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Rev 1

Flooding, Ecohydrology and Geomorphology Assessment

Northwest Treatment Hub Review of Environmental Factors Report Addendum

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Approval			
Author Name	**Bill Tran**	**Approver Name**	**Paul Dunne**
Author Title	Water Engineer	**Approver title**	Senior Water Resources Engineer
Author Signature	[redacted]	**Approver Signature**	[redacted]
Author Name	**Stephen Clarke**		
Author Title	Senior Water Resources Engineer		
Author Signature	[redacted]		

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1 Introduction

A hydrology and geomorphology impact assessment was undertaken in 2022 to inform the Review of Environmental Factors (REF) for capacity upgrades to Sydney Water's Northwest Treatment Hub (NWTH). The NWTH consists of the following Sydney Water water resource recovery facilities (WRRF):

- Castle Hill WRRF with treated water releases to Cattai Creek;
- Rouse Hill WRRF with treated water releases to Second Ponds Creek, a tributary of Cattai Creek; and
- Riverstone WRRF with treated water releases to Eastern Creek, approximately 3 km upstream from the confluence with Wianamatta-South Creek.

The increased average dry weather flows (ADWF) capacity of the treatment plants will result in increased treated water release. The phased upgrades and associated projected ADWF values which were investigated in the NWTH REF (Sydney Water, 2022) are detailed in Table 1-1.

Table 1-1 Projected ADWF for NWTH plants by year (Sydney Water, 2022)

NWTH Plants	Projected ADWF Capacity (ML/d)		
	2021 (Current)	2026	2036
Castle Hill WRRF	6.9	8.2	10.1
Rouse Hill WRRF	28.1	32.1	42.6
Riverstone WRRF	13.1	17.4	27.8

In the original NWTH REF, the 2036 ADWF capacity for Riverstone WRRF was reported as 30 ML/d, despite Table 1-1 stating 27.8 ML/d. Since the completion of the NWTH REF (Sydney Water, 2022), the capacity upgrades to Riverstone WRRF have been reviewed and amended. Consequently, an increase in ADWF from 30 ML/d to 41 ML/d is now projected. Rouse Hill and Castle Hill WRRF projected ADWF has not changed since the NWTH REF assessment in 2022. This has prompted the need to reassess the following:

1. How are the flooding, ecohydrology and geomorphology conditions affected downstream of the release points due to the NWTH upgrades?
2. How do wet and dry climatic conditions affect the flooding, ecohydrology and geomorphology conditions of the receiving waterways?

This report addendum (REFA) serves as an addendum to the existing REF, summarising the flooding, ecohydrology and geomorphology assessments undertaken with the increased flows to 41 ML/d and revised impact assessment results.

1.1 Previous Studies

The following reports were reviewed to examine the existing conditions along Eastern Creek and Wianamatta South Creek:

- Northwest Treatment Hub Review of Environmental Factors Hydrology and Geomorphology Impact Assessment Riverstone WWTP Upgrade (Sydney Water, 2022).
- Wianamatta South Creek Catchment Flood Study Existing Conditions (Advisian, 2022).

- Eastern Creek Hydraulic Assessment (Catchment Simulation Solutions, 2014).

1.2 Assumptions

Several assumptions were adopted to characterise the existing hydrological conditions and performance of Riverstone WRRF. These assumptions are summarised below:

- All flows are expected to receive as a minimum primary treatment and disinfection. Flows that bypass secondary/tertiary treatment during wet weather are combined prior to discharge with tertiary treated flows.
- Data extracted from Volume Monitoring Gauge 942020 appropriately represents the historic treated effluent and any potential bypass flows from Riverstone WRRF.
- Hydrological conditions at Eastern Creek, upstream of the confluence with Quakers Creek is representative of the catchment conditions upstream of Riverstone WRRF.
- Manning's n value of 0.045 sufficiently describes the flow conditions and hydrological environment of Eastern Creek.

2 Flooding

2.1 Maximum Peak Hourly Flow Rate

Sydney Water's HYDSTRA database contains flow data captured from flow measurement devices across various Sydney Water sites. The peak hourly flow rate from Riverstone WRRF was extracted from Sydney Water's HYDSTRA database from Volume Monitoring Gauge 942020.

The peak hourly flow rate was assumed to represent all effluent discharges from the WRRF, including bypass flows. These figures were then scaled according to the increased average dry weather flow (ADWF) capacity to represent the future operating conditions of the WRRF. The methodology adopted to represent the future WRRF operating conditions was consistent with the hydrodynamic and water quality assessment. Table 2-1 showcases the maximum peak hourly flow rate figure for the WRRF between the 1st of July 2013 to the 30th of June 2015 that was selected to inform this assessment. The process flow diagram, extracted HYDSTRA dataset and adopted methodology to derive the peak hourly flow rate for Riverstone WRRF is detailed in Appendix A.

Table 2-1 Scaled maximum peak hourly flow rate from HYDSTRA dataset

WRRF Capacity and Effluent Discharge	2013-2015 Performance	Updated Future Performance of Riverstone WRRF (2036)
ADWF Capacity (ML/d)	1.60	41.0
Max Peak Hourly Flow Rate (m^3/s)	0.21	5.37

2.2 Existing Hydrological Conditions and Predicted Impact

To assess the impact of flooding conditions from the increased ADWF capacity of Riverstone WRRF, the peak discharge and change in water level was examined. Flood study reports pertinent to Eastern Creek and Wianammata South Creek were reviewed to understand the existing hydrological conditions upstream of Riverstone WRRF. Table 2-2 summarises the discharges reported for the 1% annual exceedance probability (AEP) storm event.

Table 2-2 Reported peak 1% AEP discharges at South Creek and Eastern Creek

Location	Peak 1% AEP Discharge (m^3/s)
South Creek, Upstream of Richmond Road (Advisian, 2022)	1553
Eastern Creek, Upstream of Quakers Creek Confluence (Catchment Simulation Solutions, 2014)	604

The peak 1% AEP discharge at Eastern Creek, upstream of Quakers Creek confluence was selected as the representative upstream catchment condition of Riverstone WRRF. There were no additional reporting locations closer to the vicinity of Riverstone WRRF. Furthermore, assessing the flooding impacts at the Eastern Creek Quakers Creek confluence will yield more conservative results as flooding impacts are further attenuated downstream. By comparing the peak 1% AEP discharge and the peak hourly flow rate, less than 1% change (0.8%) is expected under the 1% AEP storm event. These results are summarised in Table 2-3.

Table 2-3 Percentage change in flow impacts compared to existing flood conditions

Eastern Creek	Existing Flood Condition (m^3/s)	Maximum Peak Hourly Flow from Updated Riverstone WRRF (2036)	Percentage Change
1% AEP Event	604	5.37	<1% (0.8%)

2.3 Impact to flood levels

To assess the potential impacts of the revised discharge on the potential effects of flooding, an estimation of the flood depth was made using a Manning's calculation. This calculation provides an indication of the relative difference in flood level associated with the maximum anticipated wet weather flow. A cross section of Eastern Creek was created using LiDAR data at the Quakers Creek confluence. The longitudinal slope of Eastern Creek at the cross section was determined from the 1% AEP flood maps. The results of this assessment are presented in Table 2-4. Details of the assessment undertaken, including the assumptions adopted are included in Appendix B.

Table 2-4 Relative flood level impact compared to existing flood conditions

Eastern Creek	Predevelopment Level (m AHD)	Post Development Level (including maximum peak hourly flow from Updated Riverstone WRRF (2036)) (m AHD)	Depth (Level) difference (m)
1% AEP Event	17.015	17.02	<0.01m

3 Ecohydrology and Geomorphology

3.1 Previous Studies

- Northwest Treatment Hub Review of Environmental Factors Hydrology and Geomorphology Impact Assessment Riverstone WWTP Upgrade (Sydney Water, 2022)
- Northwest Treatment Hub Aquatic Ecology Assessment (EcoLogical Australia, 2021)
- Upper South Creek AWRC Environmental Impact Statement (Sydney Water, 2019)

3.2 Existing Waterway Form

The existing waterway conditions identified for Eastern Creek for the 2022 NWTH REF (Sydney Water, 2022) are provided in Table 3-1.

