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Acknowledgement of Country
Fruition Environmental acknowledges the traditional custodians of the Dharug and Dharawal lands upon which this assessment was undertaken. We recognise the continuing connection to lands, waters and communities. We pay our respect to Aboriginal and Torres Strait Islander cultures; and to Elders past and present.

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Executive Summary

This report presents the findings of the Georges River Estuaries NEAP Bank and Riparian Condition Assessment. This report has been commissioned under the NSW Estuary Asset Protection Program (NEAP Program), part of the Riparian Stabilisation Package, co-funded by the Australian and NSW Governments under Disaster Recovery Funding Arrangements, managed by the NSW Department of Primary Industries and Regional Development – Fisheries.

The data and analyses from this assessment are to be used to inform future management actions to improve flood resilience, estuary asset protection, and estuary health including water quality, bank stability and riparian vegetation condition.

The dataset uses the DPIRD Fisheries Decision Support Tool for Bank Erosion Management in NSW Estuaries (the "DST"; Hydrosphere, 2020) as the basis of the assessment with additional criteria related to erosion processes and riparian vegetation attributes. In total approximately 145 km of estuary bank were surveyed, including 1,052 individual reaches. This covered the navigable sections of tidal reaches of the Georges River from Captain Cook Bridge upstream to the weir at Liverpool, Woronora River, Prospect Creek to the Hume Highway bridge, Saltpan Creek to Cutting Reserve, and the navigable extents of the major Bays of the Georges. Data was collected using a field mapping application developed by Fruition Environmental Pty Ltd. The data is stored online through an ESRI ArcGIS web portal and can be viewed and analysed using a simple web-based interface or exported to desktop GIS for further, more detailed analyses.

The mapping dataset and the identification of priorities for estuary bank and riparian vegetation management contained within this report provide specific data that address the highest ranked issue identified in the Georges River Coastal Management Program (CMP) Scoping Study (Table 27: Goerges Riverkeeper, 2022), namely "Riparian and estuarine condition and habitat/corridor loss". This data can be used to support future stages of the development of the Georges River CMP.

Estuary bank and riparian condition

The overall extent of erosion in the Georges River estuary study area is considered to be low by regional standards. The field investigations showed that the vast majority of the estuary banks in the study area have either Low or Negligible erosion (94.3%). A major factor is the very high proportion of banks protected by either bedrock or foreshore protection works. Half of the total area surveyed had either bedrock substrate or completely effective protection works (49.9%). *Low* erosion is the most frequently observed erosion severity across all zones. While driven by a range of contributing disturbance factors, this level of erosion remains within the expected natural variability of estuarine dynamics and is not typically of management concern.

However, localised instances of active erosion were identified in discrete reaches, as well as broader low-level erosion issues. The survey indicates that less than one per cent of the estuary is currently experiencing severe erosion, with 576 m (0.4%) of the mapped banks featuring Extreme erosion, while 741 (0.5%) show High erosion. Instances of High and Extreme erosion are primarily confined to the Fluvial dominated process zone of the upper Georges River estuary. These reaches are underlain by erodible alluvial bank materials and are more susceptible to fluvial erosion processes during high-flow or flood events. No High or Extreme erosion was recorded in the Woronora River estuary, Prospect Creek or Saltpan Creek.

A clear downstream reduction in erosion frequency and severity is evident in the Georges River, while in the Woronora River, the distribution of erosion is more uniform. Surveyed reaches of Salt Pan Creek exhibited minimal erosion, with 98% of bank length classified as Negligible. This pattern is likely attributable to the resistant geological composition of the mid and lower estuary, while the subdued flood history in recent decades may account for the limited erosion observed in upstream areas.

Negligible to Low erosion dominates across all process zones, accounting for 85–100% of the mapped bank lengths. Of these, Negligible erosion is the most widespread classification across the estuary. *Low* erosion is the most frequently observed active process across all zones. While driven by a range of contributing disturbance factors, this level of erosion remains within the expected natural variability of estuarine dynamics and is not typically of management concern from an erosion perspective but may potentially impact other values including important riparian vegetation assemblages or estuarine habitats.

