 day a year, the probable impact can be reduced to negligible.
- Scenario A (the 'existing' scenario) shows discharge frequencies of between 15 and 21 days per year for each of the lower flow categories (and 85 days per year for flows above 8 ML/d). This is a substantial increase compared to the compliant Scenario B which has 0-1 day per year discharge expected for the 3 lower flow categories. The impact of increased frequency of discharge has been considered in the Part A report (Sydney Water, 2021) evaluating the existing environment and impacts of discharge including EOP conditions in the period from 2014-2020.
- Scenarios C1, C2 and C3 generally perform similarly, with the exception of

- low flow conditions (0.5 – 3 ML/d) where C2 has a much larger proportion of the flow originating from discharge, however much less frequently (average 9 days per year, compared with 46 days per year for C1 and 110 days per year for C3 in this flow category)
- medium flow conditions (3 - 5 ML/d) where C2 has a similar proportion of the flow originating from discharge (range from 28%, 32%, 37% for C3, C2, C1), however less frequently for C2 (average 11 days per year, compared with 30-31 days per year for C1 and C3 in this flow category).

In general, when comparing the future proposed operating regimes to the compliant conditions (Scenario B), a far greater portion of the downstream flow would be originating from the plant. Scenario C2 results in more preferable conditions more of the time during medium and low flow conditions whereas C1 and C2 are preferable during high flow conditions (occurring on average 10% of the time).

2.1.3 Flow duration curves and key percentile flow values

The flow duration curves representing the flow regimes as simulated for site N911 (downstream of the WRP discharge point) for all five scenarios are indicated in Figure 7.

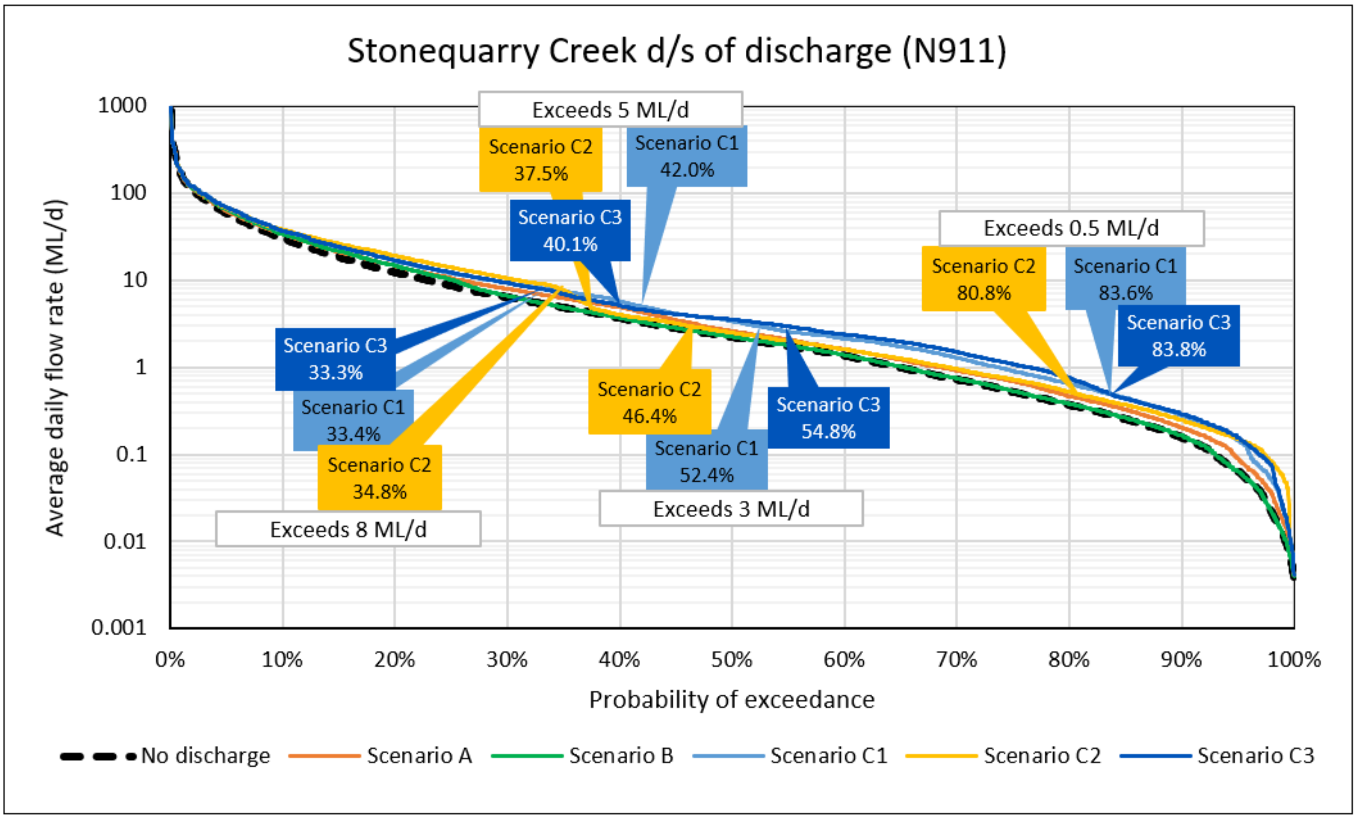

Figure 7 Stonequarry Creek downstream of the discharge location – Flow duration curves

The graph shows minimal divergence between the “No discharge” and Scenario B (compliant) flow regimes, especially in the low flow region. A more apparent divergence is observable when considering the current and proposed future discharge regimes. Scenarios C1 and C3 indicate higher divergence in the medium to low flow range, where-as Scenario C2 diverges more in the very low flow range (i.e. above 95% PoE).

The probability of exceedance values associated with each of the flow category thresholds and for each scenario are indicated in Table 7. Also indicated is the average number of additional days per year that these threshold will be exceeded, when comparing to Scenario B conditions.

Table 7 Impact on key flow thresholds – Stonequarry Creek

Category	Flow threshold (ML/D)	Upstream / No discharge	A	B	C1	C2	C3	C1	C2	C3
			Probability of Exceedance					Extra days / yr exceeding (on average)		
Very low*	*<0.5*	*24%*	*21%*	***24%***	*17%*	*19%*	*16%*	*-27*	*-17*	*-28*
Low	0.5	76%	79%	**76%**	84%	81%	84%	27	17	28
Medium	3	44%	47%	**44%**	52%	46%	55%	30	9	39
High	5	35%	40%	**35%**	42%	37%	40%	27	10	21
Very high	8	26%	30%	**27%**	33%	35%	33%	22	27	21

*Probability of non-exceedance of threshold value indicated to assess very low flow category and subsequently the number of days less per year that downstream flows will be below this threshold

The result colouring is indicative of potential risk, based on the proportionate change from the base case, as specified in Section 1.4.

There is almost no change in the distribution of flows across the flow categories for Scenario B relative to the upstream flows (only 1% higher probability of exceeding the 8 ML/d flow category).There are only small changes in the distribution of flows across the flow categories for existing Scenario A relative to Scenario B (PoE is 3 - 5% higher, increasing distribution to higher flow categories). The changes for the future scenarios are more pronounced with PoE 5 - 8% higher in the distribution at the lowest flow category, and 6-8% increase in the highest flow category.

In general, the analysis results indicate a low to medium risk level associated with impacting the creek, when comparing to the compliant conditions (Scenario B). The largest proportionate changes are associated with the very high flow conditions. The frequency of flows below the lowest threshold value (0.5 ML/d) is expected to decrease, more so for Scenario C1 and C3 than for Scenario C2.

2.1.4 USIA assessment

The principal USIA metrics have been determined for all scenarios and used as indicators for potential risk of degrading or losing creek value when comparing the future scenario values to the compliant condition values. These metrics are indicated in Table 8.

Table 8 USIA Metrics Comparison – Stonequarry Creek

Metric		Units	Upstream / No discharge	Scenario A	Scenario B	Scenario C1	Scenario C2	Scenario C3
USIA1	Mean Annual Flow Volume	ML/yr	4,848	5,299	**5,242**	5,763	5,779	5,774
		ML/d	13.3	14.5	**14.4**	15.8	15.8	15.8
USIA2	Mean duration of zero flow periods	days	None	None	**None**	None	None	None
USIA3	Percent duration of zero flow periods	%	0%	0%	**0%**	0%	0%	0%
USIA 4 /Baseflow	Baseflow index (ratio of baseflow to total flow)	%	8.0%	8.4	**7.5**	8.0	7.6	8.4
Low risk of degrading or losing creek value Moderate risk of degrading or losing creek value High risk of degrading or losing creek value								

All assessed metrics for all three proposed scenarios result indicate changes of less than 20% when comparing to the Scenario B values. This indicates a low risk of degrading or losing creek values.

2.1.5 Ecological threshold exceedance assessment

Selection of representative reaches and cross-sections

An ecological survey of Stonequarry creek, identified three representative sensitive reaches, the locations of which are shown in Figure 8.

Figure 8 Stonequarry Creek – Locations of representative reaches

Each one of these reaches include several ecologically significant features, which were assessed independently to estimate localised impacts due to the proposed discharge regime changes. The assessed features are:

- Upstream reach
  - RBC pool
- Downstream reach 1
  - Deep pool
  - Boulder choke
- Downstream reach 2
  - Outlet through boulders to Nepean

The analysis and results for each of these features are detailed hereafter.

Upstream – Pool

Two plan view figures of the representative reach showing recent aerial imagery and the bathymetric data is shown in Figure 9 and Figure 10 respectively.

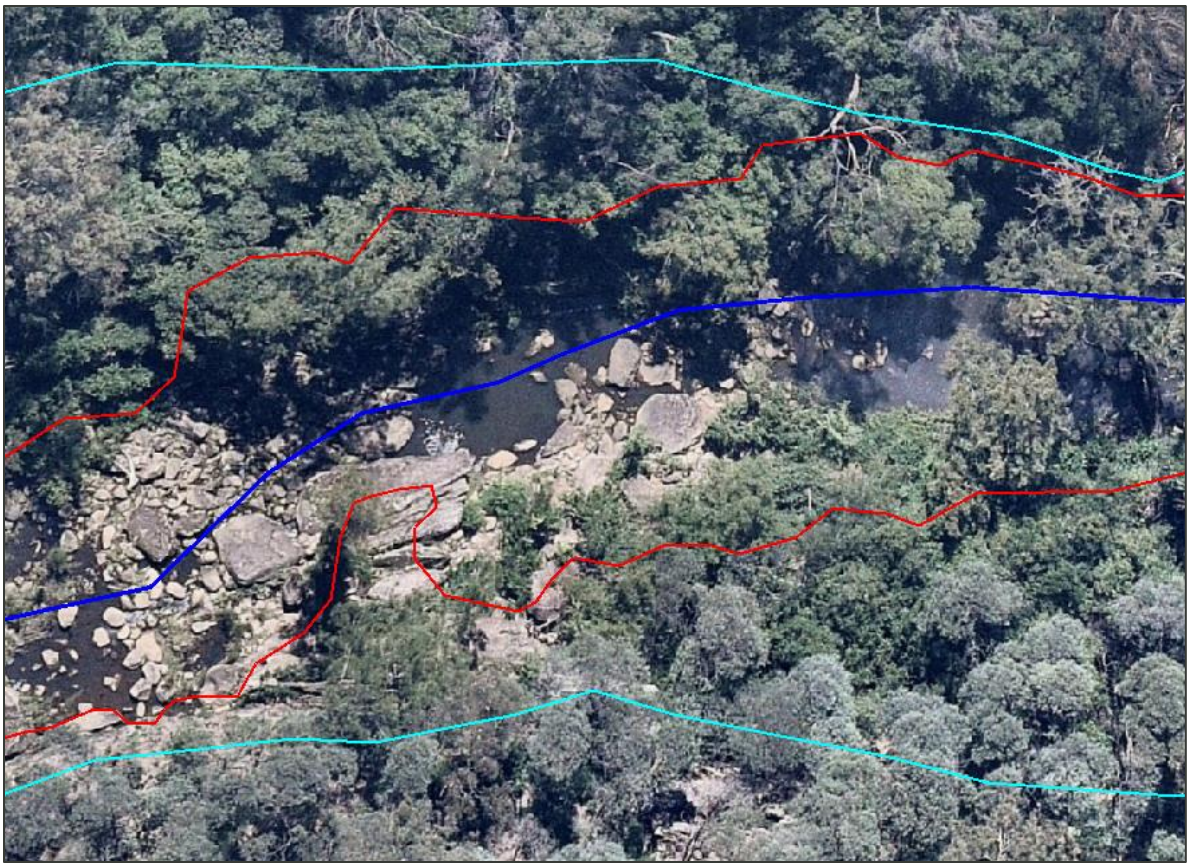

Figure 9 Upstream reach - Aerial imagery (Imagery date: 11 Feb 2021, Nearmap)

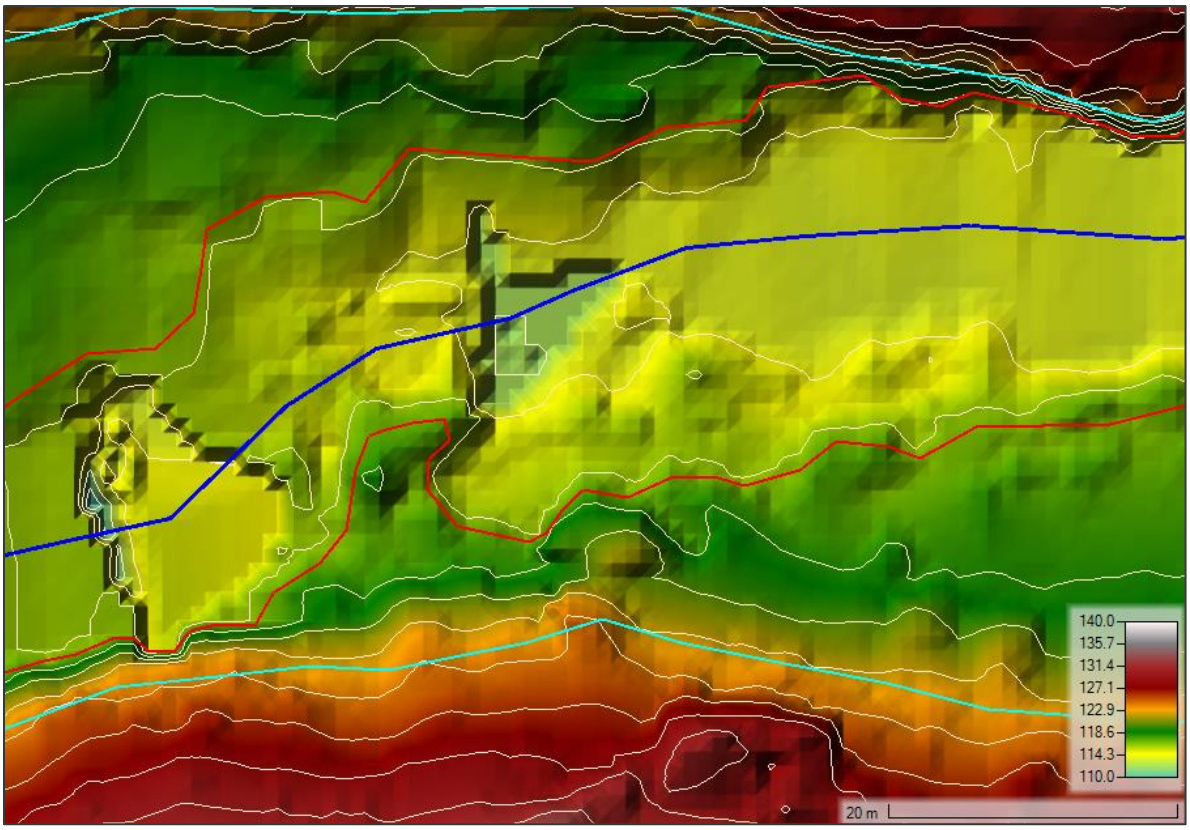

Figure 10 Upstream reach - DEM including bathymetry

The selected cross section for this reach, on which the detailed analysis was conducted, is indicated in purple in Figure 11. This cross-section was selected as it passes through the deepest area of the pool.

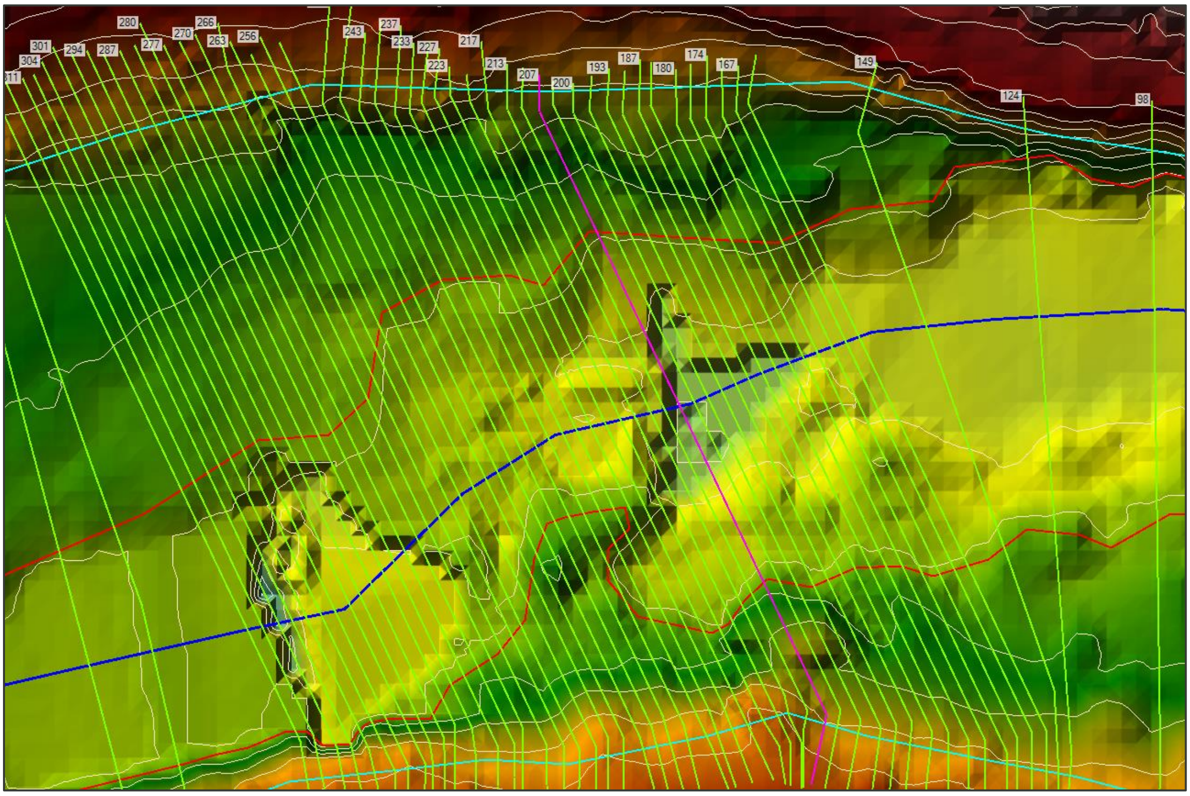

Figure 11 Upstream reach -Selected cross section (nr 207)