Table 3-1 Features of Eastern Creek downstream of wastewater treatment plant discharge (Eco Logical Australia, 2021)

Reach	Hydrology	Physical form	Instream habitat	Streamside vegetation	Overall condition
Eastern Creek Downstream of WWTP discharge point	4th order stream. Predominantly cleared catchment used for agriculture. Continual flows. Evidence of very high previous flows, with flood debris evident in trees No impoundments or significant barriers to flow, apart from a fallen tree across the creek.	Channel up to 10 m wide Banks up to 2 m high, mostly 45° slope. Channel has low grade and low sinuosity, and is well defined through a predominantly grassed floodplain. Some bank erosion observed where stock have accessed the creek and where banks have been undercut and a large tree had fallen into the creek. Substrate likely silt and clay	Key fish habitat – Type 1 highly sensitive where native macrophytes are present and Type 2 Moderately sensitive key fish habitat due to continuous flows. Flowing at time of survey 100% run sequence, no pools or riffles observed. Some large submerged woody debris, contributing to habitat. Channel suited to amphibians and small fish, though none observed. Limited macrophytes, mainly in clumps alongside right bank. Water relatively turbid.	Poor riparian extent and continuity, typically dominated by Erythrina sp. No evidence of native recruitment. Riparian structure notably absent of a native canopy, midstorey and groundcover 40% tree cover 5% shrub cover 80% exotic grass	Poor condition, stabilised bank only by exotic canopy trees.

The condition of Eastern Creek is therefore considered to be poor and in a state of degradation associated with long-term anthropogenic influence of its catchment. Of note is that the vegetation in this portion of the waterway is largely comprised of introduced species and is lacking in larger individual trees that would provide waterway stability through root mass.

3.3 Revised Impact Scenario for Ecohydrology/Geomorphology

The assessment of impacts to ecohydrology and geomorphology for this addendum has been based on changes in conditions to both treated water discharge conditions of the Riverstone WRRF and catchment land use. Changes to these conditions have been assessed relative to existing conditions (i.e. 2020) for both.

Three treated water discharge conditions have been evaluated for the Riverstone WRRF, the existing conditions ADWF capacity of 13.1 ML/d, the 2022 REF (Sydney Water, 2022) ADWF capacity of 27.8 ML/d, and the revised ADWF capacity of 41 ML/d for this 2025 REFA.

Two catchment conditions have been evaluated for land use change. These conditions are the existing development conditions and projected 2036 development conditions based on Western Parkland land use typologies (Hoban et al., 2020).

The change to these conditions has been assessed in combination for a total of four scenarios, and the details of conditions for each scenario are provided in Table 3-2.

Table 3-2 REF assessment scenarios

Scenario	Indicative Year	Catchment Conditions	Treated Water Flow Conditions
Baseline	2020	Existing development conditions	Existing discharge from Riverstone WRRF
Impact	2036	2036 development conditions for Western Parkland	2022 REF discharge from Riverstone WRRF
Revised Impact	2036	2036 development conditions for Western Parkland	2025 REFA discharge from Riverstone WRRF
Baseline + Revised	2020	Existing development conditions	2025 REFA discharge from Riverstone WRRF

The flow duration curves for each scenario are presented in Figure 3-1 below:

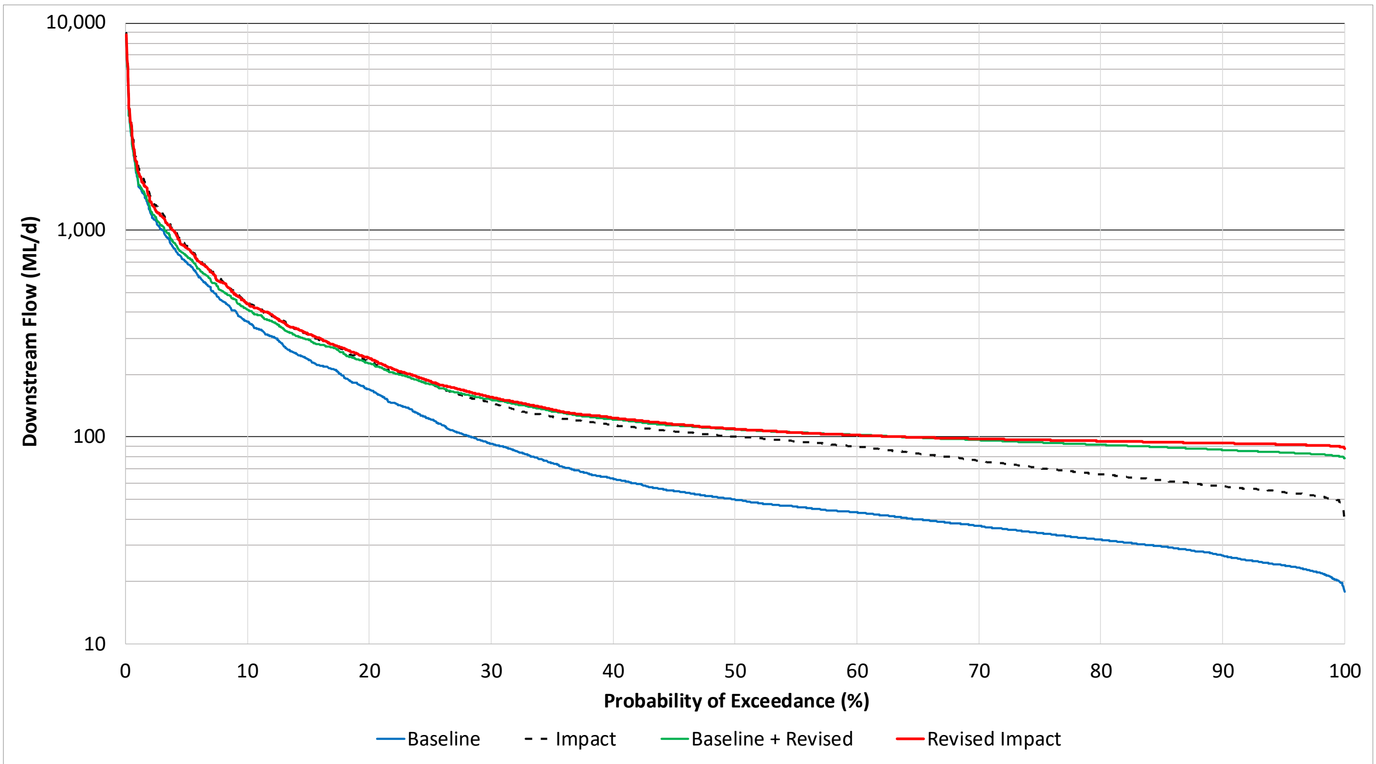

Figure 3-1 Eastern Creek flow duration curves by scenario modelled downstream of Riverstone WRRF

These scenarios have been assessed at the three nominated reporting locations of the 2022 REF which are demonstrated in Figure 3-2.