Moderate erosion was observed along 4.8% of the total mapped estuarine banks and was more broadly distributed across multiple process zones. In the Georges River, Moderate erosion was recorded along 2.6 km (8%) of the bank length in the Fluvial-dominated zone, and 1.7 km (10.1%) of the Fluvial Transition zone. Some of these areas may represent reaches recovering from earlier high severity erosion events—such as flood-induced slumping—where natural stabilisation processes are evident. In the Woronora River, Moderate erosion was mostly restricted to isolated upper reaches, totalling approximately 890 m (7.8%), and in proximity to boat ramps at Bonnet Bay and Burnum Burnum. These moderately eroded reaches typically exhibited minimal toe scour, with bank instability primarily associated with riverine or tidal flows and boat wake, leading to wave notching and subsequent bank slumping.

Riparian Vegetation Condition was assessed using a multi-metric index of riparian condition which considered vegetation width, continuity, structure, diversity and weed presence/cover. The results of the field survey show that a broad spread of condition of riparian vegetation exists throughout the estuary. Approximately half of the estuary, 53.4% of reaches surveyed equating to 77.4 km, was classified as having riparian vegetation in Good to Very Good condition. This is regionally high and is a result of the considerable lengths of near intact remnant riparian vegetation communities along the estuary, particularly along steep sandstone valley margins and in the shallow back of bays where development has not continued all the way to the foreshore. This vegetation includes several high conservation value vegetation communities, providing considerable ecological and aesthetic value to the estuary.

Approximately a third of estuary length surveyed (31% or 44.9 km) was classified as being in a Poor to Very Poor condition. Most of these reaches have been heavily modified by urbanisation, with residential developments along the immediate foreshore. In many cases, seawalls have been constructed to the exclusion of any vegetation. Reaches with Very Poor vegetation condition are particularly apparent downstream of Como Bridge and in Woronora.

A total of 15.5% of assessed riverbank was recorded as having Moderate condition riparian vegetation, indicating that a notable proportion of banks may be in a transitional state where condition could either improve or deteriorate depending on future management interventions. In reaches with Very Poor to Moderate condition vegetation, a major factor in the rating is narrow riparian width.

In the Georges River estuary there is a general pattern of decreasing vegetation condition towards the downstream end of the estuary with the proportion of banks with Poor to Very Poor condition riparian condition increasing towards the more urban and foreshore developed parts of the estuary. This pattern reflects the mix of residential development and parkland along the estuary foreshore. In the lower estuary, vegetation condition is significantly degraded. Nearly half of the riparian areas in the Mud Basin process zone (45.6%) are in Very Poor condition, which corresponds to the high degree of foreshore urbanisation. Many properties have entirely cleared riparian and fringing vegetation for access and amenity purposes. Only 26.8% of this zone retains Good or Very Good condition vegetation, typically consisting of mangrove forests in off-channel embayments and patches of Coastal Dry Sclerophyll Forest on steep sandstone slopes. Weeds such as lantana and ground asparagus are present in this zone, though their coverage is generally low (<10%).

Conversely, in the Woronora River, the upper estuary has a higher proportion (approximately one-third of mapped reaches) in Poor to Very Poor condition, primarily due to residential development. In contrast,

vegetation condition improves in the Fluvial Delta of the Woronora River, where only 13.4% of riverbanks are in Poor to Very Poor condition. Again, this reflects the pattern of residential development and parkland along the estuary foreshore.

The major impacts on riparian vegetation condition observed during the field assessment included:

- Clearing associated with urbanisation and foreshore access
- Loss due to erosion processes including bank undercutting or stripping of intertidal benches under mangrove habitat due to persistent wind or boat wave effects, particularly where only a narrow fringe of vegetation exists on the bank
- Weed incursion, particularly in the upper reaches between Liverpool Weir and Chipping Norton Lake, as well as Prospect Creek. Elsewhere typically had Low (<10%) weed cover observed. The most extensive weeds identified included lantana, ground asparagus, coastal morning glory, cockspur coral tree and madeira vine.

The full bank condition and riparian vegetation dataset is available through the NEAP Bank and Riparian Condition Assessment public web portal at https://nsw-neap-bank-riparian-condition.netlify.app/.