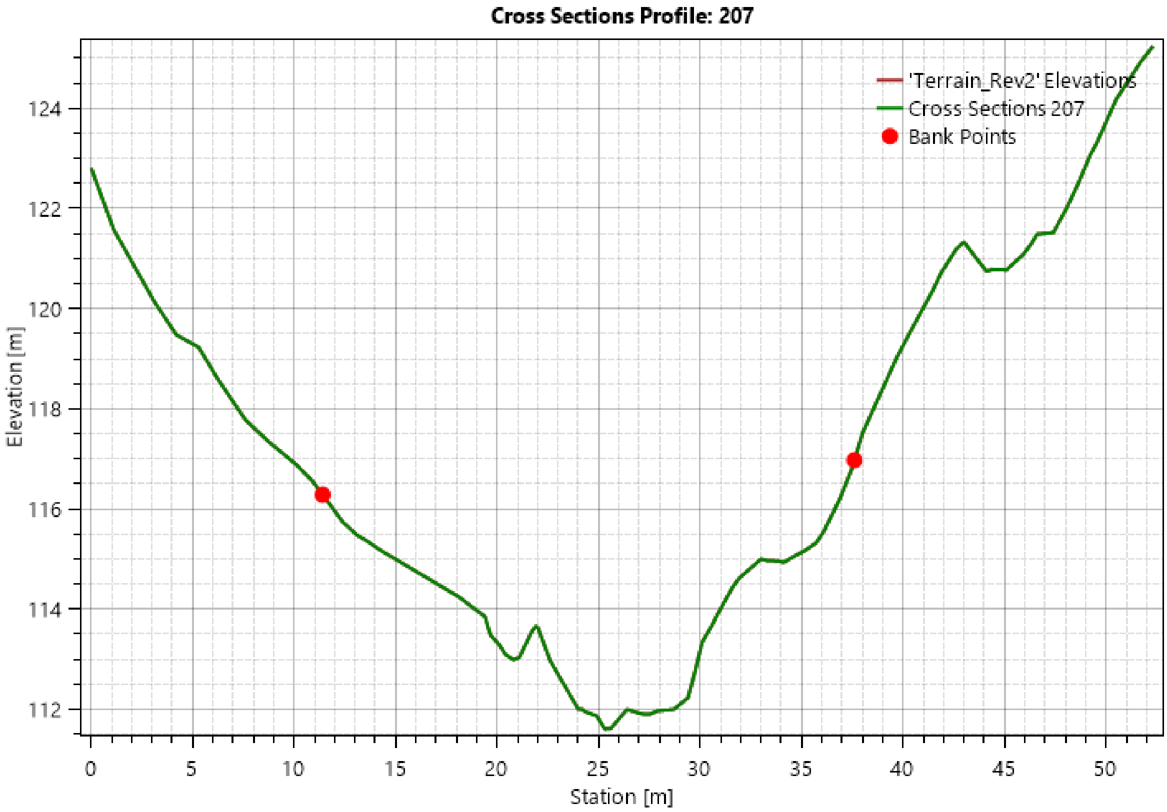

Figure 12 Upstream pool – Selected cross section profile

The upstream flowrate timeseries was applied as the upstream boundary condition for the reach and the resulting timeseries datasets analysed for the selected cross-section. The resulting average cross-sectional velocity-flowrate relationship is shown in

Figure 13. These results indicate generally low velocities within the pool, with flowrates as high as 280 ML/d resulting in average velocities below 0.2 m/s. Flowrates above 280 ML/d would result in exceedances of some of the ecological thresholds.

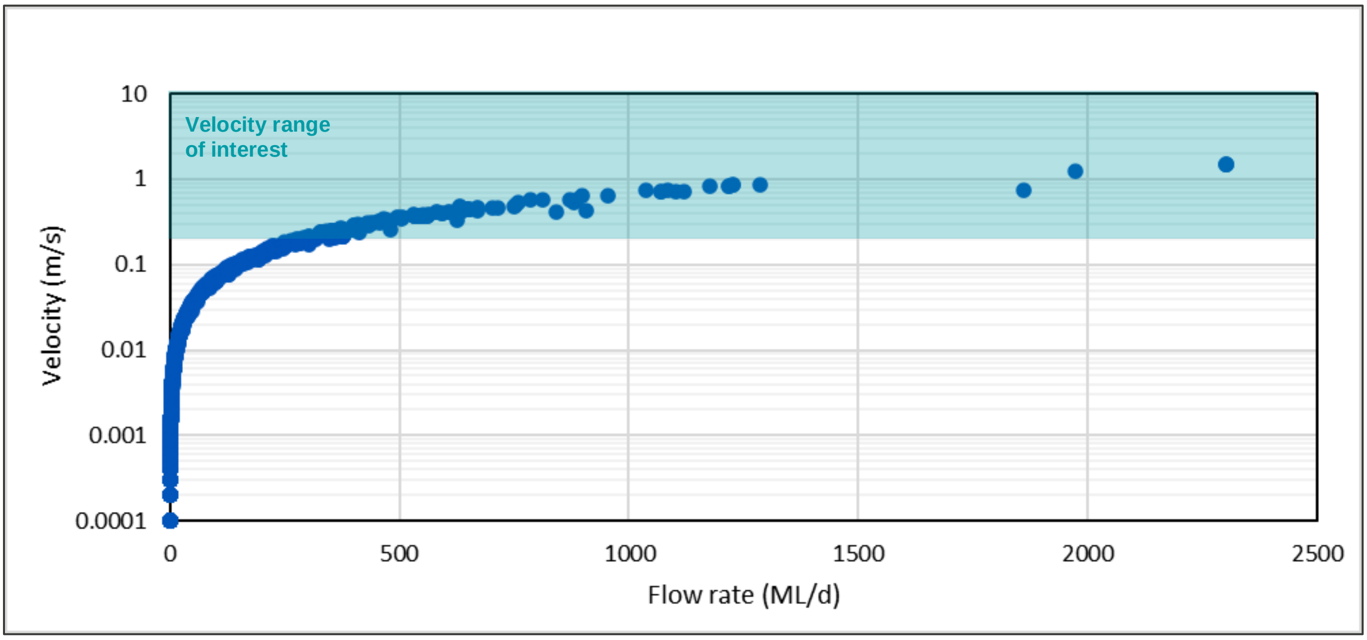

Figure 13 Upstream pool - Daily flowrate-average cross-sectional velocity relationship

The probability of exceedance curve for average daily velocity through this cross-section is shown in Figure 14. The curve indicates a median velocity of less than 0.001 m/s, with near-static conditions for more than 40% of the time.

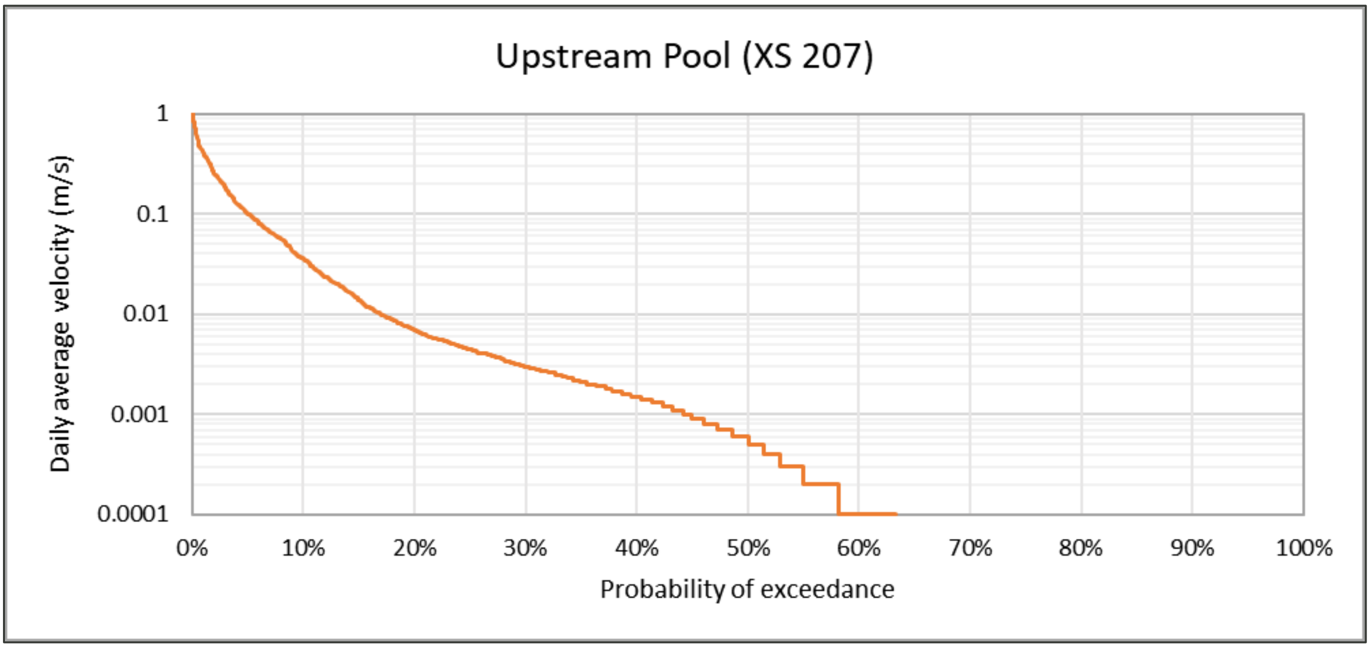

Figure 14 Upstream pool - Velocity PoE curve

The probability of exceedance curve for maximum pool depth is shown in Figure 15. Indicating that this pool remains suitable for platypus foraging even during flood flows (when considering depth alone).

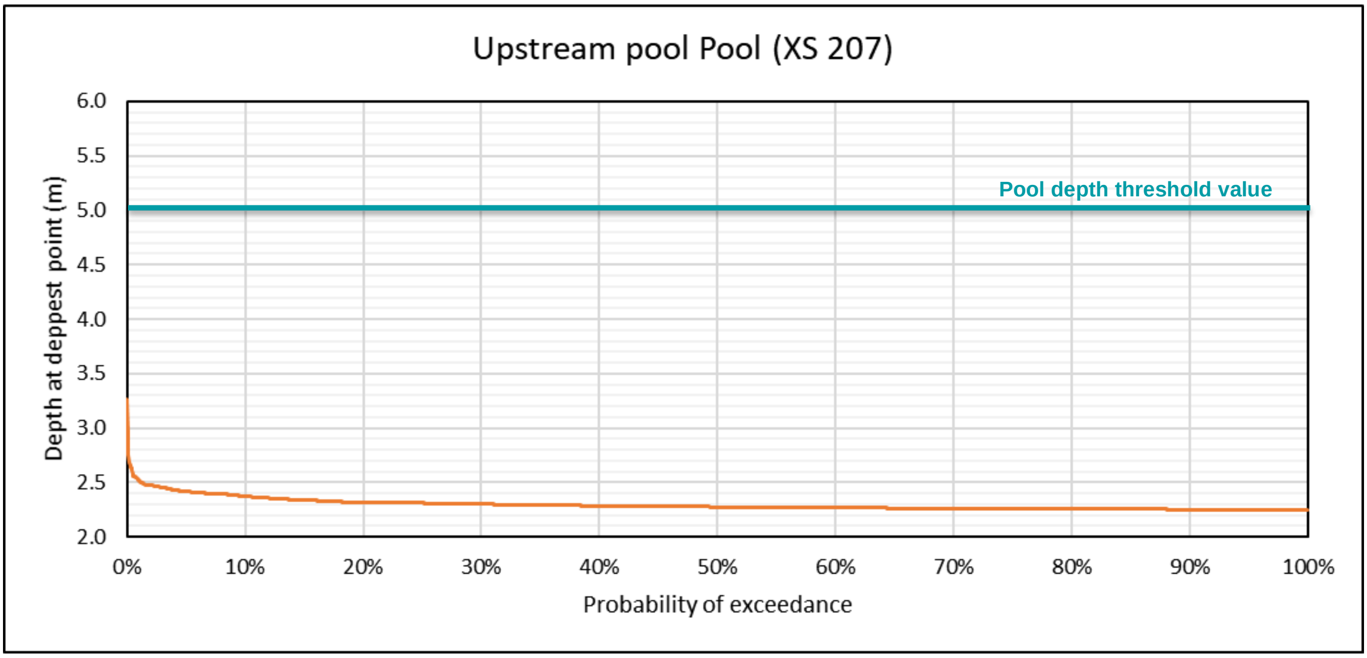

Figure 15 Downstream teach 2: Velocity PoE curves

To understand the possible velocity distribution across the cross-sectional cut, a single high flow day (3 Feb 2012) was selected from the time series that used climate data from 2010-2018, with an average flow rate recorded at the cross-section of 3.5 m^3/s (300 ML/d) (Scenario A) and an average channel velocity of 0.21 m/s. The graph in Figure 16 shows that the maximum associated point velocity may be as high as 0.26 m/s in the middle of the pool (or 24% higher than the average indicated) and much less, approaching 0 m/s within the areas closer to the banks. This analysis indicates that maximum point velocities are not significantly higher than the cross-sectional average velocities reported on and assessed for exceedances.

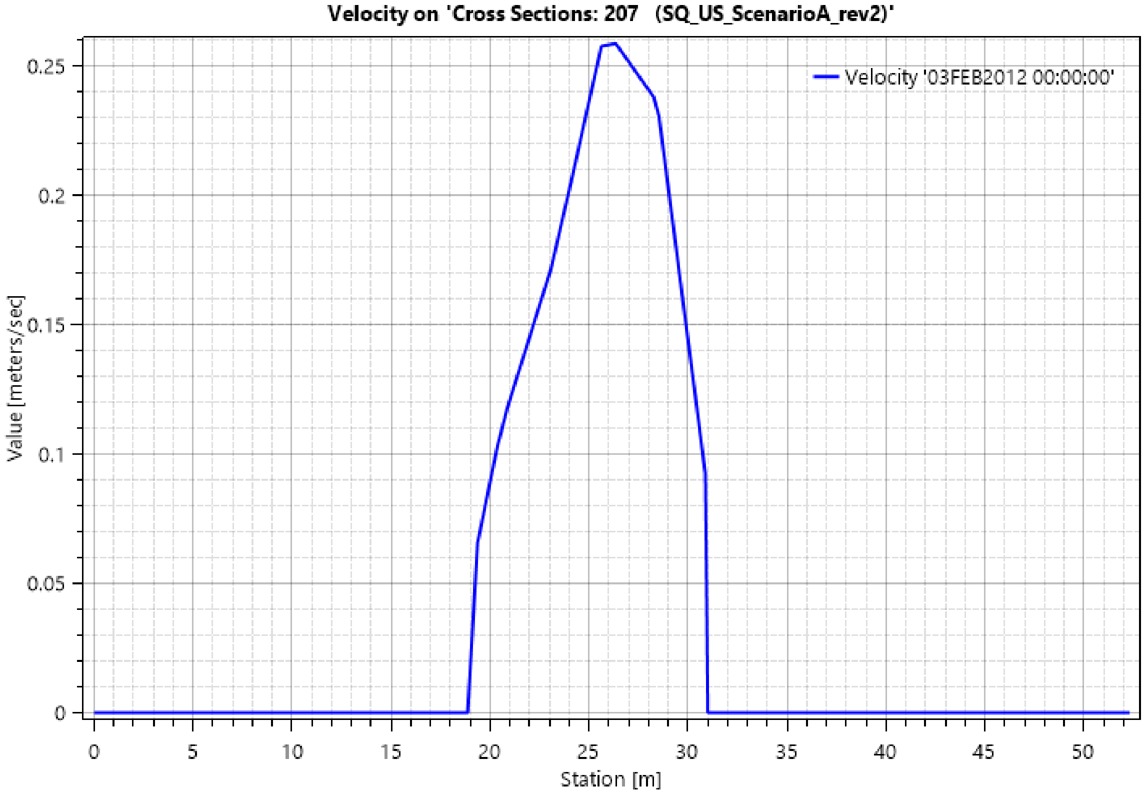

Figure 16 Upstream reach: Velocity profile plot (average v = 0.12 m/s)

A comparison of the model results and the relevant ecological threshold values is provided in Table 9. None of the velocity thresholds are exceeded for any significant amount of time within the assessed pool. The max pool depth remains below 5m throughout, thus making this pool suitable for platypus foraging throughout the year.

Table 9 Upstream pool: Ecological threshold assessment

Ecological feature	Threshold values	Probability of exceedance
Juvenile Macquarie Perch burst swimming speed	0.2 m/s	2.8 %
Erosion risk	0.2 - 1 m/s	2.7 %
Organic & invertebrate mobilisation	0.4 m/s	1.1 %
Adult Macquarie Perch burst swim speed	0.8 m/s	<0.1 %
Bass migration	1 m/s	<0.1 %
Platypus foraging depth	5 m	0%

Downstream – Pool

A plan view of the first representative reach downstream of the discharge location is shown in Figure 17. This section is characteristic of the entire reach between the discharge location and the confluence with the Nepean River. Deep pools separated by boulder chokes within a steep gorge setting.

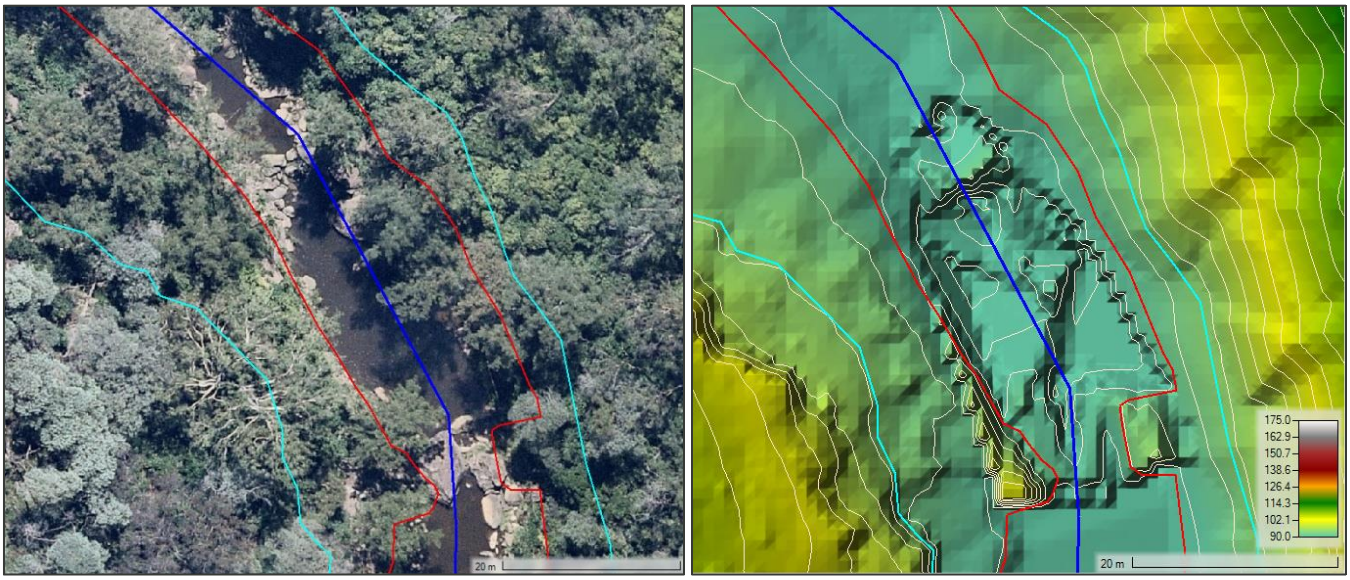

Figure 17 Downstream reach 1 – Deep pool: Plan view showing aerial imagery and bathymetry

Two cross-sections were selected to represent the two features, the deep pool as well as the boulder choke directly downstream. The first analysis is focused on the deep pool cross-section, indicated in purple in Figure 18. This cross-section was selected as it passes through the deepest point within of the large pools for which detailed bathymetry has been made available.