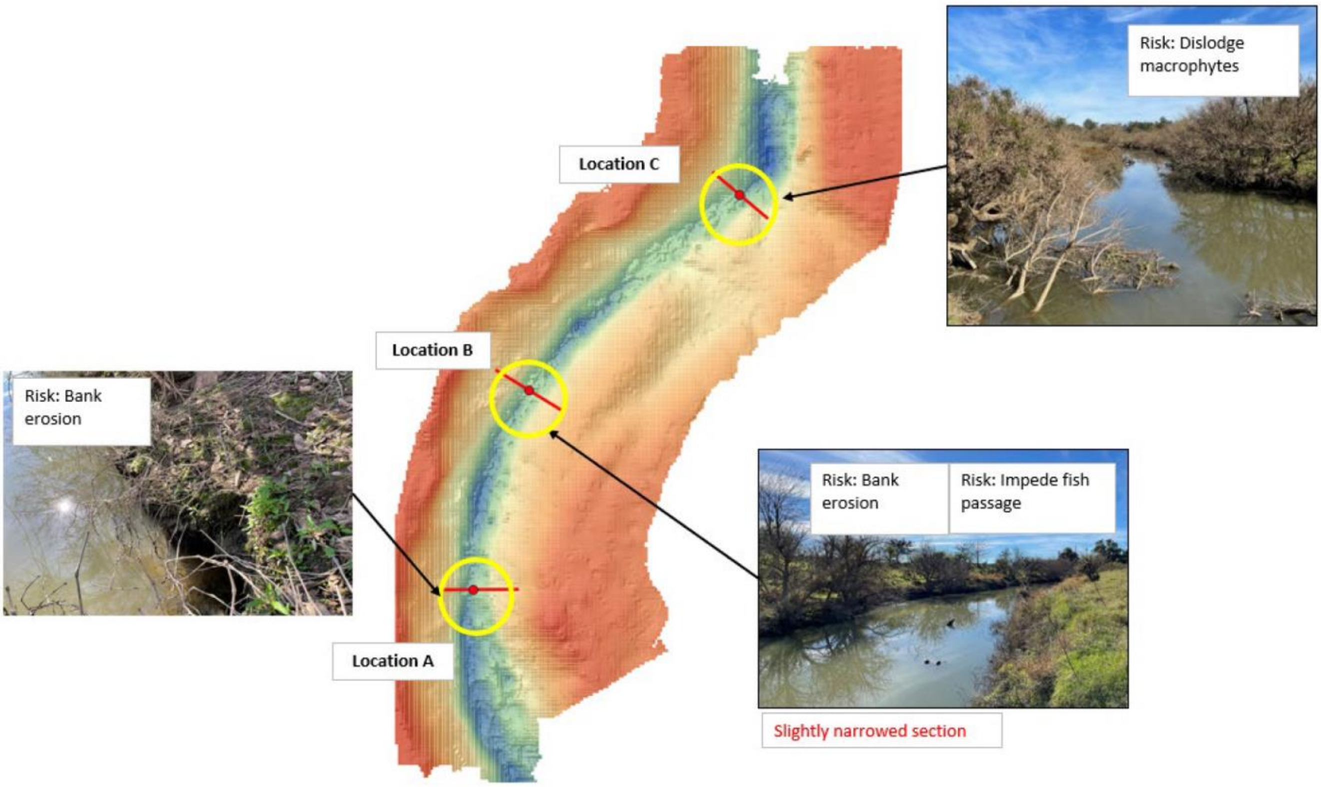

Figure 3-2 Nominated reporting locations for Eastern Creek downstream of the Riverstone WRRF

These reporting locations have been previously selected because of their representative nature with respect to the ecohydrological and geomorphological threats to the creek.

Specifically, these threats were taken to include:

- Obstructive velocities in the waterway limiting fish passage (Location B);
- Erosion and deposition of substrate modifying the physical form of the creek (Location A and B); and
- Smothering, uprooting or removal of macrophyte communities (Location C).

For all three reporting locations, three tailwater conditions for Eastern Creek have been evaluated as:

- Mean low water tailwater level – nominally the mean low tide conditions experienced by Eastern Creek of -0.05 mAHD;
- Mean sea level tailwater level – nominally the mean sea level at the year 2020 of 0.3 mAHD; and
- Mean high water tailwater level – nominally the mean high tide conditions experienced by Eastern Creek of 0.65 mAHD.

These tailwater conditions have been selected to demonstrate the influence of the receiving environment on the hydraulics of Eastern Creek and to enable a conservative assessment of impacts to ecohydrology and geomorphology for the revised treated water discharges proposed at Riverstone WRRF.

3.3.1 Impact classification

The significance of any potential project impact on Eastern Creek has been determined in the manner used in the previous NWTH REF (Sydney Water, 2022). This has consisted of two considerations for impacts – environmental sensitivity to the impact and predicted magnitude of the impact. The matrix representing this is demonstrated in Table 3-3.

Table 3-3 Impact significance two-factor matrix (Sydney Water, 2022)

Magnitude of Impact	Environmental Sensitivity to Impact		
	Low	Medium	High
Low	Negligible	Low	Moderate
Medium	Low	Moderate	High
High	Moderate	High	High

3.3.2 Ecohydrology

The impacts to ecohydrology for Eastern Creek have been based on the fish species identified in the 2022 NWTH REF (Sydney Water, 2022). These species and their threshold velocities taken from published literature (Watson et al., 2019) are provided in Table 3-4.

Table 3-4 Nominated fish species for ecohydrological impact assessment for Eastern Creek with threshold velocity

Scientific Name	Common name	Body Shape	Threshold Velocity 25th Percentile (m/s)
Macquaria novemaculeata	Australian Bass	Compressiform	0.53
Trachystoma petardi	Freshwater mullet	Fusiform	0.8
Hypseleotris compressa	Empire gudgeon	Compressiform	0.34
Hypseleotris galii	Firetail gudgeon	Compressiform	0.34
Retropinna semoni	Australian Smelt	Fusiform	0.62

The threshold velocities of these species are associated with specific flows within Eastern Creek downstream of the Riverstone WRRF. These velocities have been used to identify the flows at which they will occur for all three reporting locations under the three tailwater conditions identified. An example of a rating curve for velocity based on flow for Reporting Location B is demonstrated in Figure 3-3.

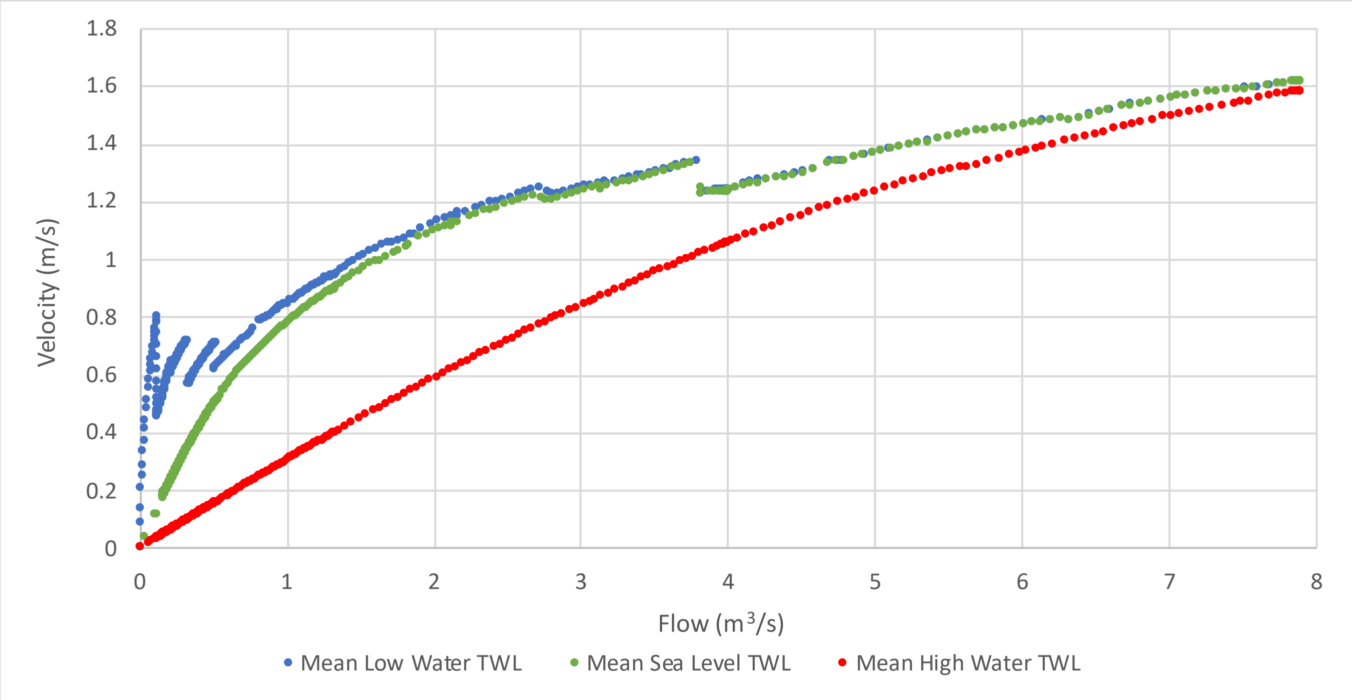

Figure 3-3 Rating curve of velocity with respect to flow for Reporting Location B in Eastern Creek downstream of Riverstone WRRF

The rating curve for the mean low water tailwater level demonstrates that the system is very sensitive to flow when this tailwater condition is occurring. Multiple flows for the nominated velocity are possible, indicating a supercritical flow condition that is dominated by kinetic energy (i.e. velocity). This tailwater condition is, therefore, the most conservative mean tailwater condition for the passage of fish; however, these velocities represent the thalweg flows in the system and are not representative of the conditions along the banks where velocities are most likely to be sufficiently reduced.

The corresponding flows associated with each threshold velocity by reporting location are provided in Table 3-5.

Table 3-5 Eastern Creek Threshold velocities and corresponding flows for nominated fish species by reporting location

Indicator or Species	Threshold Velocity (m/s)	Corresponding Flow (ML/d) by Reporting Location		
		A	B	C
Australian Bass	0.53	342.2	47.13	123.2
Freshwater mullet	0.8	802.9	89.74	182.4
Empire gudgeon	0.34	167.3	27.07	81.34
Firetail gudgeon	0.34	167.3	27.07	81.34
Australian Smelt	0.62	485.1	58.86	143.1
Sand and Silts erosion	1.00	982.3	134.9	226.1

Based on the flow duration curve in Figure 3-1 and the velocity rating curves at each of the three reporting locations, the probability of exceedance of threshold velocities by species (Table 3-4) for each of the scenarios assessed was produced. This probability can be assumed to be representative of the percentage of time that flows, and consequent velocities, are expected to exceed thresholds over the course of an average year.