Existing bank protection works

The presence, method and observed effectiveness of existing bank protection works was also recorded. Of the total length of bank field surveyed in the Georges River study area (~145 km), ~60 km or 41.6% of estuary bank had some form of existing bank protection. This is a very high proportion when compared to other estuary systems within NSW.

Almost two-thirds (60%; 36.3 km) of the existing bank protection measures observed were seawalls (recorded as either sandstone or concrete blocks, walls or slabs). The next most prevalent types of bank protection included rock armouring along 20.5 km (34% of works) and building rubble, bricks and broken concrete which occurred along 2.6 km of estuary bank (4.3% of works). Interestingly, a number of reaches were recorded with retrofitted environmentally friendly seawall designs. These design use environmentally friendly and aesthetic landscape design principles to integrate rocky foreshore habitat, estuarine vegetation and public access. Apart from revegetation in these projects there was no other recent active revegetation for bank protection projects recorded.

All other works types have been used minimally throughout the estuary, each representing < 1% of total works and include gabion baskets, rock groynes, sheet piles, and timber walls, and to an even lesser extent geotextile sandbags, cobble beaching and tyres.

Future works

On the basis of the field collected data, a number of recommendations for works have been made by the DPIRD Fisheries DST. These include recommendations for a range of works types including large woody debris works, rock fillets, rock revetment, cobble beaching and maintenance of existing works depending upon the estuary location. Approximately 8.6 km of estuary bank attracted a DST primary recommendation for works, including about 6.3 km of existing works identified as requiring “maintenance”, which in this report includes upgrading, retrofitting, or appropriate modifications to the works. In many cases the “maintenance” required is minimal and may involve simple steps to increase the bank/works resilience of the works at that location. More than 94% of estuary length attracted no primary recommendations but may have a final DST prescription of improving riparian vegetation width or introducing management controls such as boating restrictions or formalising public access. The online web portal data can be reviewed and filtered to see the full range of DST recommendations over the full Georges River estuary study area.

Importantly, whilst the recommendations are considered a best practice starting point for consideration there may be reasons why the DST recommendation may not be the most suitable option for the bank segment and these reasons may not be captured by the input data. Hydrosphere, in its documentation on the tool explicitly states that "*It is crucial that the DST recommendations are further investigated…to assess whether they are indeed applicable or if other techniques could be more suitable*" (Hydrosphere, 2020, p.18). Additionally, the fact that a surveyed reach attracts a recommendation for works or maintenance within the DST does not infer that the reach is a priority for management action. This is because the DST does not include any consideration of overall objectives for estuary management beyond bank erosion control using best practice. However, where a reach is separately assessed to be a priority for intervention, the DST provides a reasonably objective and standardised approach to determining which treatment options should be first considered.

Priorities for bank and riparian vegetation management

In terms of where activities may be directed to improve estuary bank and riparian vegetation condition in the Georges River estuary, the report outlines a priority system for determining future action and investment. A set of criteria, drawn from the objectives of a number of foundational documents relevant to the management of the estuary (including the NSW Coastal Management Act 2016, the Marine Estate Management Strategy 2018–2028, the Georges River Coastal Management Plan Scoping Study 2022 (Salt, 2022), the Georges River Estuary CZMP (BMT WBM, 2013), the Woronora River Estuary Management Plan 2008 (WBM, 2008), and to a lesser extent the various member Council Biodiversity strategies were used to create a "pool" of priority reaches drawn from the 2024 field data which could then be ranked using multicriteria analyses.

Of the 1,052 reaches field surveyed, 32 were included in the pool of priority reaches for action and management using the above system, this was reduced to 30 after adjacent reaches with similar issues and processes where combined. These are presented in the report (pages 80–93; shown in *Figure 21*) along with a breakdown of reaches which are considered a priority after the ranking criteria were applied for defined sets of typical estuary management objectives (lower ranked reaches for ongoing monitoring are included in *Appendix B*). These include a subset of priorities that address public asset protection and/or maintenance, and riparian vegetation protection and enhancement. The proposed timeframe for implementation is the next 10 years to 2035.