The cross-sectional profile for this location is shown in Figure 19. As the cross-section orientation is looking downstream, the left-bank is located on the right side of the graph and the right bank on the left. This shows the undulation of the creek bed, primarily due to rocks and boulders situated within the flow path.

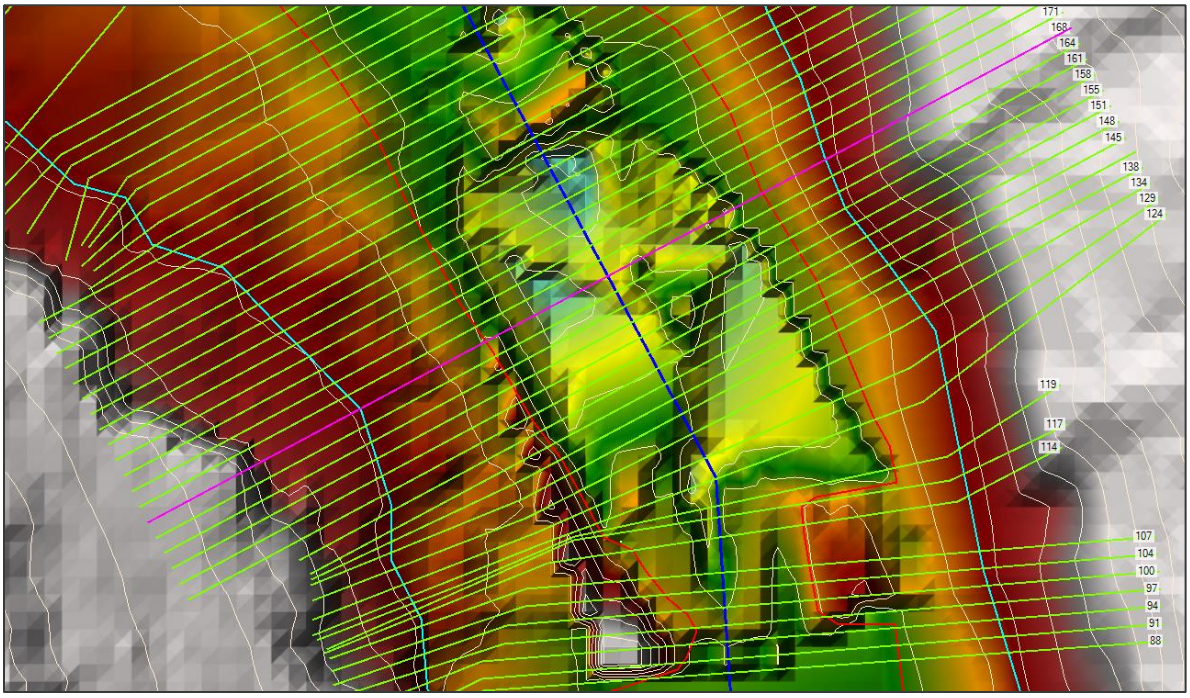

Figure 18 Downstream reach 1 – Deep pool: Selected cross-section (nr 168)

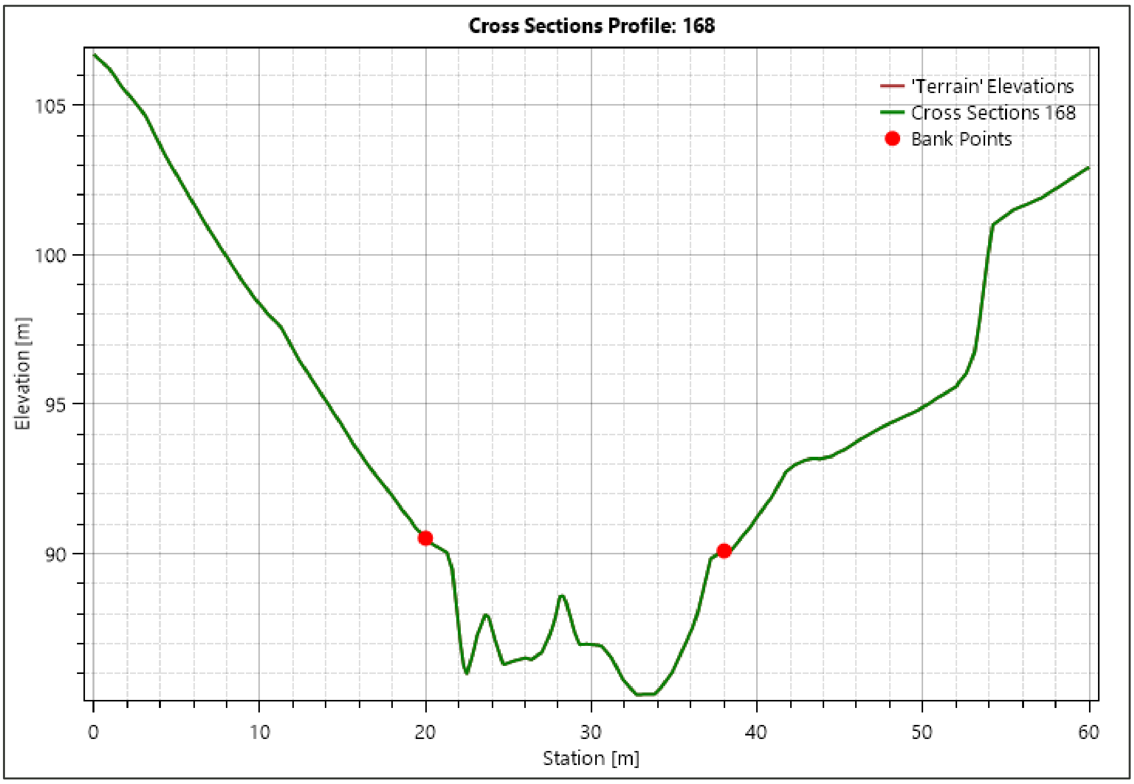

Figure 19 Downstream reach 1 – Deep pool: Selected cross-section profile

The downstream flowrate timeseries datasets for all scenarios were applied as the upstream boundary condition for the reach. The resulting timeseries datasets analysed for the selected cross-section. The resulting average cross-sectional velocity-flowrate relationships for all 5 scenarios are shown in Figure 20. These results indicate very low velocities within the pool, with flowrates as high as 1,800 ML/d resulting in average velocities below 1.0 m/s. Only in extreme flooding conditions is the pool average velocity expected to move into the range of interest where ecological features may be adverse affected.

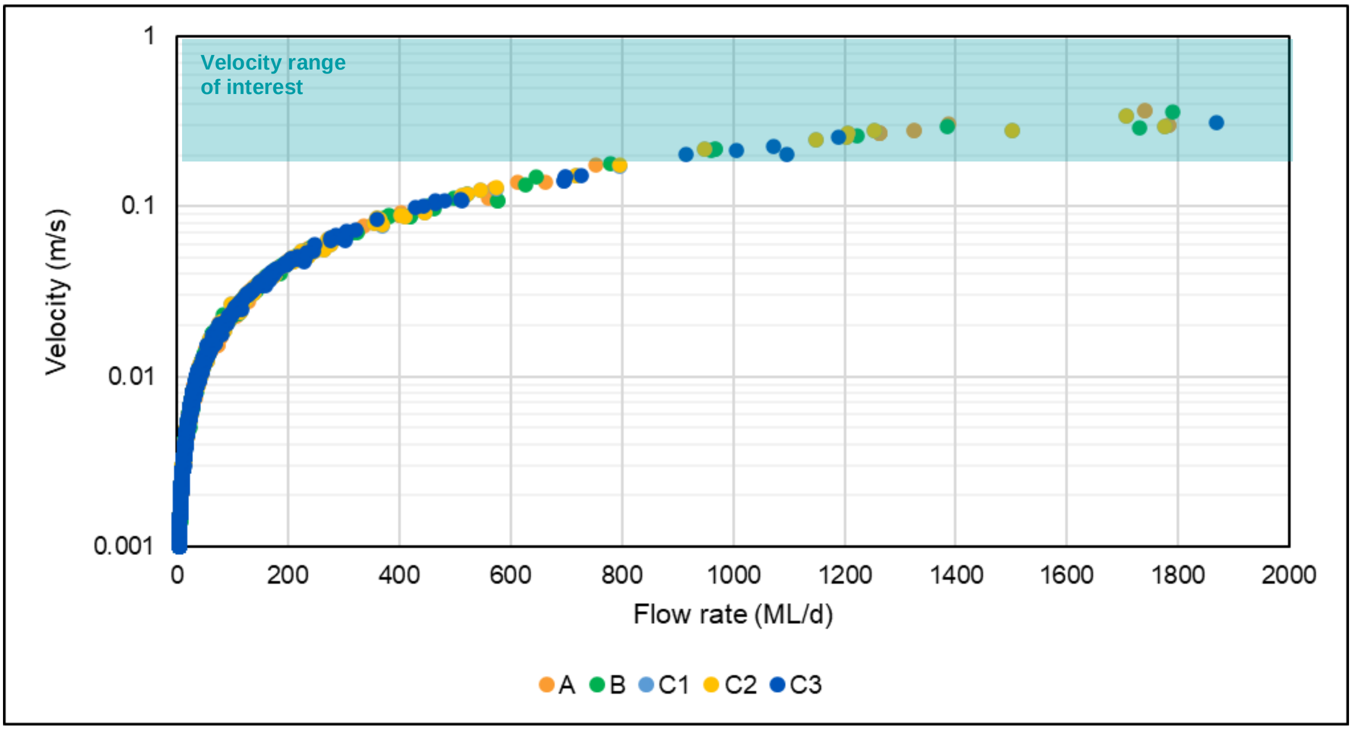

Figure 20 Downstream reach 1 – Deep pool: Daily flowrate-average cross-sectional velocity relationship

The probability of exceedance curves for average velocities through this cross-section is shown in Figure 21. The curves indicate that near static conditions are expected for more than half of the time, this ranges between 65% and 55% for the assessed scenarios. Only minimal changes within the range of interest, velocities above 0.2 m/s, are indicated. Screenshots of representative median and 90th percentile velocity days from the hydraulic model, showing the plan view distribution of velocity for the reach, are provided in Appendix A.

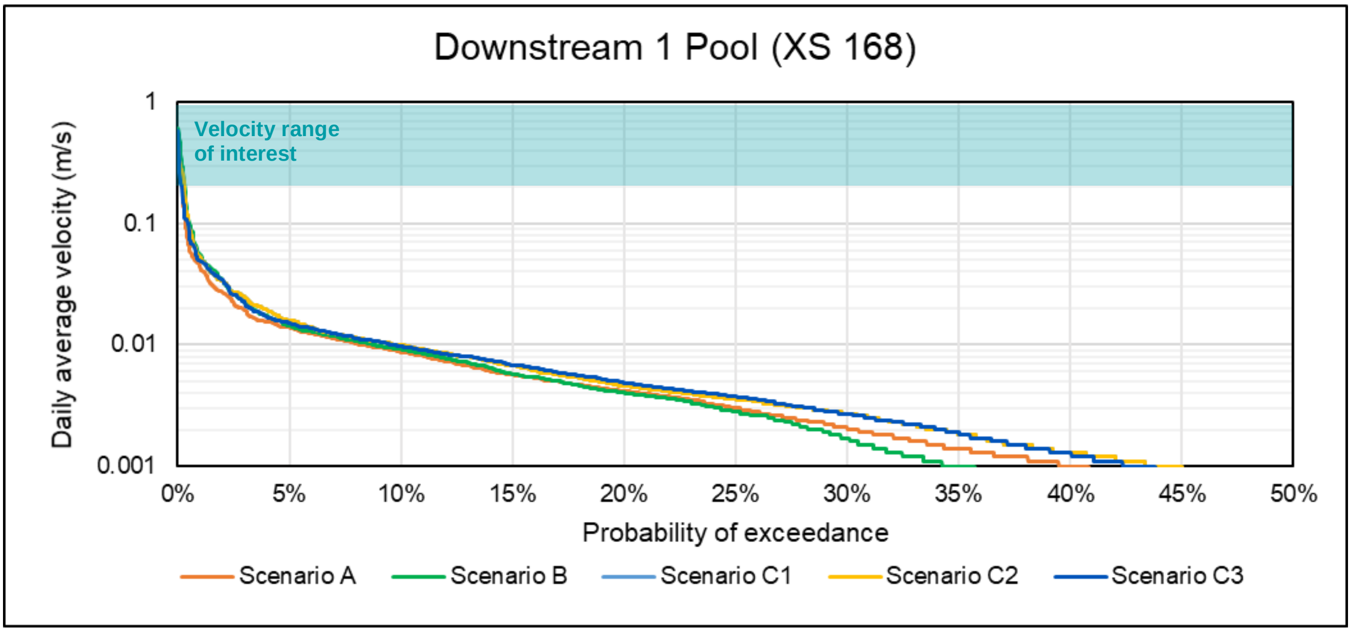

Figure 21 Downstream reach 1 – Deep pool: Velocity PoE curves

The probability of exceedance curve for maximum pool depth is shown in Figure 22. The curve indicates a maximum depth of almost 5.8m, median just over 4.2 m, and minimum depth of 4.2 m. Minimal changes are evident within the range of the indicated pool depth threshold of 5 m.

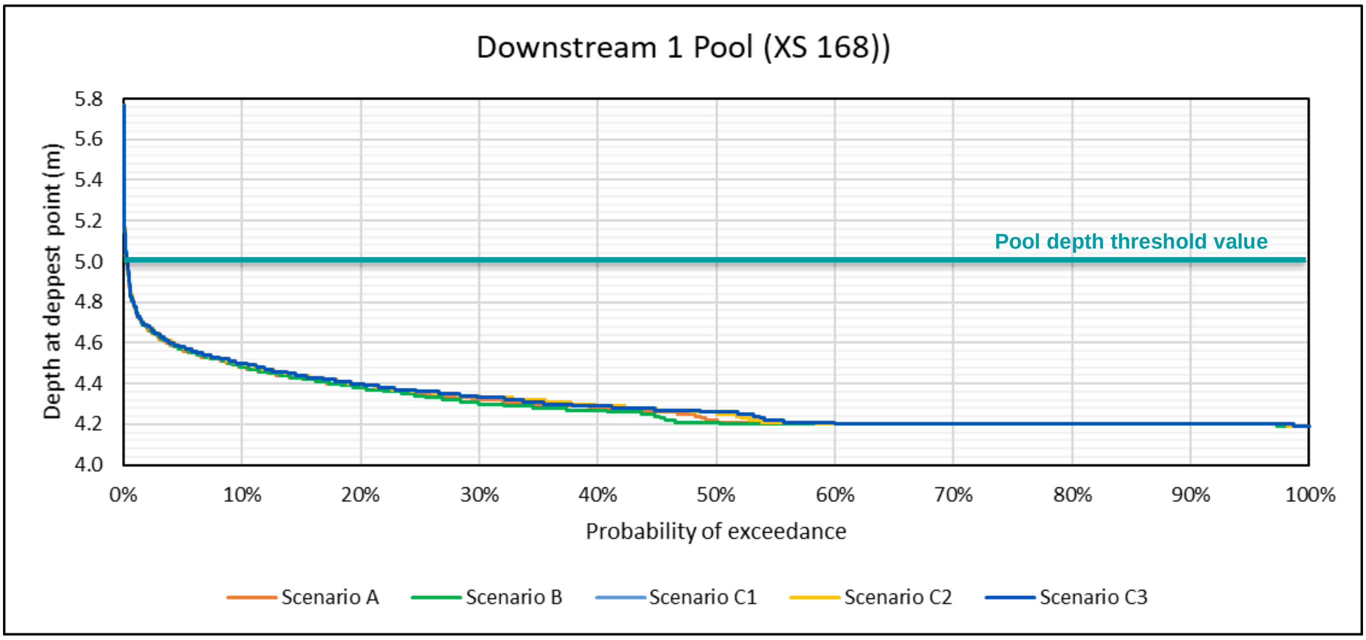

Figure 22 Downstream reach 1 – Deep pool: Depth PoE curves

A comparison of the model results and the relevant ecological threshold values is provided in Table 10.

Table 10 Downstream reach 1 – Deep pool: Ecological values and threshold comparison

Ecological feature	Threshold values	A	B	C1	C2	C3
		Probability of exceeding				
Juvenile Macquarie Perch burst swimming speed	0.2 m/s	0.2%	0.3%	0.3%	0.3%	0.3%
Erosion risk	within 0.2 - 1 m/s range	0.2%	0.3%	0.3%	0.3%	0.2%
Organic & invertebrate mobilisation	0.4 m/s	<0.1%	0.1%	<0.1%	<0.1%	<0.1%
Adult Macquarie Perch burst swim speed	0.8 m/s	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
Bass migration Erosion risk	1 m/s	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
Platypus foraging depth	< 5 m	0.3%	0.3%	0.3%	0.3%	0.3%

The velocity ranges expected within the pool are generally below any of the key threshold values, except under extreme flooding conditions. The probability of exceeding these lower end values (i.e. 0.2 m/s, which is associated with juvenile Macquarie Perch burst swimming speeds) is not expected to increase due to the proposed increase in discharge associated with all future scenarios. The probability of exceeding the key 5m pool depth is also not expected to change.

Thus, the changes associated with all three future scenarios are deemed to have negligible impact on the ecological value of the assessed pool.

Downstream - Boulder choke

A plan view of the first representative reach downstream of the discharge location is shown in Figure 17.

Two cross-sections were selected to represent the two features, the deep pool as well as the boulder choke directly downstream. The second analysis is focused on the boulder choke area, with the representative cross-section indicated in purple in Figure 23 (XS 107). This cross-section was selected as it passes through the constricted flow area created by the in-stream boulders. *It should be noted that additional flow paths through the boulders would be present, and these are not captured within the model, thus any velocity profile results are likely to be conservative, i.e. overestimating the movement of water through the observable pathway.*

The cross-sectional profile for this location is shown in Figure 24. As the cross-section orientation is looking downstream, the left-bank is located on the right side of the graph and the right bank on the left. This shows the rocky creek bed and banks obstructing the flow path.