Flows nominated are for centreline velocities in Eastern Creek and are likely to overpredict the time in which conditions exceed threshold velocities for the nominated species as per the mapped velocity distributions at each reporting location in Figure 3-4.

3.3.2.1 Reporting Location A

The percent of time that threshold velocities are exceeded at Reporting Location A by indicator or species for each of the four scenarios modelled are outlined in Table 3-6.

Table 3-6 Nominated fish species for ecohydrological impact assessment for Eastern Creek with threshold velocity at Reporting Location A

Indicator or Species	Threshold Velocity (m/s)	Scenario				Sensitivity of Environment to Impact
		Baseline	Impact	Baseline + Revised	Revised Impact	
Australian Bass	0.53	12%	15%	15%	15%	Low
Freshwater mullet	0.8	6%	7%	6%	7%	Low
Empire gudgeon	0.34	22%	28%	28%	30%	Low
Firetail gudgeon	0.34	22%	28%	28%	30%	Low
Australian Smelt	0.62	9%	11%	10%	11%	Low
Sand and Silts erosion	1.00	5%	6%	5%	6%	Low

These results indicated that Reporting Location A is not likely to experience an impact to velocities that would endanger the migration of fish to the upstream reaches of Eastern Creek and that any impacts would likely be of low significance.

3.3.2.2 Reporting Location B

Table 3-7 provides the percent of time that threshold velocities are exceeded at Reporting Location B by indicator or species for each of the four scenarios modelled.

Table 3-7 Nominated fish species for ecohydrological impact assessment for Eastern Creek with threshold velocity at Reporting Location B

Indicator or Species	Threshold Velocity (m/s)	Scenario				Sensitivity of Environment to Impact
		Baseline	Impact	Baseline + Revised	Revised Impact	
Australian Bass	0.53	55%	100%	100%	100%	Medium
Freshwater mullet	0.8	33%	62%	86%	100%	Medium
Empire gudgeon	0.34	91%	100%	100%	100%	Medium
Firetail gudgeon	0.34	91%	100%	100%	100%	Medium
Australian Smelt	0.62	44%	90%	100%	100%	Medium
Sand and Silts erosion	1.00	25%	34%	36%	37%	Medium

These results predict that resultant velocities for the revised Riverstone WRRF treated water discharges are likely to increase the amount of time that velocities exceed the thresholds for the species nominated to 100% of the time. This is likely to have a substantial impact for fish passage in the centre of flow in Eastern Creek at Reporting Location B.

Despite this, the distribution of flows is provided in Figure 3-4 for the 50th percentile of flows, demonstrating that conditions for the passage of all fish species is possible at least 50% of the time along the banks of Eastern Creek at Reporting Location B. This is likely attributable to the full record of tailwater conditions caused by tidal influence.

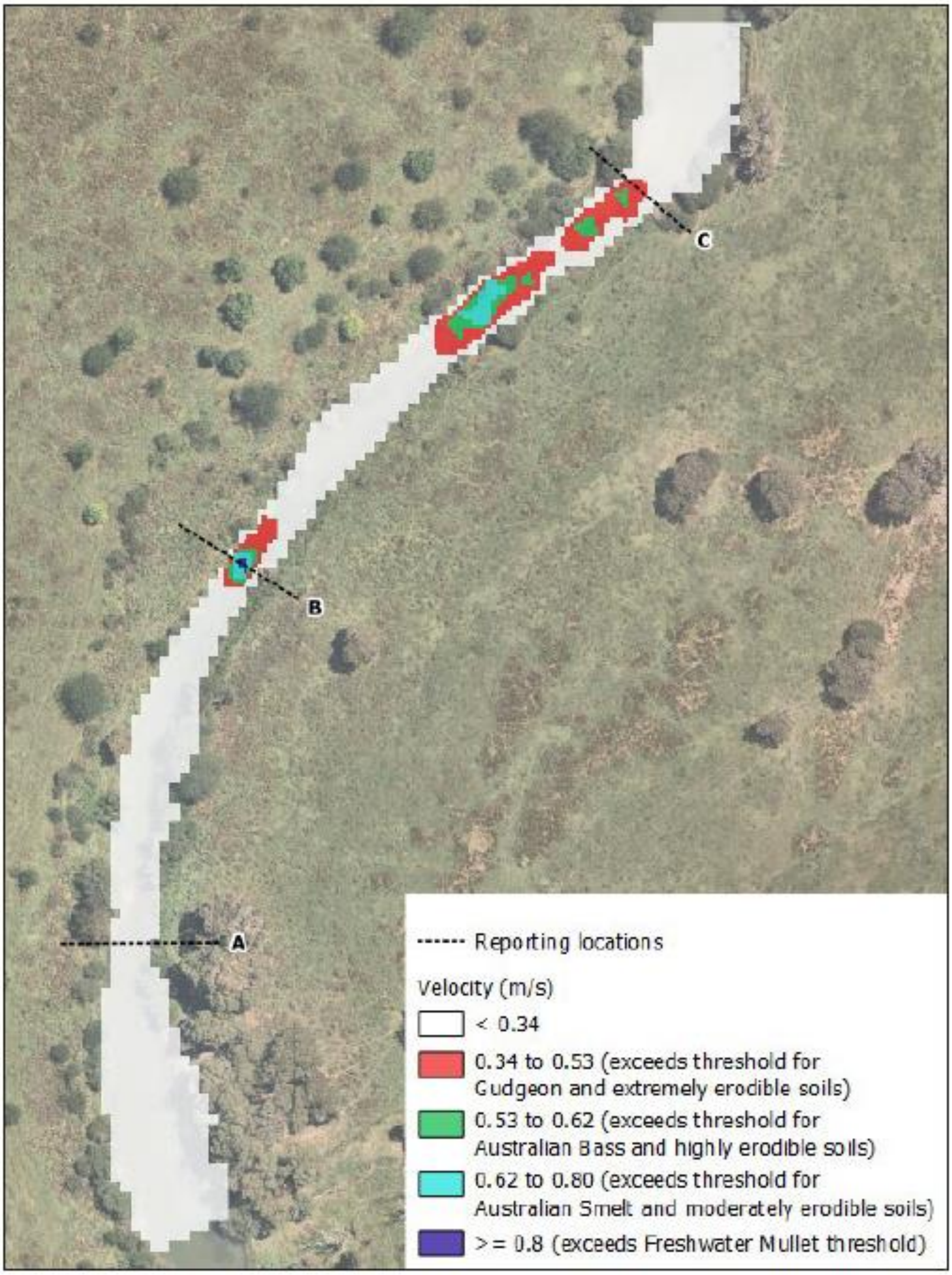

Figure 3-4 2036 Discharge scenario velocity at 50th percentile flow (Sydney Water, 2022)

Combined with the results of the threshold velocity assessment, this predicts that there is likely to be little to no opportunities for native fish to move through the thalweg (the deepest section of flow) in the creek, however, no isolation of the upstream reaches is predicted to occur under the revised discharges because of the low near-bank velocities. Nonetheless, it will be crucial to ensure that near-bank velocities do not exceed thresholds under future discharge conditions to ensure that the movement of fish upstream of Reporting Location B is maintained.

3.3.2.3 Reporting Location C

The threshold velocity results by scenario at Reporting Location C are provided in Table 3-8.

Table 3-8 Nominated fish species for ecohydrological impact assessment for Eastern Creek with threshold velocity at Reporting Location C

Indicator or Species	Threshold Velocity (m/s)	Scenario				Sensitivity of Environment to Impact
		Baseline	Impact	Baseline + Revised	Revised Impact	
Australian Bass	0.53	27%	38%	41%	42%	Moderate
Freshwater mullet	0.8	21%	27%	26%	27%	Low
Empire gudgeon	0.34	35%	69%	100%	100%	Moderate
Firetail gudgeon	0.34	35%	69%	100%	100%	Moderate
Australian Smelt	0.62	24%	32%	34%	35%	Low
Sand and Silts erosion	1.00	17%	22%	22%	23%	Low

As with Reporting Location B, velocities at Reporting Location C are non-uniform across the cross-section of the creek (Figure 3-4). Near-bank velocities for this location, and approximately 50m of waterway upstream, are sufficiently low to enable the passage of native fish species.