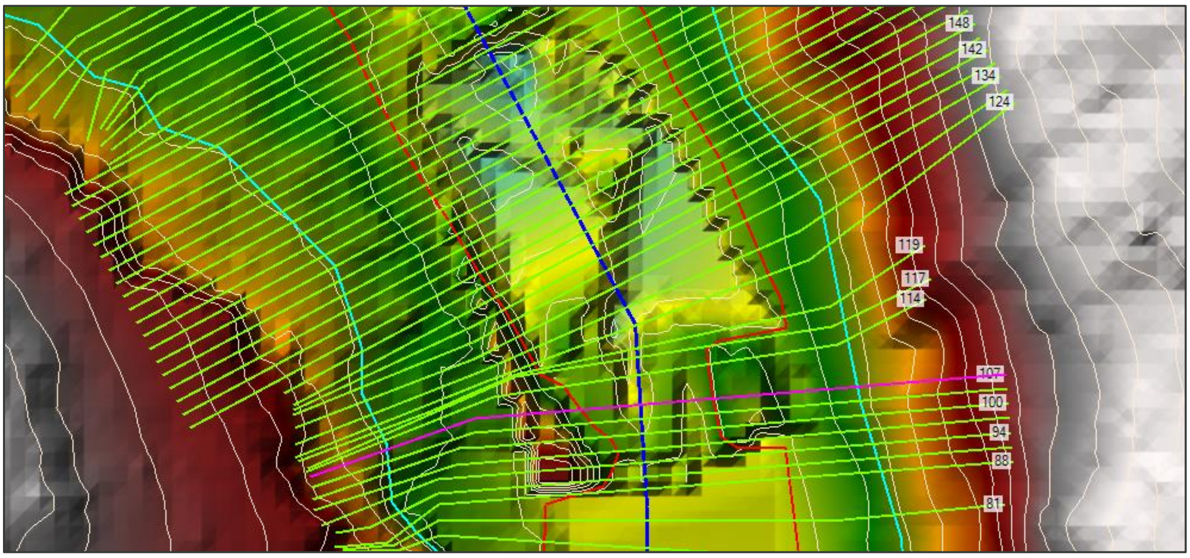

Figure 23 Downstream reach 1 – Boulder choke: Selected cross-section (nr 107)

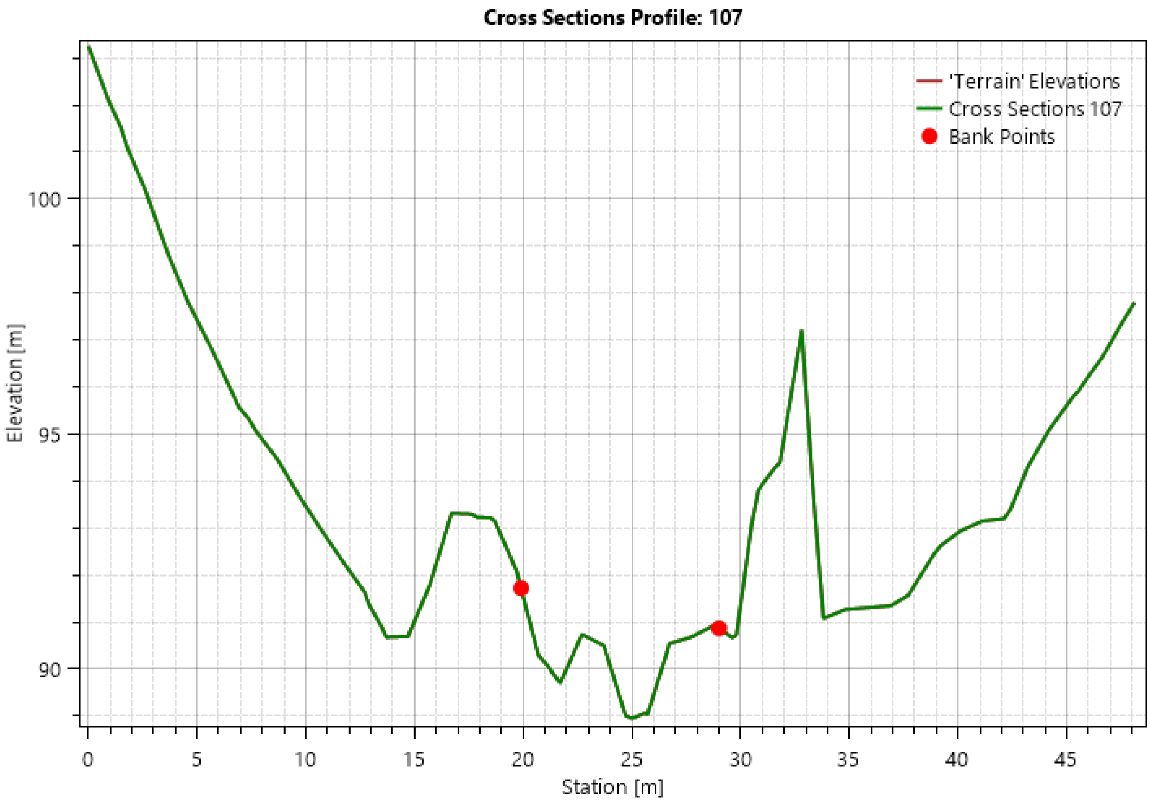

Figure 24 Downstream reach 1 – Boulder choke: Selected cross-section profile

The downstream flowrate timeseries datasets for all scenarios were applied as the upstream boundary condition for the reach. The resulting timeseries datasets were then analysed for the selected cross-section. The resulting average cross-sectional velocity-flowrate relationships for all 5 scenarios are shown in Figure 25. These results indicate a large range of velocities through this restricted flow section, with average velocities up to 3 m/s expected.

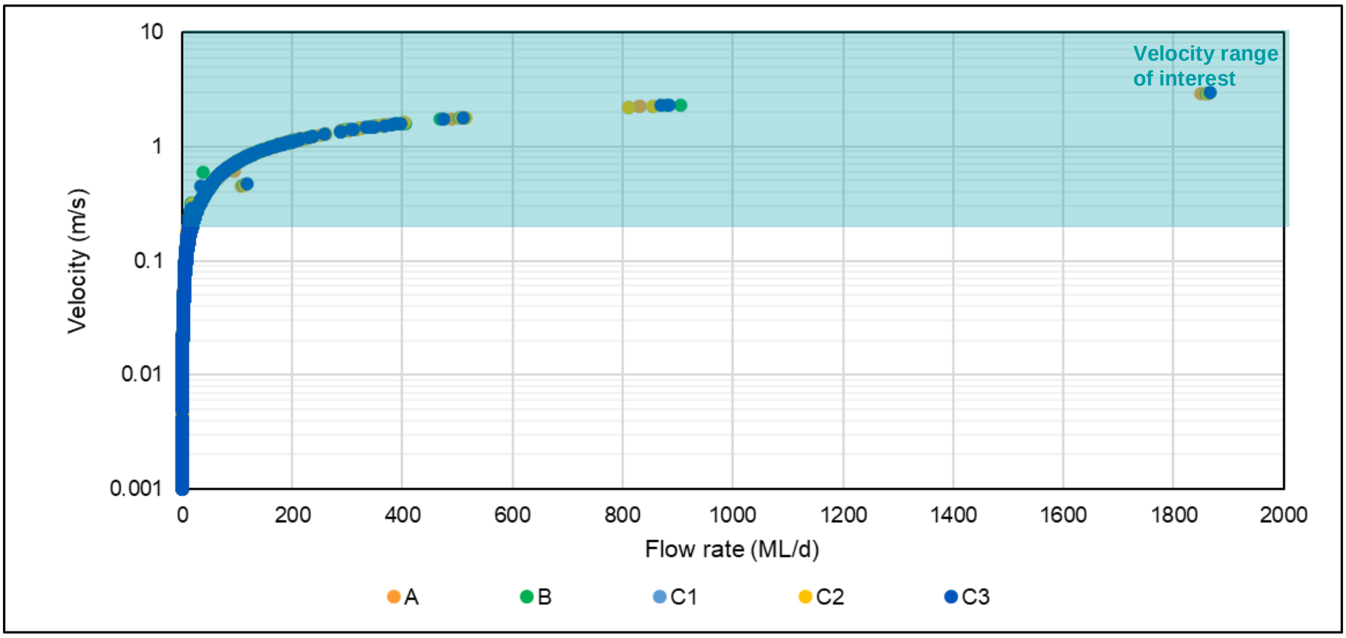

Figure 25 Downstream reach 1 – Boulder choke: Daily flowrate-average cross-sectional velocity relationship

The probability of exceedance curves for average velocities through this cross-section is shown in Figure 26. The curves indicate that near static conditions are expected for around 40% of the time, this ranges between 35% and 45% for the assessed scenarios. Only minimal changes within the range of interest, velocities above 0.2 m/s, are indicated. Screenshots of representative median and 90th percentile velocity days from the hydraulic model, showing the plan view distribution of velocity for the reach, are provided in Appendix A.

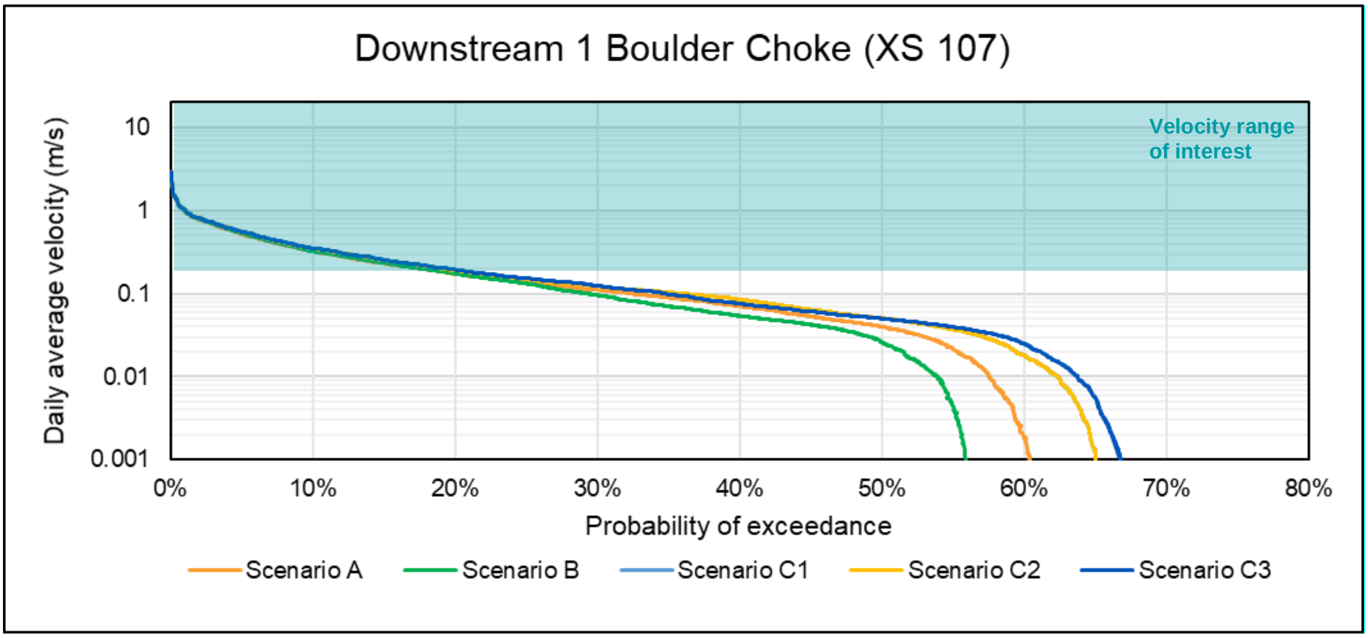

Figure 26 Downstream reach 1 – Boulder choke: Velocity PoE curves

A comparison of the model results and the relevant ecological threshold values is provided in Table 11.

Table 11 Downstream reach 1 – Boulder choke: Ecological values and threshold comparison

Ecological feature	Threshold values	A	B	C1	C2	C3	C1	C2	C3
		Probability of exceeding					Extra days / yr exceeding (on average)		
Juvenile Macquarie Perch burst swimming speed	0.2 m/s	17%	18%	19%	19%	20%	5	5	7
Erosion risk	within 0.2 - 1 m/s range	16%	17%	18%	18%	18%	5	5	7
Organic & invertebrate mobilisation	0.4 m/s	7.5%	7.7%	8.2%	8.2%	8.4%	2	2	2
Adult Macquarie Perch burst swim speed	0.8 m/s	1.9%	2.0%	2.1%	2.1%	2.1%	1	1	1
Bass migration Erosion risk	1 m/s	1.0%	1.0%	1.0%	1.0%	1.0%	0	0	0

The risk of erosion and adverse conditions for Juvenile Macquarie Perch is expected around 20% of the time through this section, with only a slight increase in the expected frequency when considering the proposed scenarios (i.e. from 18% to 20% for Scenario C3).

The changes associated with all three future scenarios are deemed to have negligible impact on the ecological values of the assessed boulder choke.

Downstream – Outlet to Nepean

A plan view of the second representative reach downstream of the discharge location is shown in Figure 27. This section is key as a controlling element linking to the Nepean River. *It should be noted that modelling of the Nepean River flows was not included in the hydraulic model and actual discharge rates would be impacted by the fluctuating energy gradients within the Nepean at this location.*

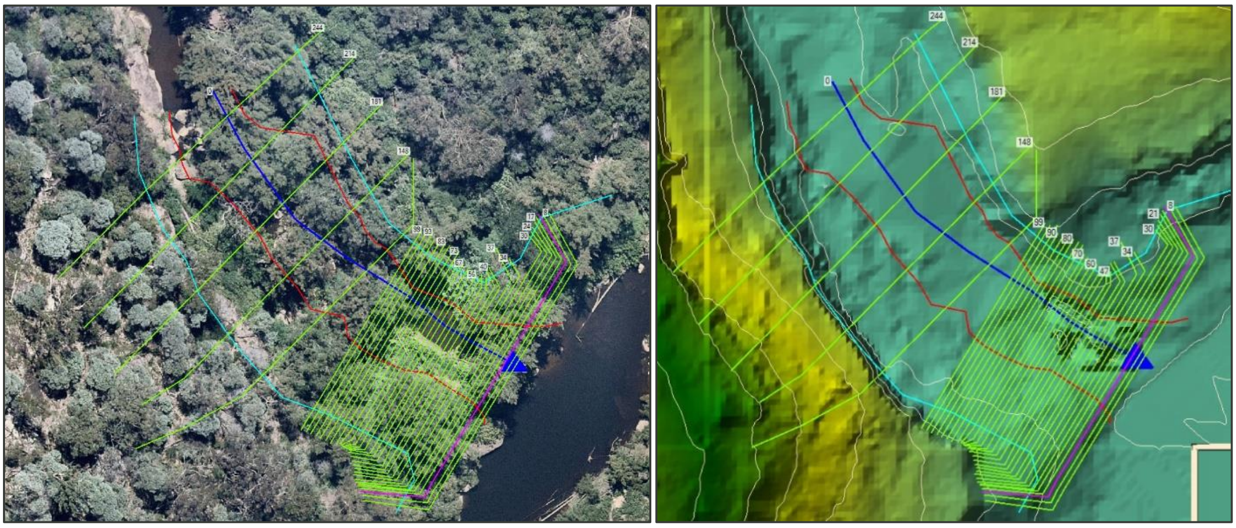

Figure 27 Downstream reach 2 – Stonequarry outlet to Nepean

A cross-section through the riffles at the outlet point was selected to assess the flow regime and velocities at this key location. The cross-sectional profile for this location is shown in Figure 28.

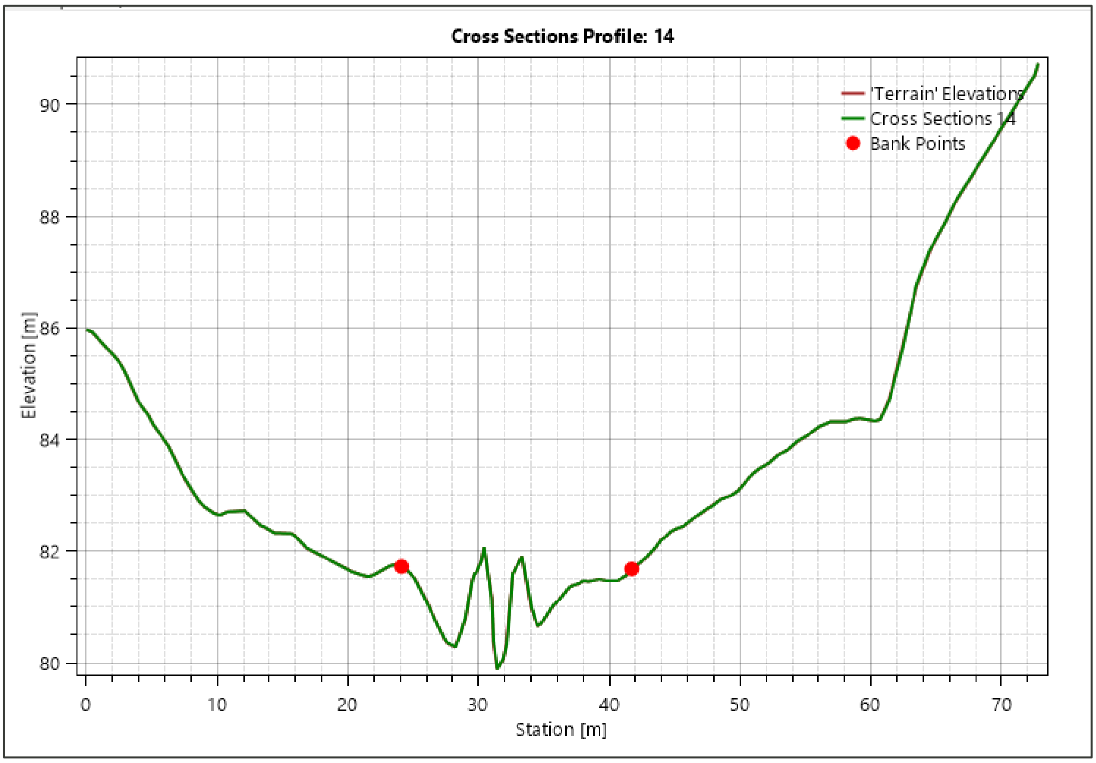

Figure 28 Downstream reach 2 - selected cross section profile

The downstream flowrate timeseries datasets for all scenarios were applied as the upstream boundary condition for the reach. The resulting timeseries datasets were then analysed for the selected cross-section. The resulting average cross-sectional velocity-flowrate relationships for all 5 scenarios are shown in Figure 29. The results indicate a large range of velocity through this cross-section, up to 5 m/s. The split curve is a feature of both sub- and super-critical flow occurring here and resulting in two flowrate-velocity relationship profiles.

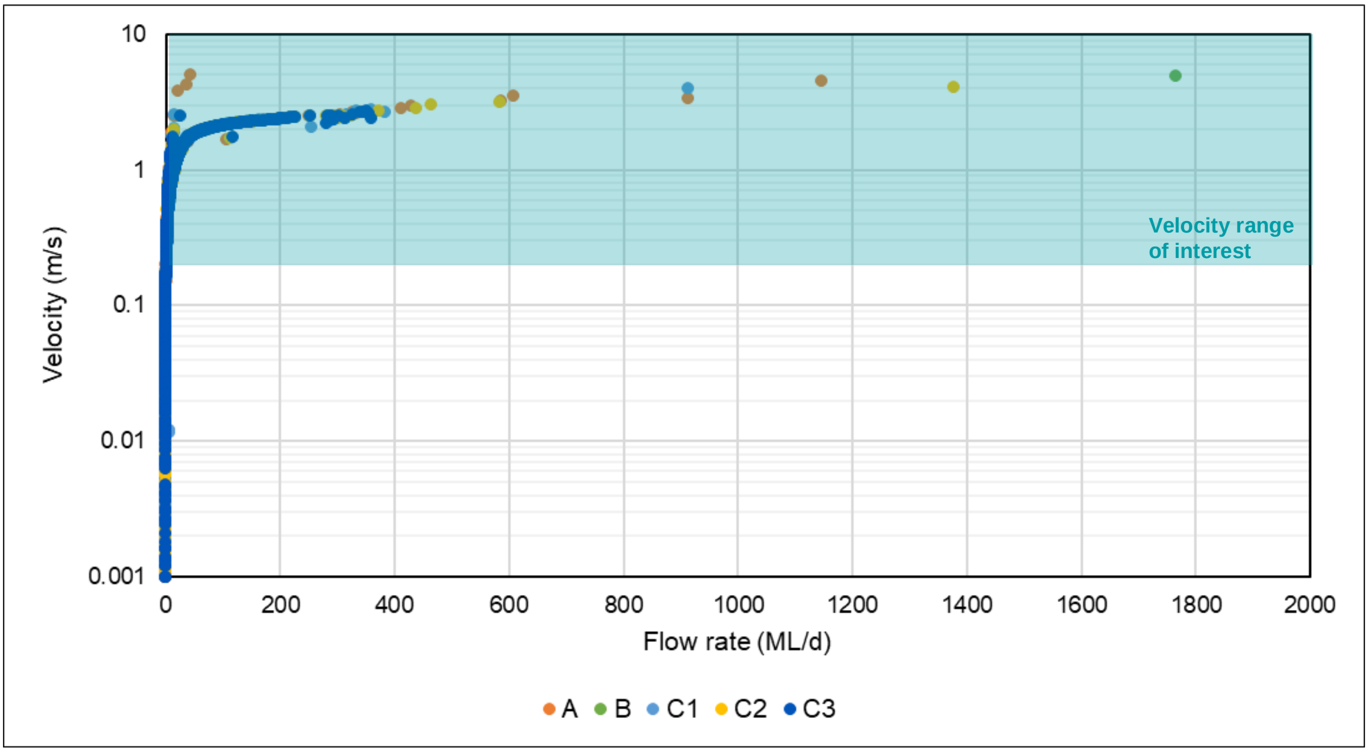

Figure 29 Downstream reach 2 - Daily flow rate average cross-sectional velocity relationship

The probability of exceedance curves for average velocities through this cross-section is shown in Figure 30. Screenshots of representative median and 90th percentile velocity days from the hydraulic model, showing the plan view distribution of velocity for the reach, are provided in Appendix A.

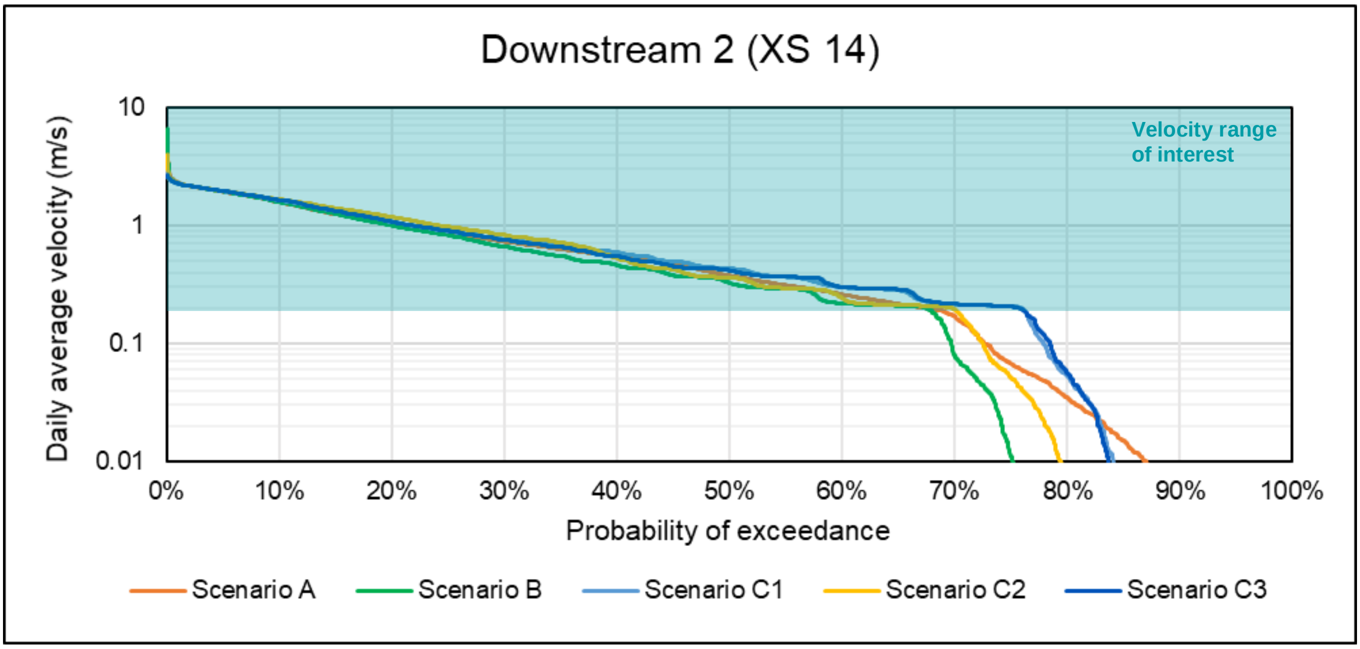

Figure 30 Downstream reach 2 - Velocity PoE curves

A comparison of the model results and the relevant ecological threshold values is provided in Table 13.

Table 12 Downstream reach 2 - Ecological values and threshold comparison

Ecological feature	Threshold values	A	B	C1	C2	C3	C1	C2	C3
		Probability of exceeding					Extra days / yr exceeding (on average)		
Juvenile Macquarie Perch burst swimming speed	0.2 m/s	64%	60%	69%	61%	69%	33	7	34
Erosion risk	within 0.2 - 1 m/s range	44%	40%	47%	37%	47%	27	-9	27
Organic & invertebrate mobilisation	0.4 m/s	49%	44%	52%	46%	51%	29	6	24
Adult Macquarie Perch burst swim speed	0.8 m/s	27%	26%	28%	31%	28%	9	19	10
Bass migration Erosion risk	1 m/s	21%	20%	22%	24%	22%	6	15	7

The frequency of exceeding the stated ecological threshold values increases for all metrics and for all scenarios, except for the erosion risk associated with Scenario C2 (which reduces for particles mobilised within the 0.2 – 1 m/s range). The proportionate increases in frequency of exceeding the relevant thresholds are low throughout. The highest proportionate increases are associated with Scenario C2 for the 0.8 and 1 m/s threshold exceedances, though the average number of additional days exceeding over a year are still less than 20. The biggest changes, when considering extra days of exceedances, are associated with the low velocity thresholds for Scenario C1 and C2. For this reach a clear variance between low flow (and velocity) impacts and high flow impacts for the three future scenarios becomes clear again with C2 exhibiting less change below 0.4 m/s and a greater shift above this, compared to C1 and C3.

2.1.6 Qualitative flood impact assessments

The maximum discharge rate to Stonequarry Creek will be 15 ML/d or 0.17 m^3/s (during wet weather). Estimated flowrates within Stonequarry Creek during flood conditions were sourced from the Wollondilly Shire Council's 2019 Flood Study as indicated in Table 13. These results indicate that the WRP discharge will proportionally add less than 1% of the flow during a 50% AEP event (or 1- in 2-year event). This ratio decreases even further when looking at larger, less frequent flood events. The resultant impact on flood levels would thus be negligible.

Table 13 Flood Frequency Analysis (FFA) Results – Stonequarry Creek at Picton Gauge (WMAwater, 2019)

AEP	Peak Flow (m^3/s)		
	FFA	2017 Flood Study	1989 Flood Study
50%	23.4	Not documented	Not documented
20%	68	Not documented	Not documented
10%	121	Not documented	Not documented
5%	193	431	345
2%	331	509	424
1%	474	578	494

2.2 Nepean River

2.2.1 Flow duration curves and key percentile flow values

The flow duration curves associated with all five the scenarios for site N91 (downstream of Stonequarry Creek and the Nepean River confluence) are indicated in Figure 31.

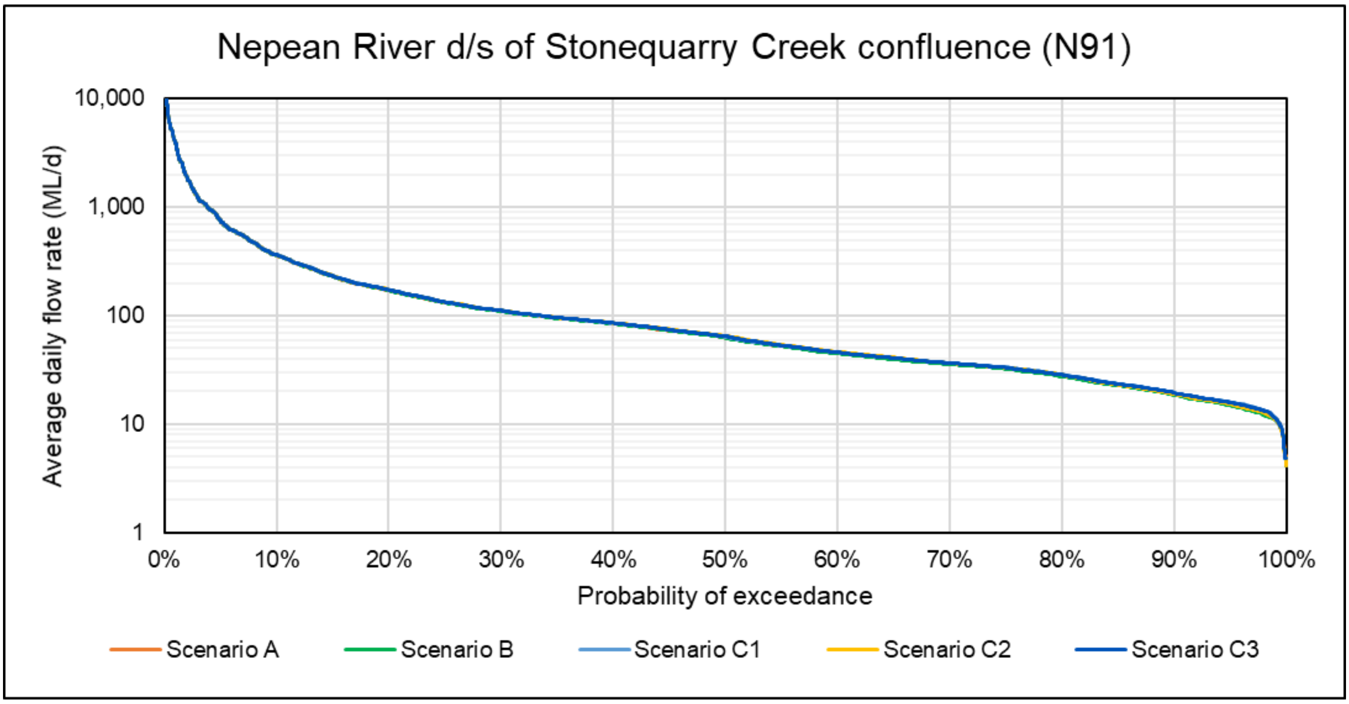

Figure 31 Nepean river downstream of Stonequarry Creek confluence – Flow duration curves

Five discrete percentile values were selected to compare the curve data numerically: 10th, 25th, 50th, 75th and 90th probabilities of exceedance, with 10th and 25th related to high flows and 75th and 90th representing low flows. The flowrates linked to these probabilities for each of the datasets are shown in Table 14. Colouring criteria have been kept consistent with that used in the USIA assessment. The results indicate minimal risk associated with changes brought about in for any of the proposed future discharge scenarios.

Table 14 Key percentile flow rates (ML/d) at N91 (Nepean River d/s of Stonequarry confluence)

Category	PoE	Scenario A	Scenario B	Scenario C1	Scenario C2	Scenario C3
Very low	90%	19	19	19	19	19
Low	75%	33	32	33	33	33
Medium	50%	63	63	64	65	64
High	25%	132	132	133	133	134
Very high	10%	360	361	363	362	363

2.2.2 Proportionate flows

Time averaged

The proportionate flow in the Nepean River downstream of the confluence for each of the scenarios and split into five flow categories (based on the compliant conditions flow duration curves) are shown in Figure 32.

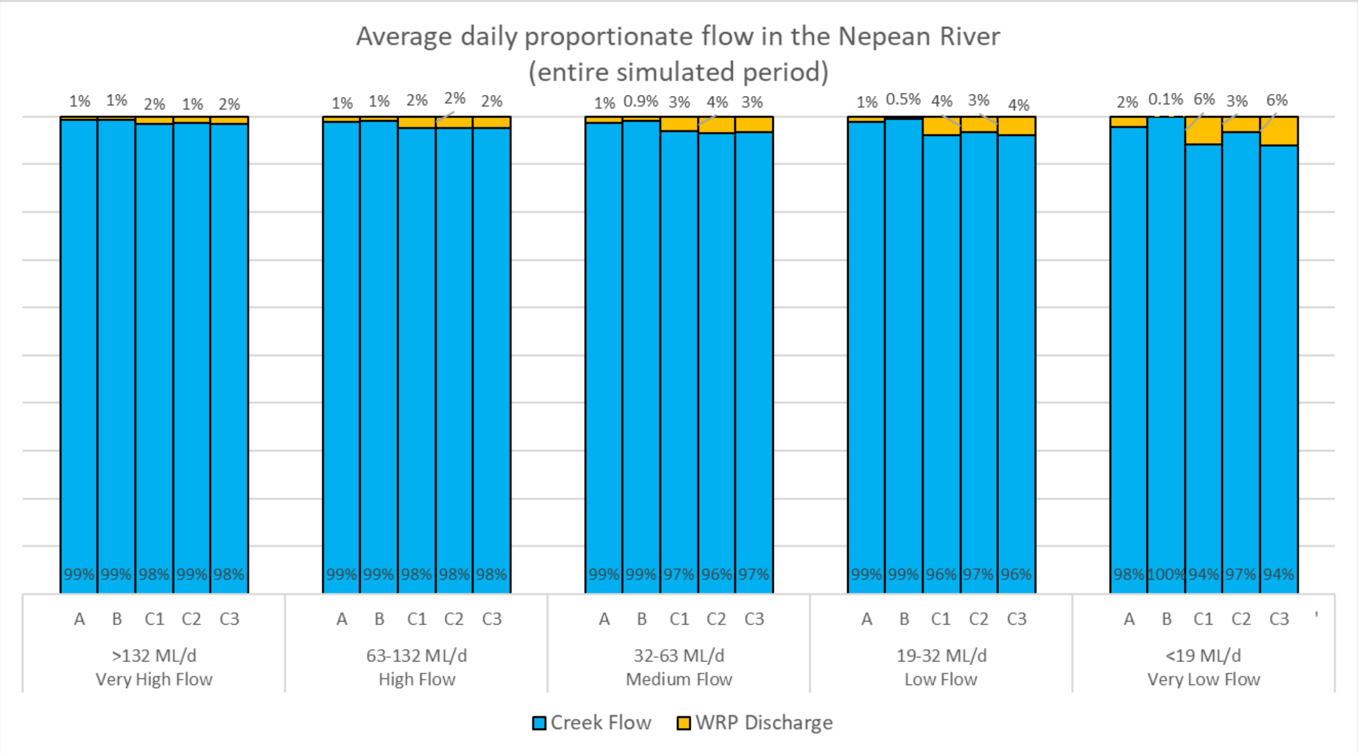

Figure 32 Average daily proportionate flow in the Nepean River (entire simulated record)

From the graph the following interpretations can be made:

- As expected, Scenario B (the compliant scenario) results in the lowest proportionate discharge flows for all conditions.

- When comparing Scenarios C1, C2 and C3: All three scenarios perform similarly during all flow conditions, except very low flows, where Scenario C2 indicates an average portion of 3% for the downstream flow attributable to the plant discharge, whereas C1 and C3 indicate a 6% contribution.

The results shown in Figure 33 only consider the days when discharge is occurring. The ratios associated with all scenarios and under all conditions are thus equal to or worse than that presented in Figure 32. The frequency of the discharges for each condition and scenario is also indicated.

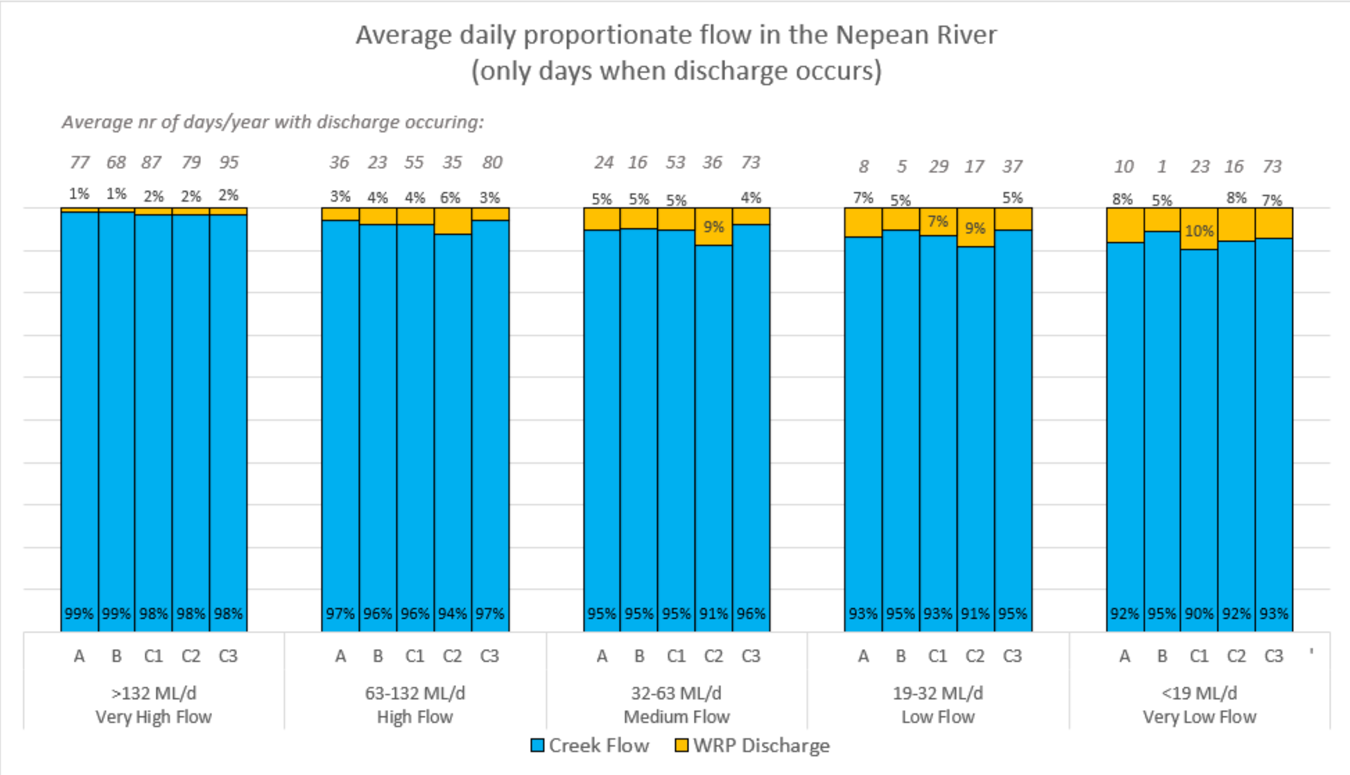

Figure 33 Average daily proportionate flow in the Nepean River (only discharge days)

**Figure note: Direct comparisons of the datasets should be avoided, without taking all factors into account, such as frequency of occurrence*

From the graph the following interpretations can be made:

- As expected, Scenario B (the compliant scenario) still results in the lowest proportionate discharge flows for all conditions, other than the high flow conditions, where Scenarios A and C3 indicate only slightly more favourable results
- Scenario C2 generally shows higher proportional discharge flows compared to C1 and C3 . However, the frequency of discharge is less throughout all flow conditions.