During high-tide events, it’s likely that Reporting Location C would experience reduced velocities and greater possible fish migration for the nominated species.

3.3.3 Geomorphology

To complement the previous NWTH REF (Sydney Water, 2022), an updated risk-based impact assessment was undertaken for fluvial geomorphology to consider erosion risk and macrophyte dislodgement for the proposed changes to the Riverstone WRRF’s treated water discharges to Eastern Creek. This impact assessment has used bed shear stress as the metric of risk for the model scenarios outlined in Table 3-2 using the same methodology outlined in the previous NWTH REF.

For all three reporting locations, bed shear stress was evaluated at the thalweg to generate a conservative representation of shear stress based on the highest likely velocity by cross-section.

The erosion of substrate into flowing water is dependent on several factors that contribute to the shear strength or resistance of the waterway to erosion. These can be best represented by substrate particle diameter and the extent and condition of instream or riparian vegetation (DEECA, 2024).

Critical bed shear stresses used in this assessment are provided in Table 3-9 and the relationship between critical shear stress and particle diameter of substrates is provided in Figure 3-5.

Table 3-9 Critical bed shear stress by boundary material type for uniform noncohesive sediments in waterways (Fischenich, 2001)

Substrate	Class	Diameter (mm)	Critical Shear Stress (N/m²)
Boulders	Very Large	>2000	1800
	Large	>1000	900
	Medium	>500	400
	Small	>250	230
Cobble	Large	>130	110
	Small	>60	50
Gravel	Very Coarse	>30	30
	Coarse	>15	12
	Medium	>8	6
	Fine	>4	3
	Very Fine	>2	1
Sand	Very Coarse	>1	0
	Coarse	>0.5	0.3
	Medium	>0.25	0.19
	Fine	>0.13	0.14
	Very Fine	>0.08	0.1
Silt	Coarse	>0.05	0.05
	Medium	>0.03	0.05

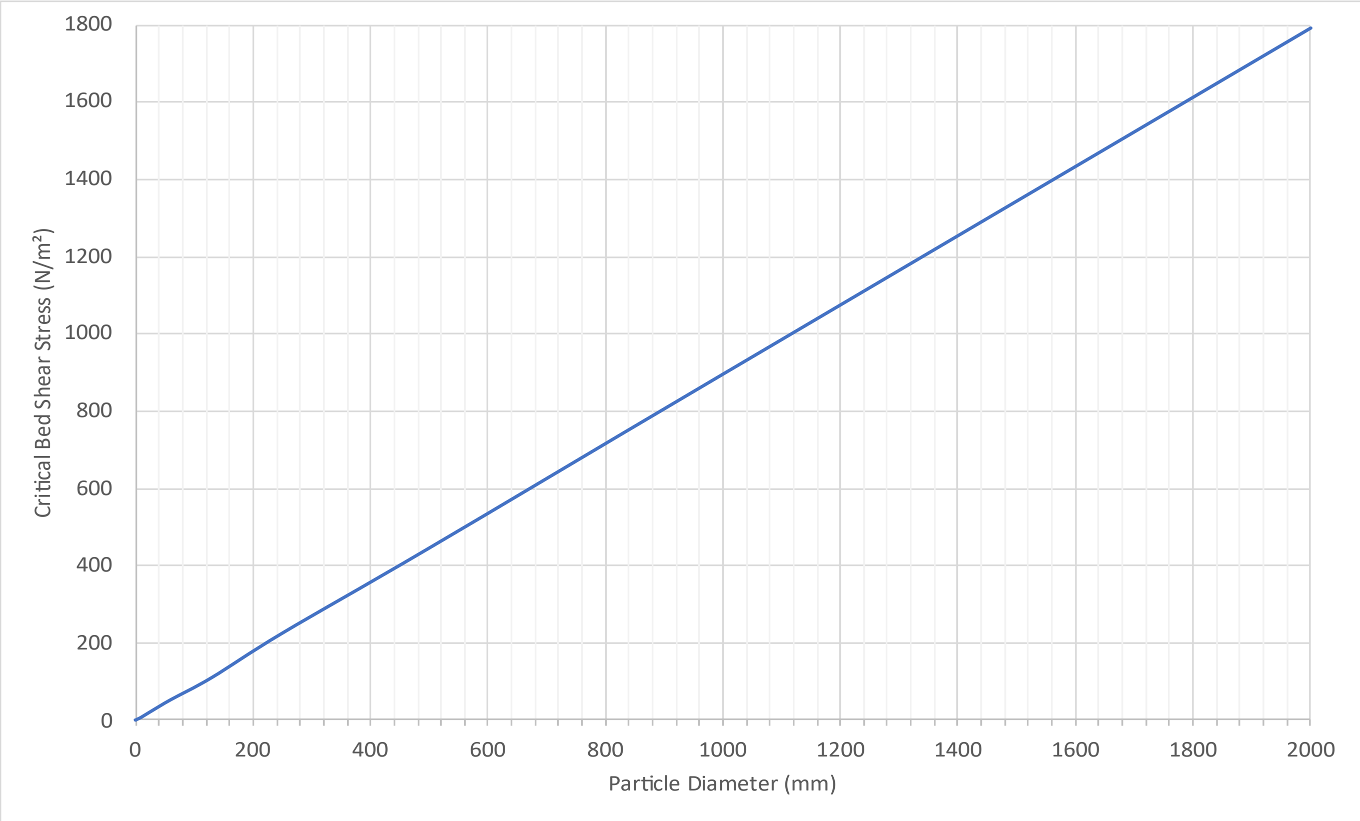

Figure 3-5 Critical bed shear stress relative to particle diameter for erosion in waterways (Fischenich, 2001)

Bed shear stresses for each reporting location have been extracted and evaluated against these thresholds and the tabulated results and exceedance curves for each are provided in the sections below.

3.3.3.1 Reporting Location A

Impact assessment for erosion based on threshold shear stress conditions is provided in Table 3-10 below and complemented by a threshold shear stress exceedance curve in Figure 3-6.

Table 3-10 Predicted threshold shear stress exceedances by scenario for Eastern Creek at Reporting Location A

Substrate or Vegetation Type	Threshold Shear Stress (N/m²)	Percentage of Time Above Threshold				Impact Significance
		Baseline	Impact	Baseline + Revised	Revised Impact	
0.125mm fine sand	3.7	8.4%	10.0%	9.0%	9.7%	Low
0.5mm coarse sand	3.9	7.9%	9.5%	8.7%	9.3%	Low
1mm very coarse sand	4.3	7.4%	8.5%	7.7%	8.6%	Low
2mm gravel	5.2	5.7%	7.0%	6.1%	6.7%	Low
64mm cobble	51	0.0%	0.0%	0.0%	0.0%	Negligible
Aquatic vegetation	105	0.0%	0.0%	0.0%	0.0%	Negligible
Tussock and sedge	240	0.0%	0.0%	0.0%	0.0%	Negligible
Disturbed tussock and sedge	180	0.0%	0.0%	0.0%	0.0%	Negligible