In general, when comparing the future proposed operating regimes to the compliant conditions (Scenario B), a slightly greater portion of the downstream flow would be originating from the plant. All three sets of future scenario results are comparable with slight variances in the slight variances in the proportionate flow offset by the frequency of discharges occurring.

Volumetric averaged

The proportionate flows on an average volumetric basis over the entire simulated period are indicated in Figure 34. From these results it is clear that total average flows in the Nepean River will be negligibly affected for all scenarios and under all flow conditions.

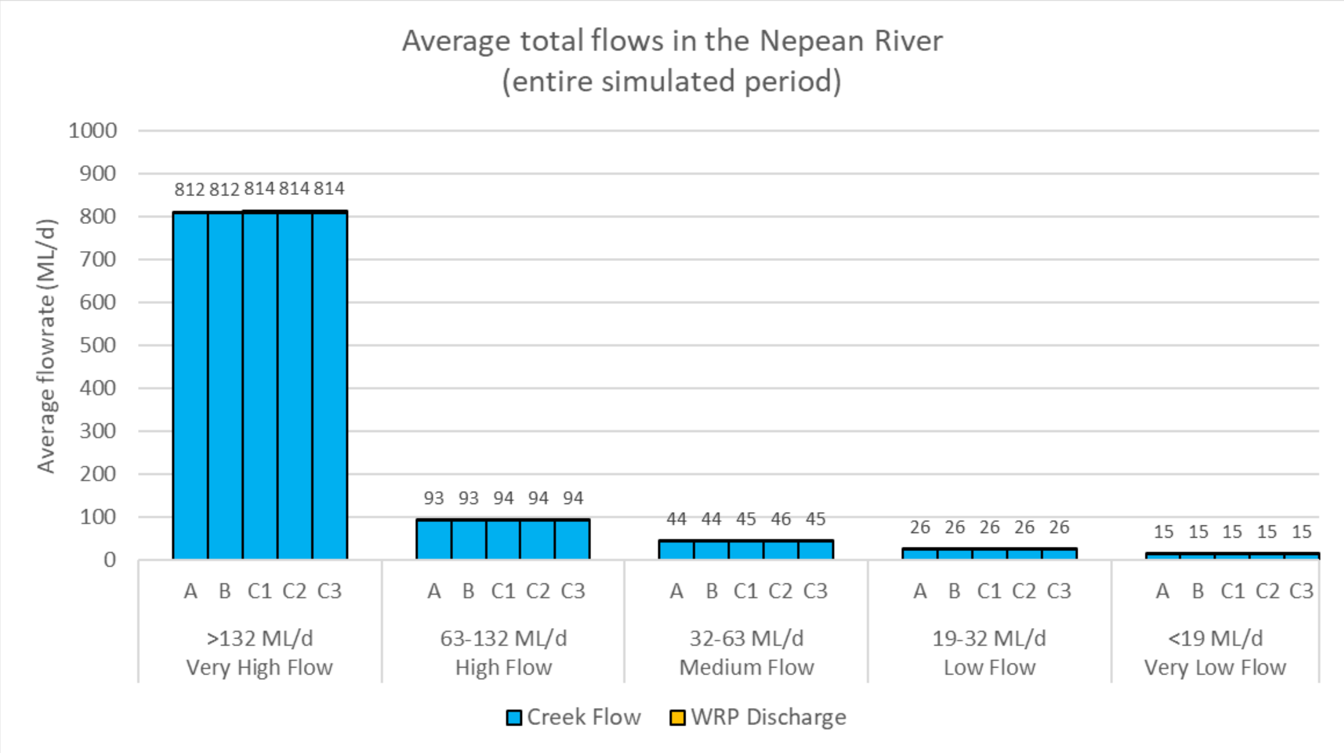

Figure 34 Average total proportionate flow in the Nepean River (entire simulated record)

2.2.3 USIA assessment

The principal USIA metrics have been determined for all scenarios and used as indicators for potential risk of degrading or losing creek value when comparing the future scenario values to the compliant condition values. These metrics are indicated in Table 15.

Table 15 USIA Metrics Comparison – Nepean River

Metric		Units	Scenario A	Scenario B	Scenario C1	Scenario C2	Scenario C3
USIA1	Mean Annual Flow Volume	ML/yr ML/d	92,628	**92,572**	93,093	93,109	93,104
USIA2	Mean duration of zero flow periods	days	None	**None**	None	None	None
USIA3	Percent duration of zero flow periods	%	0%	**0%**	0%	0%	0%
USIA 4 /Baseflow	Baseflow index (ratio of baseflow to total flow)	%	14%	**14%**	14%	14%	14%

Low risk of degrading or losing creek value
Moderate risk of degrading or losing creek value
High risk of degrading or losing creek value

All assessed metrics for all three proposed scenarios result indicate changes of less than 20% when comparing to the Scenario B values. This indicates a low risk of degrading or losing river values.

2.2.4 Ecological threshold exceedance assessment

As any expected changes in the flow duration curves as well as the key general USIA metrics are negligible, no further detailed assessment or hydraulic modelling to inform changes in ecological threshold exceedances have been conducted.

2.2.5 Qualitative flood impact assessments

For all proposed future scenarios the maximum discharge rate will be 15 ML/d or 0.17 m^3/s. Historic (pre-environmental flows) flood frequency curves (Sammut & Erskine, 1995) for the Nepean River at Maldon weir were sourced and compared to this maximum discharge rate (red line on graph in Figure 35). The data suggest a 50% AEP flow rate of almost 100,000 ML/d. The resultant impact of ARP discharges on flood levels would thus be negligible.

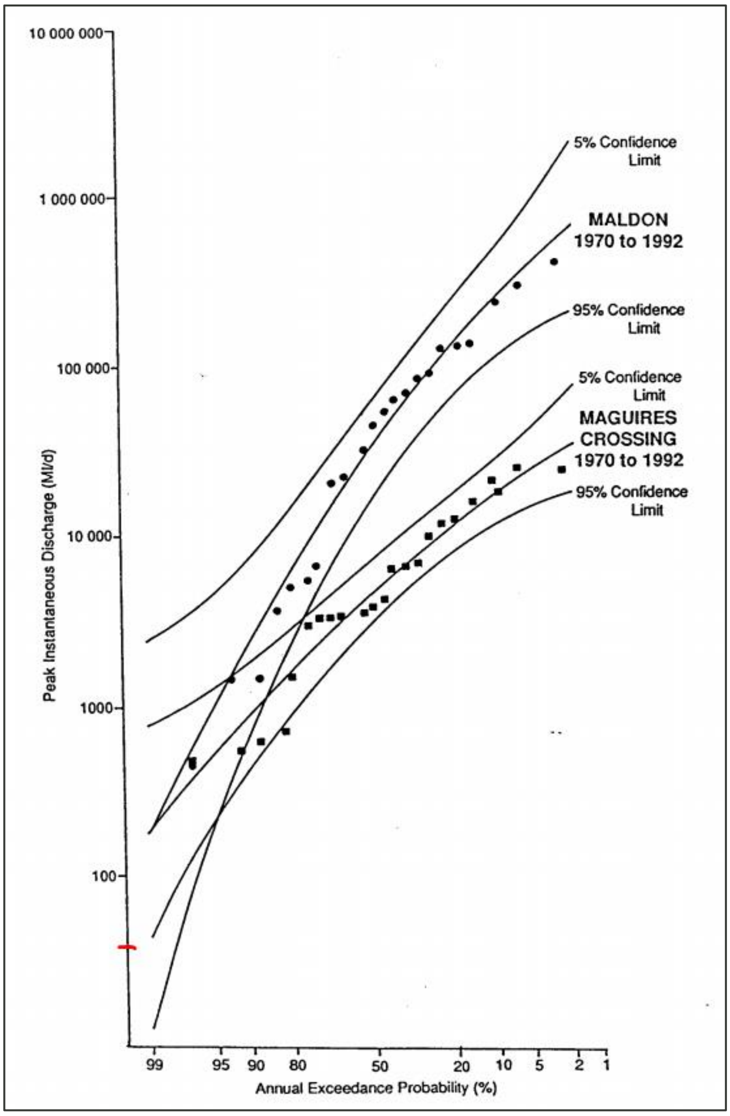

Figure 35 Flood frequency curves for the Nepean River (1970-1992)

2.3 Impact Assessment Summary

The significance of any potential project impact on the local hydrology has been determined by considering the sensitivity of the environment related to the assessed criteria as well as the magnitude of the expected change. The guiding matrix of significance is shown in Table 16.

Table 16 Matrix of significance

Magnitude of impact	Sensitivity of Environmental Values		
	High	Moderate	Low
High	Major	High	Moderate
Moderate	High	Moderate	Low
Low	Moderate	Low	Negligible

The *Sensitivity of Environmental Values* evaluation is influenced by the following criteria:

- Condition of the environmental value, i.e. how far is it understood to have already been changed from its original natural form or state?
- How unique or rare is the condition or value or it's dependant ecological receptors?
- How sensitive are the dependant receptors to changes?

Due to significant land use changes within both the Stonequarry Creek and Nepean River catchments, the flow profiles are assumed to have already been impacted to a moderate extent at both assessed locations. These impacts would lead to higher peak flowrates, and steeper recession responses following a storm event, resulting in lower baseflow volumes. High flow values at these locations are also relatively common and are likely to have changed significantly from natural conditions due to areas of urbanization and resultant quick stormflow response from these areas. Thus, metrics relating to high flows are generally allocated a "Low" sensitivity.

For the ecological threshold exceedance assessment, results from all reaches and cross-sections were lumped and the worst outcomes in terms of proportionate change indicated. The sensitivity to environmental values for this metric was deemed "Moderate", given the direct link to local ecological values, however also considering the base case (compliant scenario) results, which indicated either very high exceedances or none at all.

Using the above assessment technique, the significance of the potential impacts for all three future scenarios were determined and are shown in Table 17.

Table 17 Summary of the significance of impact for all assessed metrics

Metric/Value		Sensitivity to Environmental Values	Magnitude of impact			Significance of impact		
			Scenario C1	Scenario C2	Scenario C3	Scenario C1	Scenario C2	Scenario C3
Stonequarry Creek								
Flow duration curves / Probability of exceeding assessed flow thresholds	*Very low flow**	*Moderate*	*Moderate*	*Low*	*Moderate*	*Moderate*	*Low*	*Moderate*
	Low flow	Moderate	Low	Low	Low	Low	Low	Low
	Medium flow	Low	Low	Low	Low	Low	Low	Low
	High flow	Low	Moderate	Low	Low	Low	Low	Low
	Very high flow	Low	Moderate	Moderate	Moderate	Low	Low	Low
Mean Annual Flow Volume	USIA1	Moderate	Low	Low	Low	Low	Low	Low
Mean duration of zero flow periods	USIA2	Moderate	Low	Low	Low	Low	Low	Low
Percent duration of zero flow periods	USIA3	Moderate	Low	Low	Low	Low	Low	Low
Baseflow index (ratio of baseflow to total flow)	USIA 4 /Baseflow	Moderate	Low	Low	Low	Low	Low	Low
Ecological threshold exceedances		Moderate	Low	Low	Low	Low	Low	Low
Flooding		Low	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
Nepean River								
Flow duration curves / Probability of exceeding assessed flow thresholds	Very low flow	Moderate	Low	Low	Low	Low	Low	Low
	Low flow	Moderate	Low	Low	Low	Low	Low	Low
	Medium flow	Low	Low	Low	Low	Low	Low	Low
	High flow	Low	Low	Low	Low	Low	Low	Low
	Very high flow	Low	Low	Low	Low	Low	Low	Low
Mean Annual Flow Volume	USIA1	Moderate	Low	Low	Low	Low	Low	Low
Mean duration of zero flow periods	USIA2	Moderate	Low	Low	Low	Low	Low	Low
Percent duration of zero flow periods	USIA3	Moderate	Low	Low	Low	Low	Low	Low
Baseflow index (ratio of baseflow to total flow)	USIA 4 /Baseflow	Moderate	Low	Low	Low	Low	Low	Low
Flooding		Low	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible

**Note: As per the Picton Addendum Modelling Report (Sydney Water and Alluvium, 2021), model calibration for flows below 0.5 ML/d was less accurate and thus any analysis of results within this range should be mindful of this*

3 Conclusion

Extension of the previously completed REF work (Aurecon Arup, 2020) has been conducted to link ecological values and thresholds to the predicted hydrological and hydraulic responses associated with the proposed scenarios, specifically considering magnitudes of change.

The assessment was supported by the development of a hydraulic modelling platform and informed by the results of the eWater Source modelling (Sydney Water and Alluvium, 2021). The hydraulic modelling results were then analysed to enable comparison to the locally relevant ecological threshold values (CTEnvironmental, 2021).

The analysis results indicate the following for Stonequarry Creek downstream of the discharge location:

- The flow duration curves are expected to shift slightly, with the very low flow thresholds being exceeded more frequently (Scenario C1, C2 and C3) as well as very high flow conditions (all three future scenarios).
- The USIA metrics, looking at total average flowrate, zero flow periods and baseflow are expected to undergo minimal change, with a low risk rating allocated for all scenarios
- Changes in velocities within deep pools are expected to be negligible, remaining below all indicated threshold values except under extreme flood conditions
- Velocities through the restricted flow passages, such as the boulder choke associated with Downstream Reach 1, do currently exceed the stated thresholds periodically however these exceedances are not expected to increase in any significant way
- The analysis of the outlet location at the confluence with the Nepean River, indicates a minor increase in time that the potential for bass migration upstream will be impacted. A low risk rating has been allocated for all scenarios here.
- Negligible flood impacts.

Analysis of the Nepean flowrates, downstream of the confluence, indicate:

- Negligible changes in the flow duration curves
- Negligible changes in the assessed USIA metrics (total average flowrate, zero flow periods and baseflow)
- Negligible flood impacts

As a whole, the only metrics which indicate a potential for moderate risk are the exceedances of very low flows downstream for Scenarios C1 and C3. The Scenario C2 results indicate low risk levels associated with all the assessed metrics.

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- Chow V.T (1959), Open-channel hydraulics: New York, McGraw-Hill Book Co.
- CTEnvironmental (2021). Assessment of Potential Hydraulic Driven Impacts to Ecological Values of Stonequarry Creek, May 2021
- Sammut J. & Erskine W (1995). Hydrological impacts of flow regulation associated with the Upper Nepean Water Supply Scheme, NSW, Australian Geographer 26(1):71-86
- Streamology Pty Ltd. (2019). Stormwater and Outflow Planning Controls for Waterway Health: Applying the Urban Streamflow Impact Assessment, Stormwater Victoria 2019 Conference.
- Sydney Water and Alluvium (2021). Picton Addendum Modelling Report, Stonequarry Creek and Nepean River – Flow and Water Quality, May 2021
- Sydney Water (2021). Licence Variation – Waterway Assessment, Part A current impacts, February 2021
- WMAWater (2019). Wollondilly Shire Council - Stonequarry Creek (Picton) Flood Study Update, June 2019

Appendix A

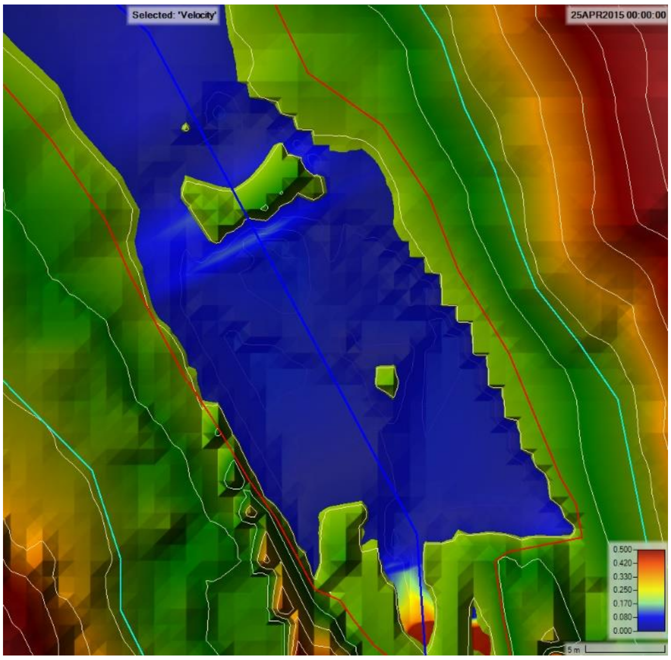
HEC-RAS model images – Velocity Profiles

Downstream Reach 1 – Pool and Boulder Choke

Median Velocity – Deep Pool XS

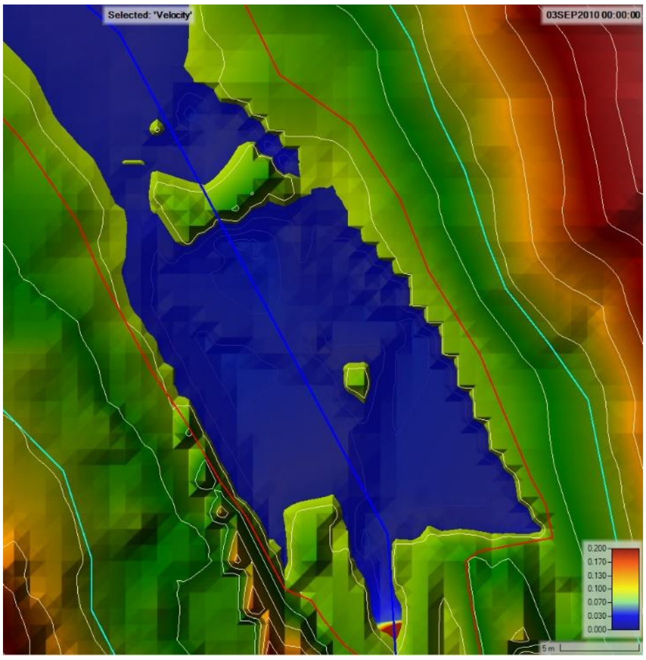
Scenario A

Avg velocity: 0.0005 m/s



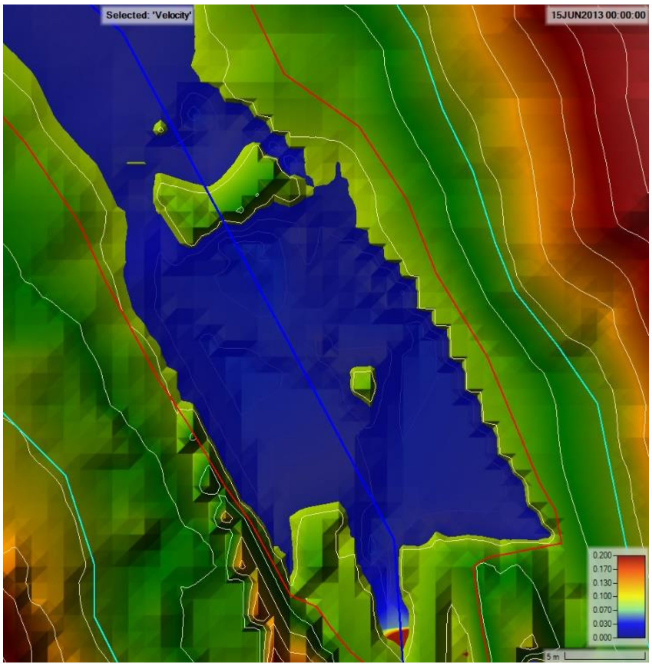
Scenario B

Avg velocity: 0.0001 m/s



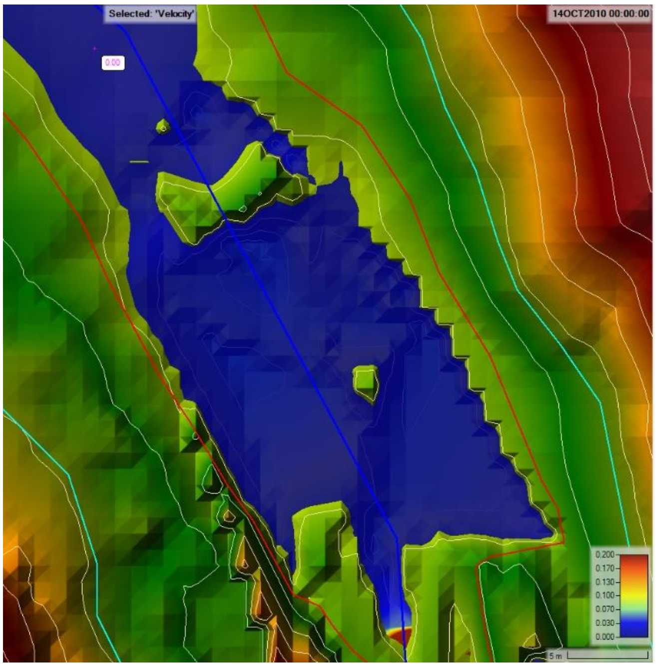
Scenario C1

Avg velocity: 0.0007 m/s



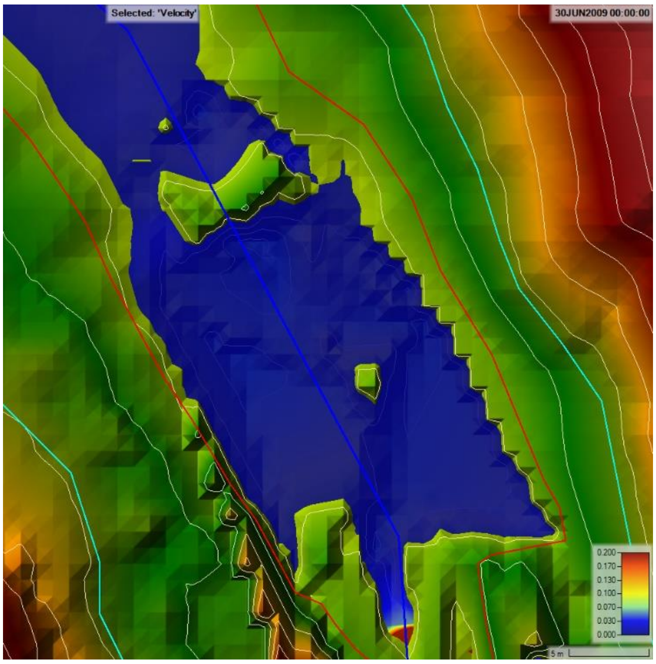
Scenario C2

Avg velocity: 0.0007 m/s



Scenario C3

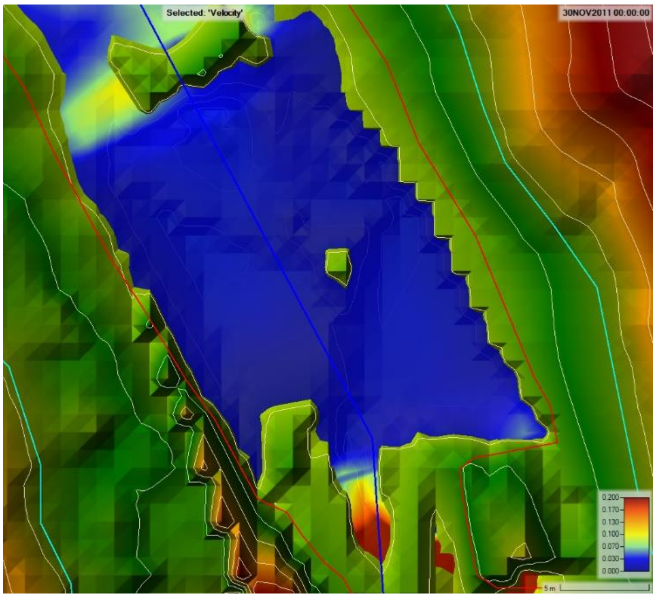
Avg velocity: 0.0007 m/s



90th Percentile Velocity – Deep Pool XS

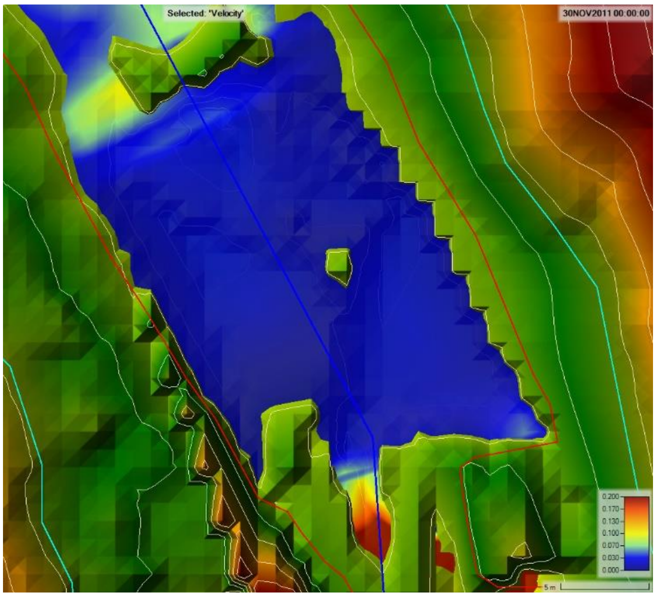
Scenario A

Avg velocity: 0.009 m/s



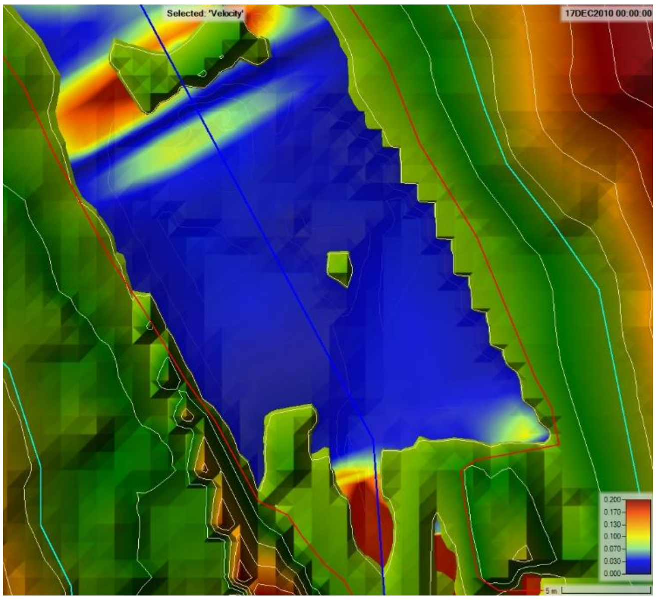
Scenario B

Avg velocity: 0.009 m/s



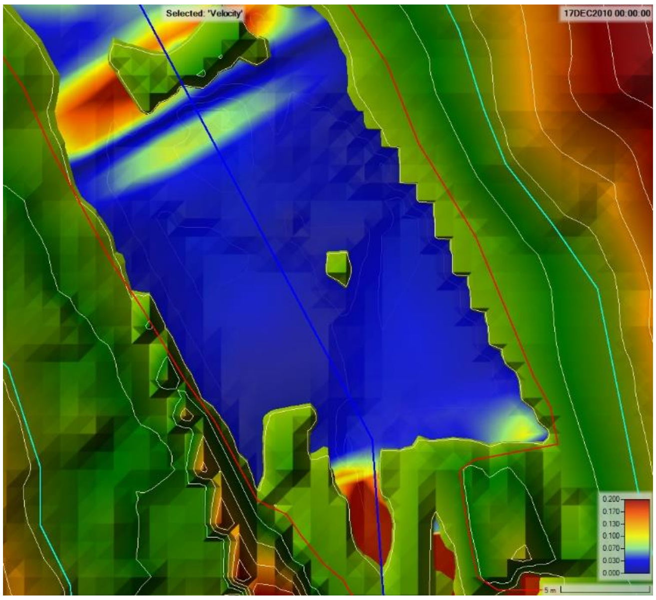
Scenario C1

Avg velocity: 0.010 m/s



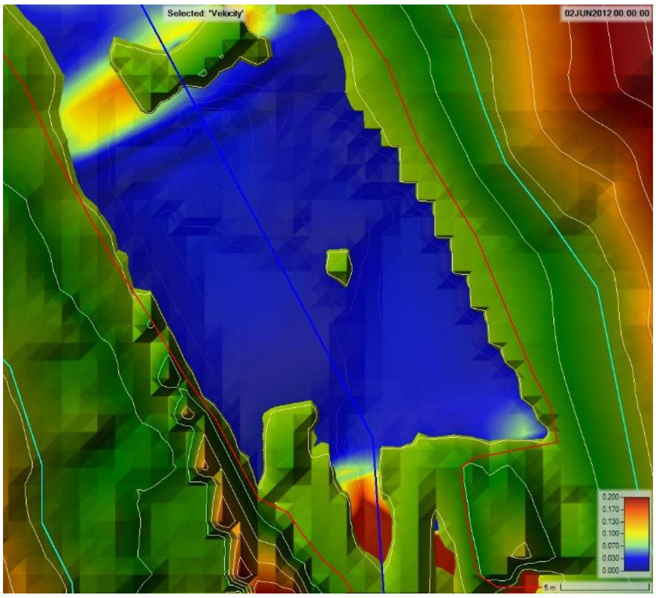
Scenario C2

Avg velocity: 0.010 m/s

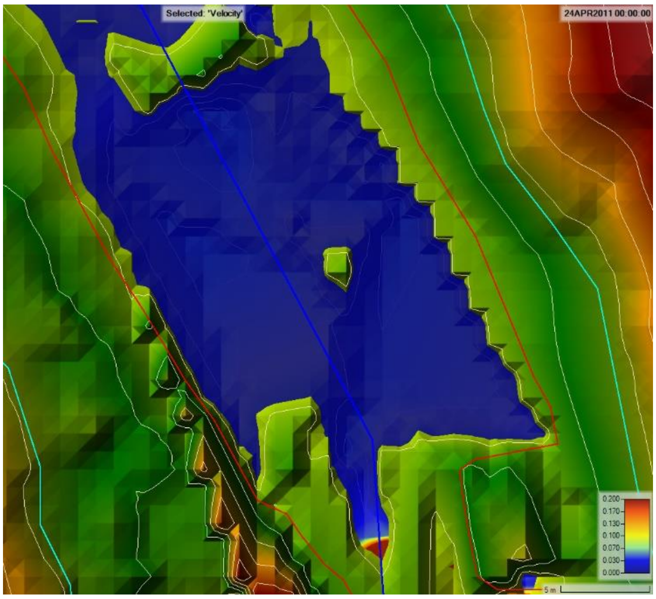
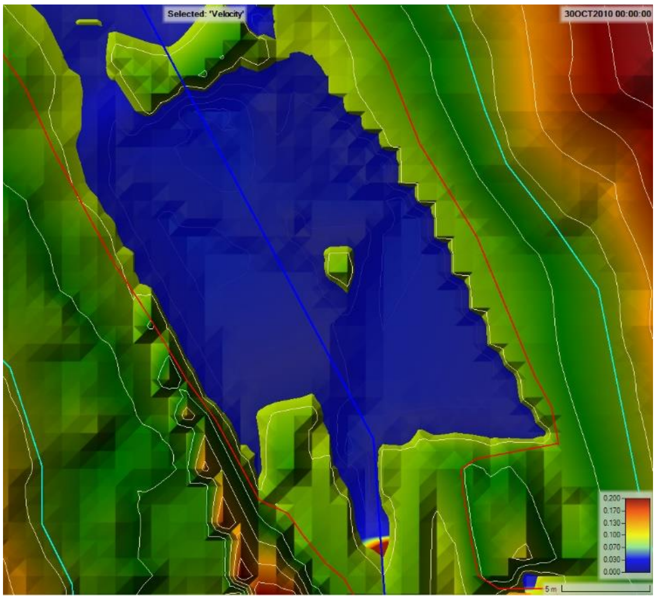
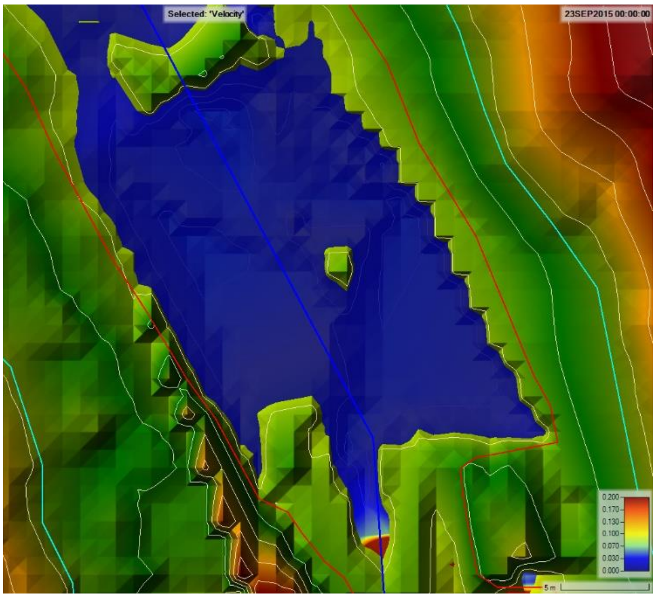
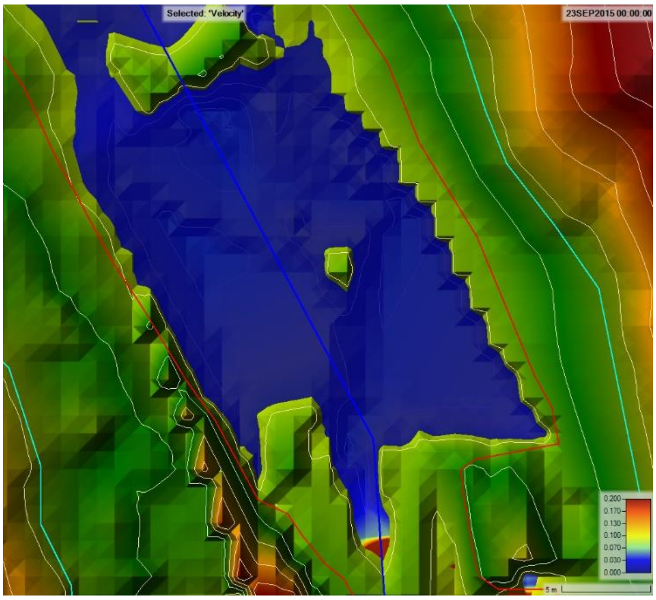


Scenario C3

Avg velocity: 0.010 m/s

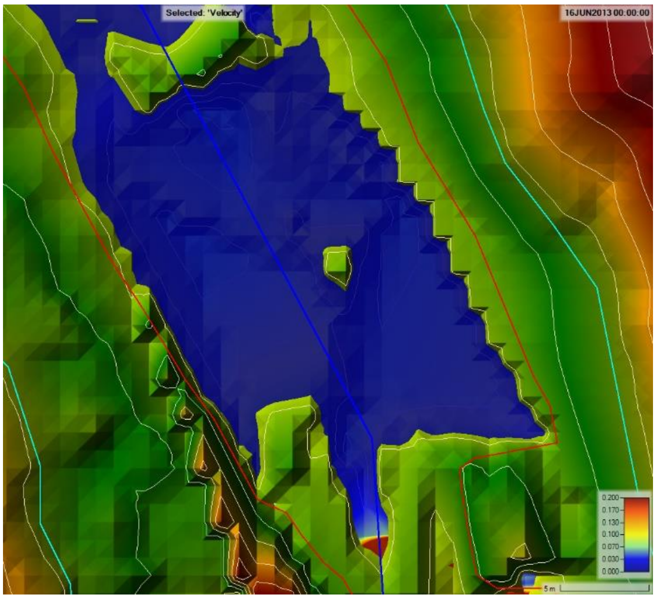


Median Velocity – Boulder Choke XS

Scenario A Avg velocity: 0.040 m/s	**Scenario B** Avg velocity: 0.026 m/s
	
Scenario C1 Avg velocity: 0.051 m/s	**Scenario C2** Avg velocity: 0.051 m/s
	

Scenario C3

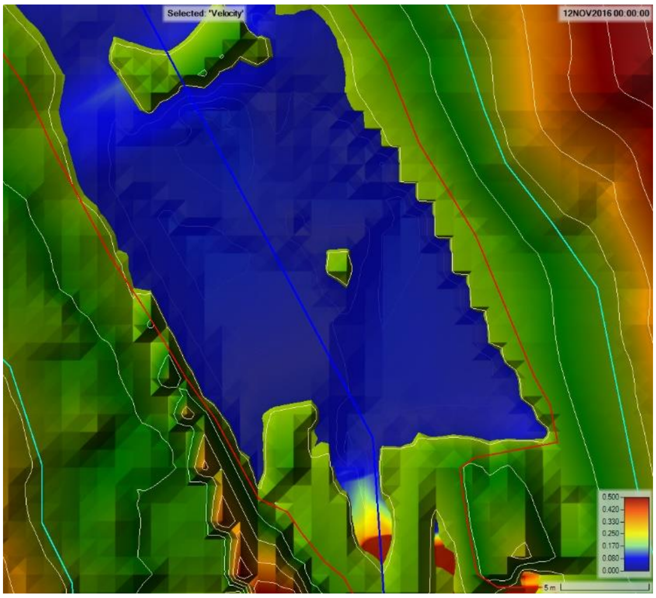
Avg velocity: 0.050 m/s



90th Percentile Velocity – Boulder Choke XS *(Note: adjusted colour scale used, max 0.5 m/s)*