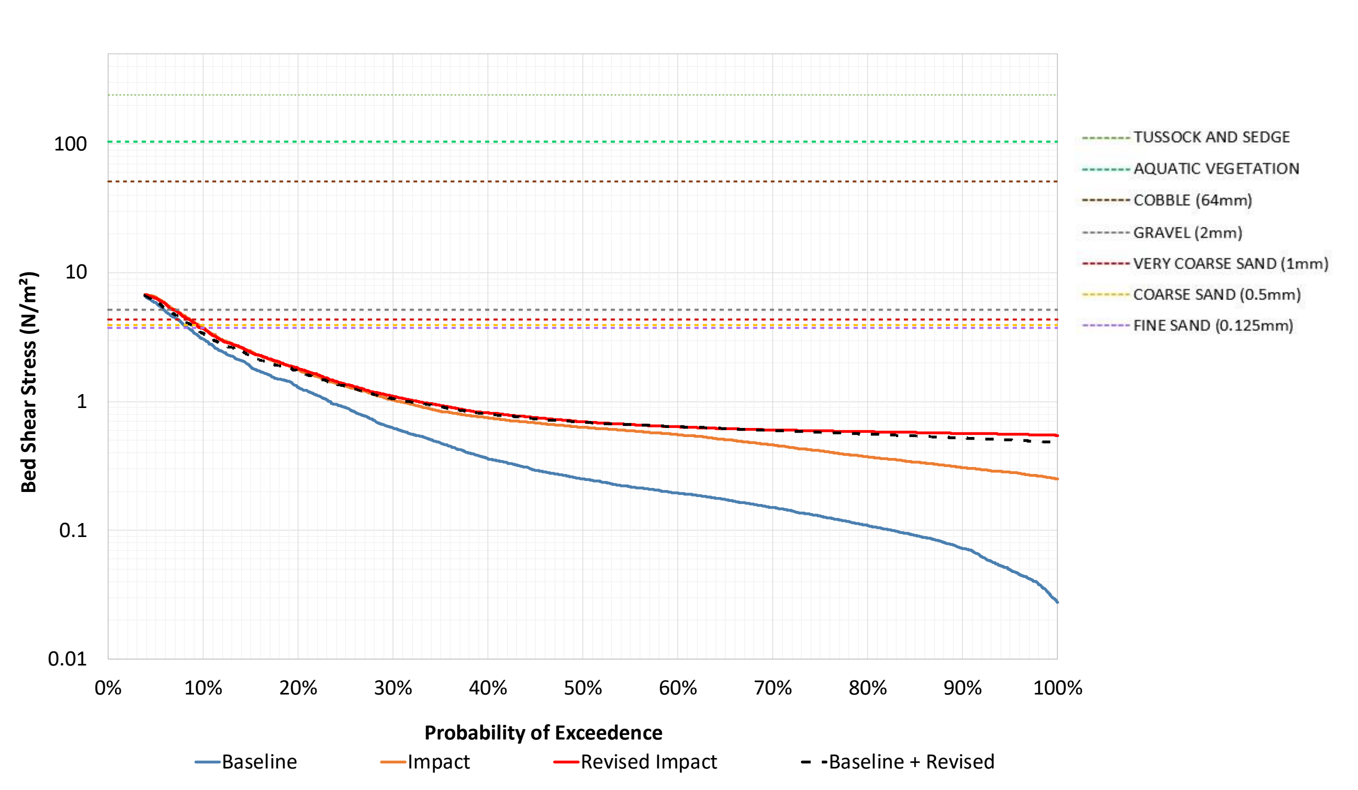

Figure 3-6 Threshold bed shear stress exceedance curve for Reporting Location A in Eastern Creek

The results of this analysis predict that there is a low likelihood of erosion or dislodgement of macrophytes at Reporting Location A. Furthermore, any impacts that are attributable to the flow regime changes from Riverstone WRRF are likely to have low to negligible significance.

3.3.3.2 Reporting Location B

Impact assessment for erosion based on threshold shear stress conditions is provided in Table 3-11 below and complemented by a threshold shear stress exceedance curve in Figure 3-7.

Table 3-11 Predicted threshold shear stress exceedances by scenario for Eastern Creek at Reporting Location B

Substrate or Vegetation Type	Threshold Shear Stress (N/m²)	Percentage of Time Above Threshold				Impact Significance
		Baseline	Impact	Baseline + Revised	Revised Impact	
0.125mm fine sand	3.7	72%	100%	100%	100%	High
0.5mm coarse sand	3.9	69%	100%	100%	100%	High
1mm very coarse sand	4.3	64%	100%	100%	100%	High
2mm gravel	5.2	51%	100%	100%	100%	High
64mm cobble	51	0%	0%	0%	0%	Negligible
Aquatic vegetation	105	0%	0%	0%	0%	Negligible
Tussock and sedge	240	0%	0%	0%	0%	Negligible
Disturbed tussock and sedge	180	0%	0%	0%	0%	Negligible

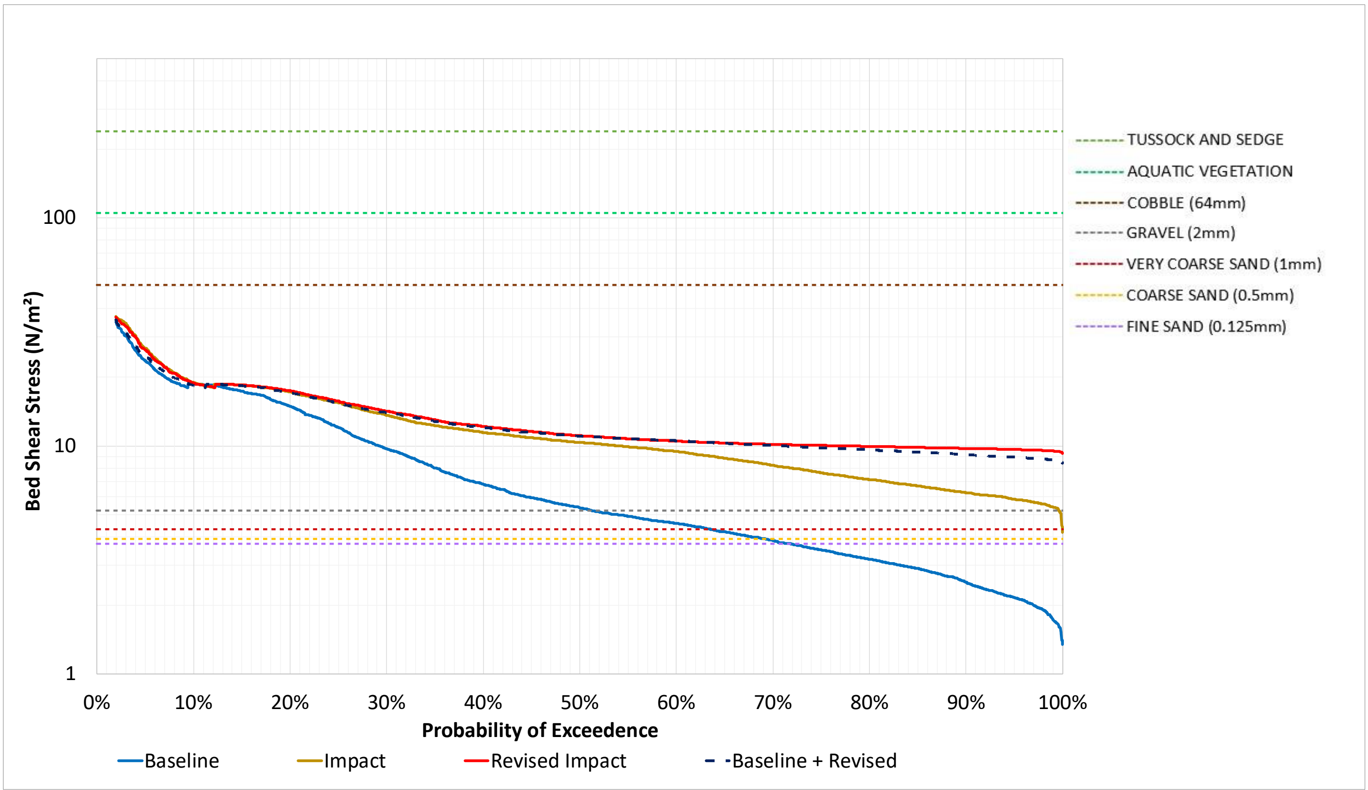

Figure 3-7 Threshold bed shear stress exceedance curve for Reporting Location B in Eastern Creek

The results of this impact assessment predict that there is likely to be limited sand content on the bed of Eastern Creek at Reporting Location B under current conditions and that flow regime changes attributable to the Riverstone WRRF are likely to result in the erosion of the bed until the substrate is primarily consisting of cobbles or a matrix of materials with equivalent resistance to shear stresses.

As mentioned in the previous NWTH REF (Sydney Water, 2022), Reporting Location B appears to be located within a deposition zone or potentially within a sand slug that is progressing downstream slowly. The consequence of this is that the depth of flow is reduced and the velocities are elevated, generating higher bed shear stress, while simultaneously being likely to be a transient condition of the creek. The significance of the erosion impacts is considered high for all substrate types assessed below cobbles at Reporting Location B, however, these impacts are most likely to occur to the bed of the creek and have minimal impact on its banks. Should aquatic vegetation be present on the bed of the creek, the likelihood of erosion will be further reduced as dislodgement of aquatic vegetation and macrophytes is predicted to experience a negligible change.

3.3.3.3 Reporting Location C

Impact assessment for erosion based on threshold shear stress conditions is provided in Table 3-12 below and complemented by a threshold shear stress exceedance curve in Figure 3-8.