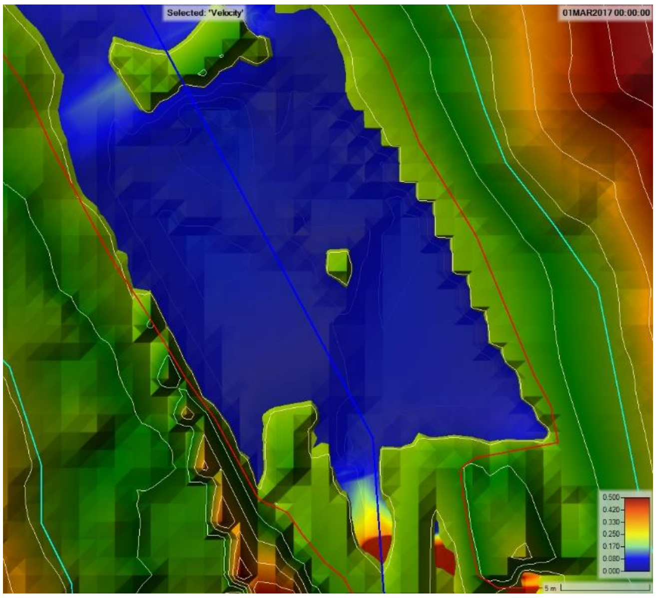
Scenario A

Avg velocity: 0.323 m/s



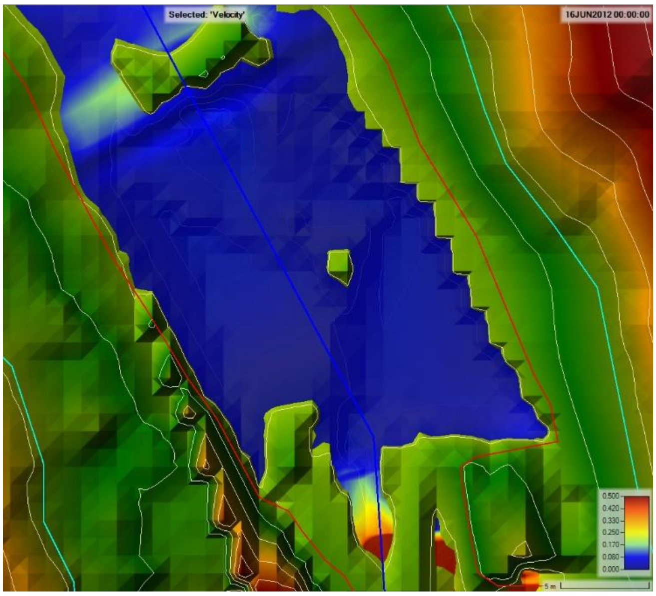
Scenario B

Avg velocity: 0.325 m/s



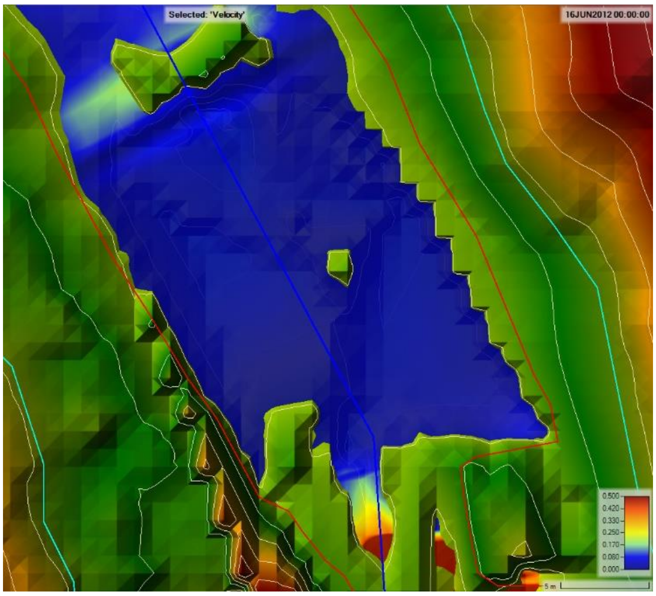
Scenario C1

Avg velocity: 0.350 m/s



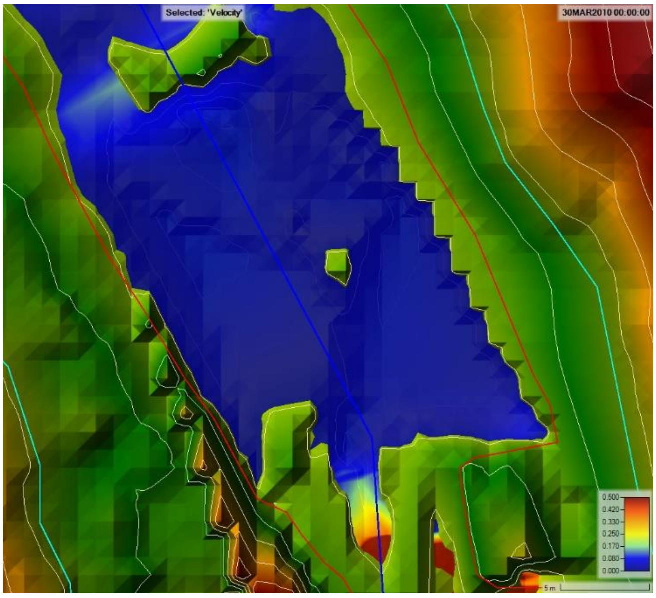
Scenario C2

Avg velocity: 0.350 m/s



Scenario C3

Avg velocity: 0.352 m/s

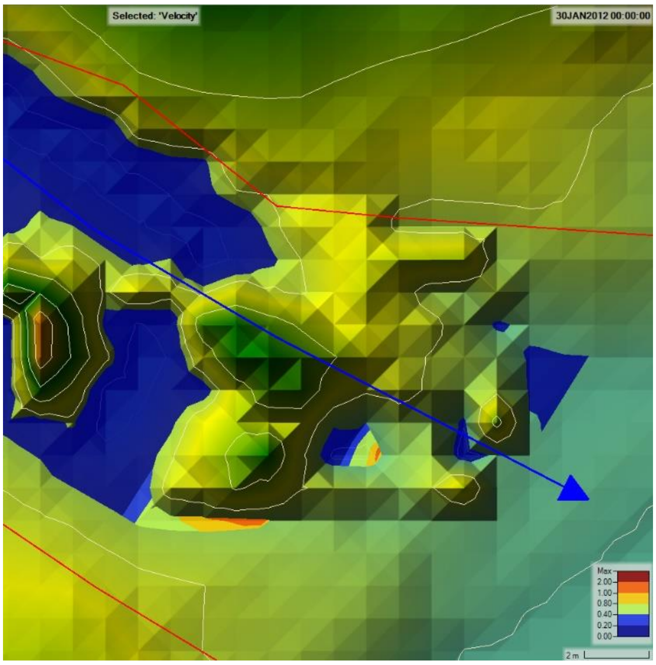


Downstream Reach 2 – Nepean Outlet

Median Velocity

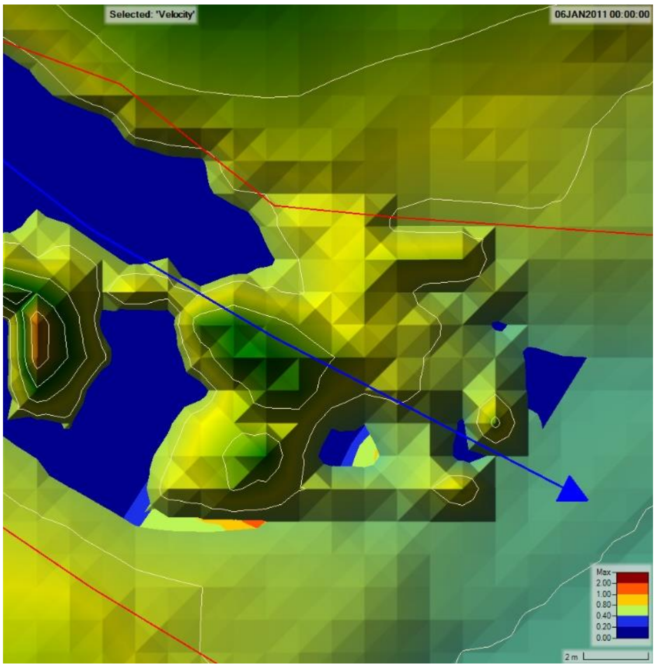
Scenario A

Avg velocity: 0.329 m/s



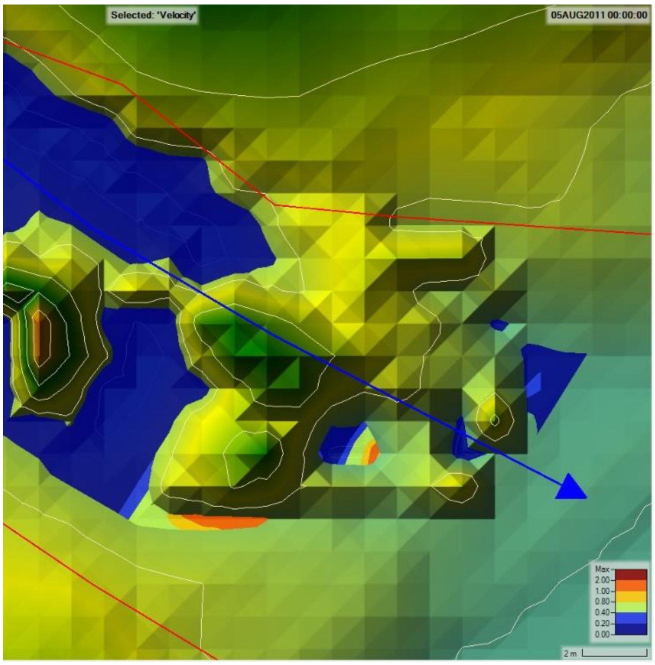
Scenario B

Avg velocity: 0.280 m/s



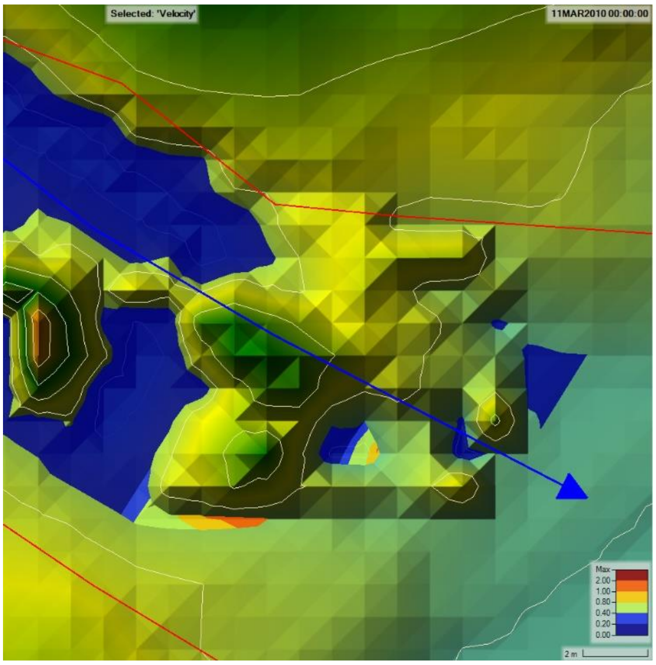
Scenario C1

Avg velocity: 0.369 m/s



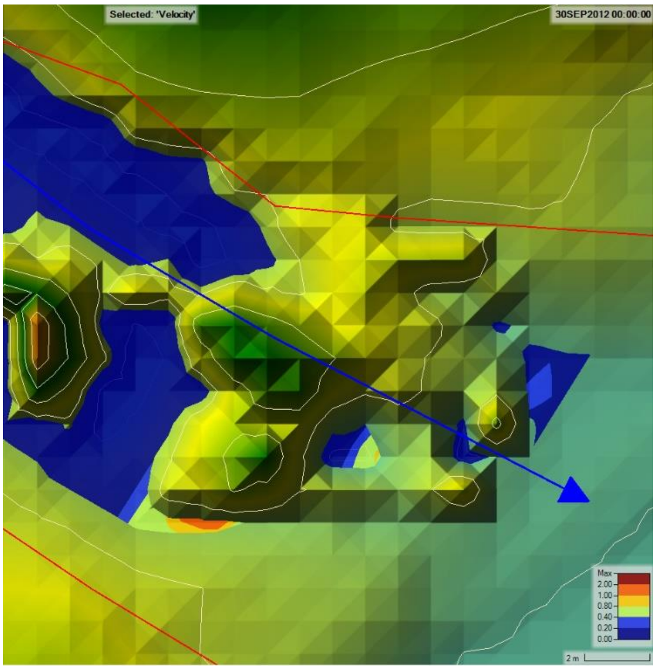
Scenario C2

Avg velocity: 0.291 m/s



Scenario C3

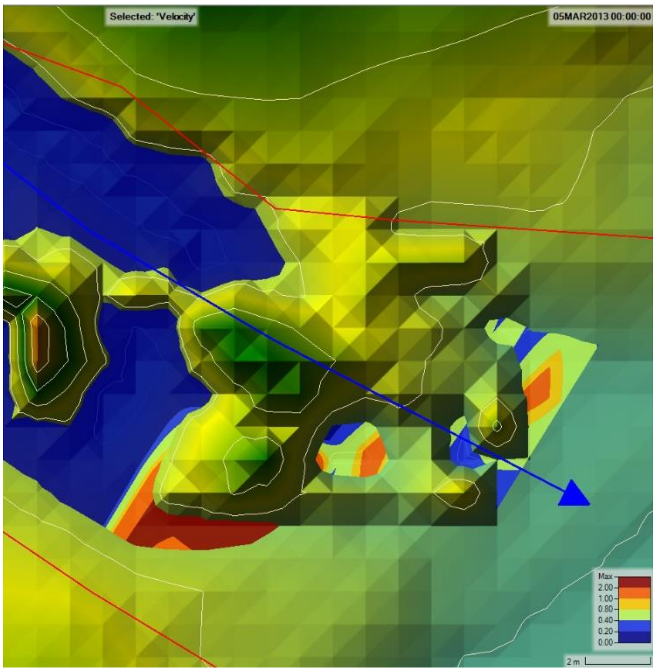
Avg velocity: 0.361 m/s



90th Percentile Velocity

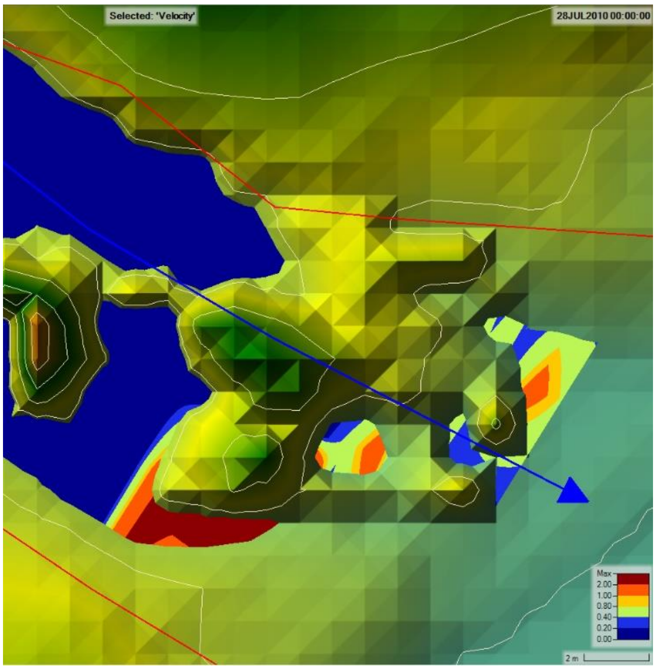
Scenario A

Avg velocity: 1.173 m/s



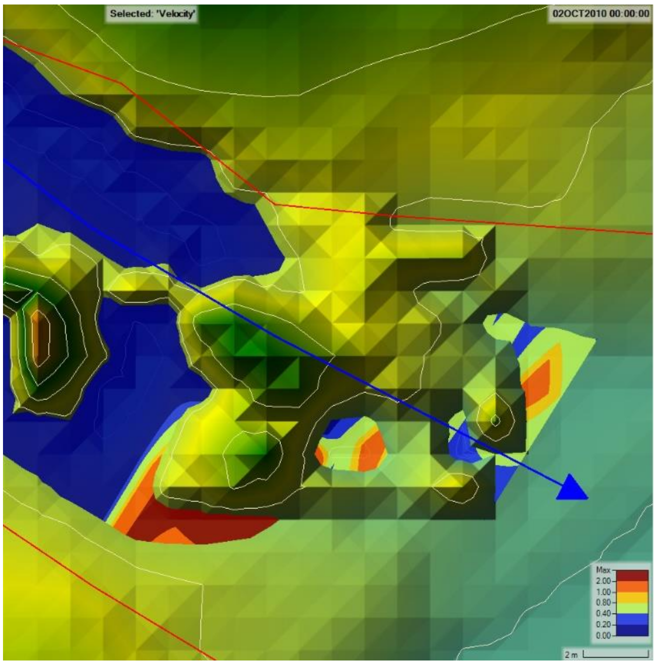
Scenario B

Avg velocity: 1.170 m/s



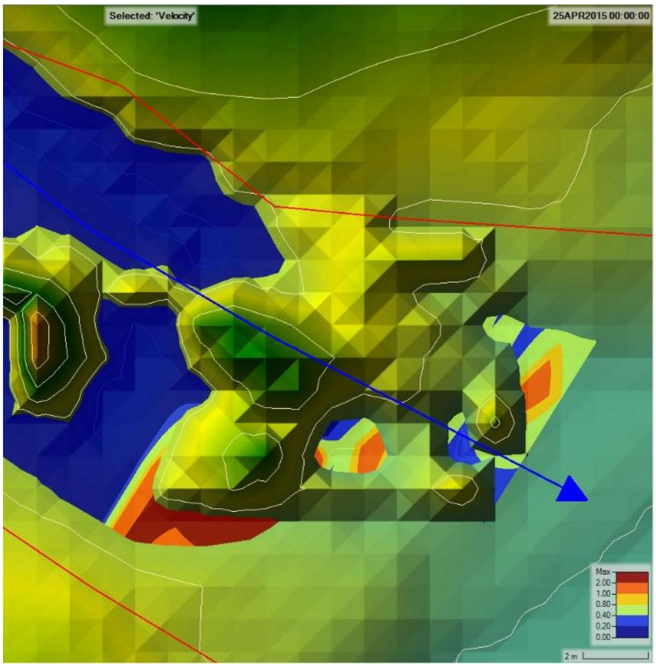
Scenario C1

Avg velocity: 1.190 m/s



Scenario C2

Avg velocity: 1.144 m/s



Scenario C3

Avg velocity: 1.199 m/s