Table 3-12 Predicted threshold shear stress exceedances by scenario for Eastern Creek at Reporting Location C

Substrate or Vegetation Type	Threshold Shear Stress (N/m²)	Percentage of Time Above Threshold				Impact Significance
		Baseline	Impact	Baseline + Revised	Revised Impact	
0.125mm fine sand	3.7	31%	54%	69%	71%	High
0.5mm coarse sand	3.9	30%	52%	65%	65%	High
1mm very coarse sand	4.3	29%	48%	57%	57%	Moderate
2mm gravel	5.2	28%	42%	46%	47%	Moderate
64mm cobble	51	13%	16%	15%	16%	Low
Aquatic vegetation	105	10%	12%	11%	12%	Low
Tussock and sedge	240	7%	9%	8%	9%	Low
Disturbed tussock and sedge	180	8%	10%	9%	9%	Low

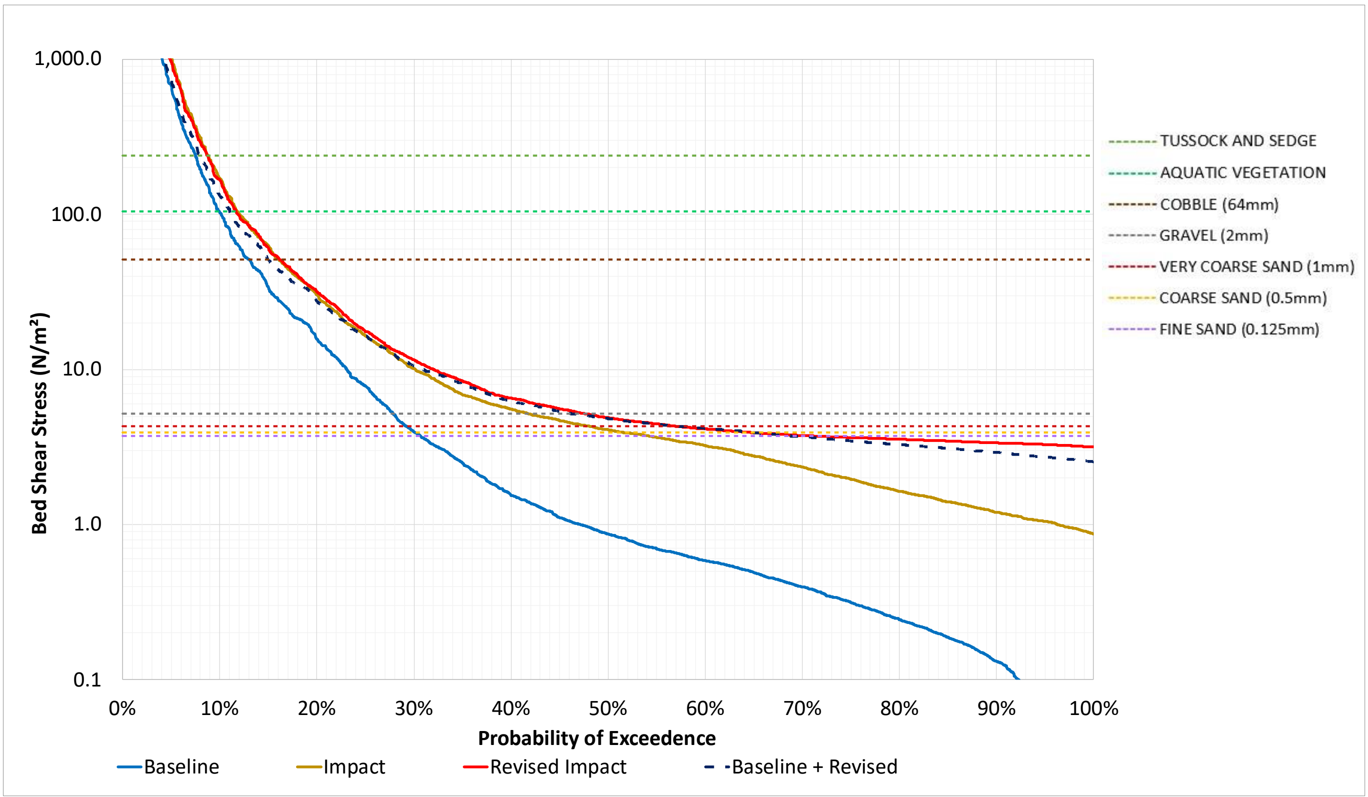

Figure 3-8 Threshold bed shear stress exceedance curve for Reporting Location C in Eastern Creek

The results of the threshold bed shear stress assessment at Reporting Location C predict that relatively high shear stresses are experienced under baseline conditions. These shear stresses would indicate that limited sand is present within Reporting Location C and that the bed material would more likely be a matrix dominated by coarse materials such as gravel and cobbles.

The modelling results predict that the increase in percentage of time flows exceed threshold shear stresses within Reporting Location C could range from as much as 40% for fine sand to 19% for gravel and as little as 3% for cobbles.

These resultant increases could lead to destabilisation of the bed and banks of Eastern Creek and represent a vector of dislodgement for macrophytes that is not represented in the threshold shear stress assessment above.

This represents a risk of bank erosion and meander migration for Eastern Creek at Reporting Location C which possesses a high impact significance.

3.4 Summary of Impact Assessment and Recommended Mitigation

The average treated water discharge rate from the Riverstone WRRF is projected to increase from approximately 7.7 ML/day to 40 ML/day. The predicted impacts to geomorphology and ecohydrology of Eastern Creek from this increased discharge are commensurate to the magnitude of the change in flow and subject to the sensitivity of the receiving environment of Eastern Creek.

Predicted vectors of impact that have been considered consist of:

- Disequilibrium of Eastern Creek's physical form;
- Flow-based barriers to passage of native fish as a consequence of elevated velocities; and
- Dislodgement and redistribution of macrophyte habitat or aquatic vegetation.

Recommendations have been developed in response to these vectors of impact and their likely impact outcomes focusing on mitigation and management measures ranging from monitoring to instream works for stabilisation of the physical form and to promote a new or renewed equilibrium between ecohydrology and physical form. These recommendations are consistent with those of the 2022 REF, but have been expanded upon for clarity.

A summary of the key impact assessment outcomes and recommended mitigation and management measures is provided in Table 3-13.

Table 3-13 Potential impacts of revised treatment discharge regime

Potential Impact	Analysis	Discussion	Impact Severity			Mitigation Measures Recommended
			Sensitivity	Magnitude	Significance	
Redistribution or removal of macrophyte habitat	Shear stress assessment of threshold conditions for macrophyte roots	Shear stresses are not predicted to be above the nominated thresholds for macrophyte stability for sufficient periods of time as to present a risk to macrophytes.	Low (Consistent with 2022 REF)	Low (Consistent with 2022 REF)	Low (Consistent with 2022 REF)	An adaptive management plan is recommended to ameliorate any observed impacts. This could include maintenance / planting of riparian vegetation along the creek banks, providing additional protection / stabilisation to creek features that are impacted
Alteration of physical form of Eastern Creek or South Creek from erosion and subsequent deposition	Shear stress assessment of threshold conditions for substrate erosion	Low risk for the waterways where subcritical flows are expected. Supercritical conditions associated with shallow, narrow or sections with steeper energy grades possess higher risk and high significance as a result. This is likely mitigated by the real-world conditions at these locations being transient or in a state of flux such as that occurring as a consequence of a sand slug moving through the Eastern Creek system.	Low to Medium (Elevated from Low in 2022 REF)	Low to High (Consistent with 2022 REF)	Moderate to High (Elevated from Moderate in 2022 REF)	Armouring of bed and banks as required to prevent propagation of any erosion upstream. Installation of revetments or other bank works to protect from erosion. Use of rockwork will provide long term erosion protection, but at the expense of recovery opportunities for the ecology of Eastern and South Creeks.

Potential Impact	Analysis	Discussion	Impact Severity			Mitigation Measures Recommended
			Sensitivity	Magnitude	Significance	
Obstructive flow velocities	Threshold velocity assessment for specific fish species	Current conditions produce velocities that limit the movement of small native fish less than 55% of the time, with the exception of the gudgeon species evaluated for which threshold velocities are currently predicted to be exceeded approximately 90% of the time. The frequency of these thresholds being exceeded is predicted to increase slightly from current conditions under the new treated water discharges but still on occur less than 10% of the time. Gudgeon thresholds are predicted to be exceeded 20% of the time under the new treated water discharge regime.	Low (Consistent with 2022 REF)	Low to Moderate (Consistent with 2022 REF)	Low (Consistent with 2022 REF)	Monitor conditions for velocity. Construction of instream structures to concentrate velocities and produce low velocity corridors for fish passage. Introduction of large woody debris or root-wad revetments at near-bank locations to reduce velocities.

3.5 Mitigation Measures Examples

3.5.1 Adaptive Management Planning

An adaptive management plan for Eastern Creek would, ideally, be focused on key features of the waterway's physical form and ecology. The plan should possess critical guidance regarding the condition of those features, identifying measurable indicators against which a trigger condition for intervention could be set.

To support the plan, monitoring would be required for the identified indicators as a means to ensuring that the trigger condition is appropriately evaluated on a regular basis.

3.5.2 Instream Works

3.5.2.1 Erosion Control Works

For the purpose of controlling erosion downstream of the Riverstone WRRF, rockwork has been recommended as both a proactive and reactive erosion control. Sizing of the rockwork can be undertaken using rock sizing equations and guidance provided by Catchments & Creeks (Catchment & Creeks, 2011).

Figure 3-9 Rockwork examples for erosion control (Catchments & Creek, 2011)

Rockwork should be installed only if it is deemed acceptable to have reduced outcomes for the ecology of the waterway.

Rockwork is a relatively inexpensive erosion control measure. However, the permanence of the solution introduces additional costs if the rockwork is to be removed for improved ecological outcomes or otherwise.

3.5.2.2 Velocity Controls

Velocity controls for Eastern Creek are recommended to consist of natural materials including native vegetation and large woody debris. These materials are recommended for their ecological benefits and relative ease of construction and installation.

Native vegetation is recommended to be planted where depth of flow in the waterway is sufficient and vegetation survival is most likely based on the guidance of ecologists. Large woody debris should be introduced in line with the Land and Water Australia's design guideline for the reintroduction of wood into Australian streams (Brooks et al., 2006). An example of the effect to be achieved through the installation of large woody debris is provided below in Figure 3-10.

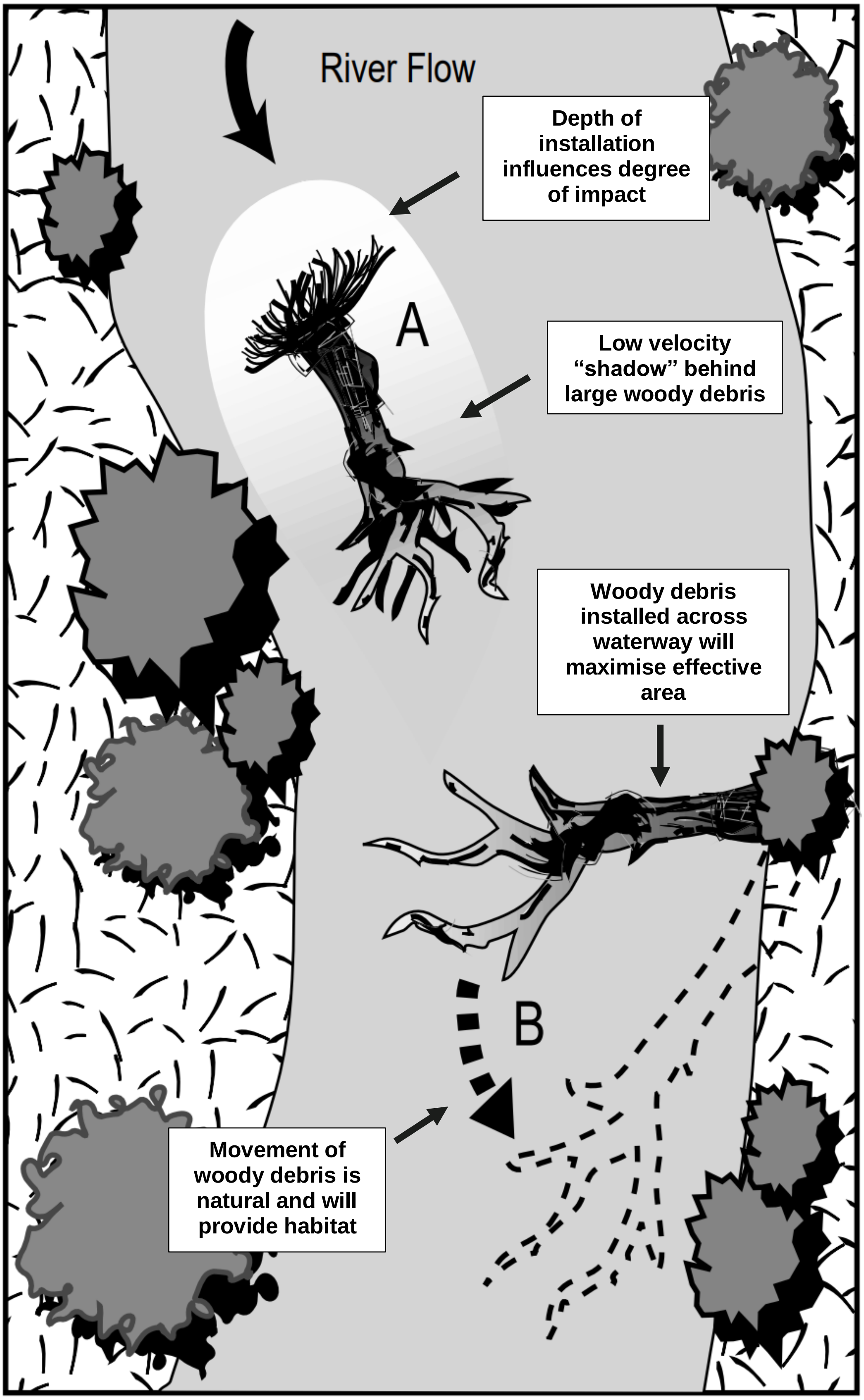

Figure 3-10 Large woody debris examples for velocity reduction and expansion of habitat (Department of Natural Resources and Environment Tasmania, 2003)

4 Conclusion

A review of the relative potential for flood level impact was undertaken to assess the potential for the project to have an impact to flood risk associated with wet weather flow releases to Eastern Creek. This was undertaken by obtaining the flow at the nearest available reporting location and undertaking an estimation on the relative impact to water level at this location. The results of this indicated that the additional flows from the Riverstone WRRF were relatively minor with respect to flood flows, and would likely result in a relative impact of less than 10 mm. This change would be considered negligible. Note that the reporting location for flood flows is located upstream of the Riverstone WRRF. It is expected that further downstream, where the flood flows are greater, the relative impact of the discharge to the creek would be further reduced.

Ecohydrological and geomorphological impacts were reassessed considering the revised discharge scenario for the three reporting locations in Eastern Creek downstream of the Riverstone WRRF. This impact assessment consisted of remodelling of the flows for the new treatment capacity at the WRRF and evaluating the scenario results for key metrics of flow as they pertain to identified species and substrate types within the reach. In total, four scenarios were assessed to depict the trajectory of Eastern Creek into the future and to represent the range of outcomes.

The results of the ecohydrological impact assessment identified marginal impacts to fish movement throughout this section of the creek with respect to the nominated native fish species evaluated. While threshold velocities were shown to be considerably elevated for Reporting Location B in particular, the cross-sectional influence on velocity for Eastern Creek identified that near-bank velocities were likely to be below the threshold velocities for all the nominated fish species. Additionally, tailwater conditions were selected to be at mean low tide tailwater conditions. These were used to assess the threshold velocities to provide a conservative assessment of velocity conditions. All tailwater conditions above this are likely to have reduced velocity implications and greater opportunities for fish passage to the upstream reaches of Eastern Creek in this region.

The geomorphological impact assessment identified that sand was likely to experience erosion for Reporting Locations B and C in response to the elevated velocities that these locations reported for each scenario. The significance of the potential impacts to the geomorphology of Eastern Creek identified have been determined to be moderate to high because of the threshold shear stress exceedances predicted for fines under the revised impact scenario. The high significance of the geomorphological impacts is likely to be mitigated by real world conditions at Reporting Locations B and C and offset by the conservative nature of the assessment undertaken. These impacts are also well addressed by the recommendations of this addendum.

In conclusion, this addendum has largely arrived at the same conclusions of the NWTH REF (Sydney Water, 2022). Eastern Creek is already in a significantly disturbed state due to anthropogenic activities upstream of the Riverstone WRRF discharge location. Flood impacts associated with the catchment are likely to result in extremely significant impacts to the ecohydrology and geomorphology of the waterway. The impacts to ecohydrology and geomorphology for Eastern Creek associated with the increased Riverstone WRRF treated water discharges are likely short lived, easily managed or mitigated and to generate a new equilibrium for the waterway downstream that will be sensitive to the mitigation and management measures employed by Sydney Water.

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Appendix A: Maximum Peak Hourly Flow Rate

Hourly Max and Mean Flow Data – Riverstone

Appendix B: Flood Level Impact Assessment

Channel Capacity Spreadsheet

1% AEP Flood Map for Eastern Creek