The highest priority reaches for management intervention are heavily weighted towards the protection of estuary assets and increasing flood resilience by directing works towards vulnerable areas of the estuary. This is a key objective of the NEAP program. The term "estuary assets" has been interpreted broadly and includes both infrastructure (such as roads and public foreshore) and natural assets such high conservation vegetation types, important estuarine habitats, and water quality.

Priorities for improving overall bank and riparian condition are included in *Table 17* which includes the top 11 reaches identified. Addressing the management issues identified at these locations will lead to lasting improvements in flood resilience, estuarine health, and public amenity. *Tables 18* and *19* in the report separately identify the top ranked sites for assets riparian vegetation protection and enhancement respectively.

In addition to the prioritisation tables based on the multicriteria analyses, a number of potential projects are proposed that were identified during engagement activities with the La Perouse Local Aboriginal Land Council and Gamay Rangers group. These activities are currently being finalised and will be included in the final report.

Introduction

This report has been commissioned under the NSW Estuary Asset Protection Program (NEAP Program), part of the Riparian Stabilisation Package, co-funded by the Australian and NSW Governments under Disaster Recovery Funding Arrangements, managed by the NSW Department of Primary Industries and Regional Development – Fisheries. The aims of the NSW Estuary Asset Protection program are to:

- Assess the severity of flood impacts on estuarine and floodplain assets
- Identify priority areas for asset protection and increased resilience
- Implement actions that will provide increased resilience for estuarine and floodplain assets from flooding events.

This report presents the findings of the Georges River Estuary Bank and Riparian Condition Assessment undertaken by Fruition Environmental Pty Ltd. The field assessment component was undertaken in March 2025.

The study area encompasses the navigable tidal reaches of the Georges River estuaries including the navigable reaches of Woronora River, Prospect Creek and Salt Pan Creek (*Figure 1*). 163.2 km of estuary bank was delineated through digitising of the estuary bank using February 2023 Worldview Imagery at a reference scale of 1:2000. Approximately 144.9 km of this bank length was field surveyed recording more than 1052 individual reaches. Areas not surveyed (~18.3 km) were not accessible by powered watercraft. Further detail of the estuary characteristics including climate, geology, land use, and broader management context are available in the Woronora River Estuary Processes Study (WBM, 2006) and Georges River Data Compilation and Estuary Processes Study *(*SMEC, 2010).

The mapping from this assessment is to be used to inform future management actions to improve the stability, resilience, and ecological condition of the estuary. In addition to an updated and comprehensive understanding of the distribution of estuary bank erosion and riparian vegetation condition, the report:

- Reviews the existing knowledge and data relating to estuary bank erosion, erosion processes, riparian vegetation distribution and condition, sediment sources and loads, existing bank protection works, and bank and riparian management priorities.
- Describes the process zones existing in the estuary in terms of the estuary character and behaviour.
- Maps bank condition and riparian vegetation condition as at the time of field assessment (March 2025).
- Maps existing bank protection works as at the time of field assessment (March 2025 including methods used and current effectiveness.
- Reports the recommendations of the NSW *Decision Support Tool for Bank Erosion Management*, developed by DPIRD Fisheries as part of the Marine Estate Management Strategy Initiative 2, for each surveyed segment.
- Presents a prioritisation system based on the objectives of the Coastal Management Act, NSW Marine Estate Management Strategy and other relevant plans covering the study area.
- Lists management priorities for improving bank and riparian condition in the estuary framed around the main objectives of increasing resilience to flooding, improving asset protection, water quality improvement, and riparian vegetation protection and enhancement.

The report draws on existing information and data provided by Georges Riverkeeper staff on behalf of member Councils including local knowledge of bank erosion and vegetation management issues affecting the Georges and Woronora River estuaries.

The Georges Riverkeeper organisation has also played a valuable role in reviewing the field dataset, review and feedback on the data portal, and review and feedback on the drafts of this report, all of which is gratefully acknowledged.

This report summarises the findings of the field and desktop assessments of bank and riparian condition.

Requests for access to the full online mapping dataset, which includes up to 106 individual attributes per reach, should be addressed to NSW Department of Primary Industries and Regional Development – Fisheries. The dataset is expected to be available on the SEED data portal in due course. A public viewable version of the dataset is available at https://nsw-neap-bank-riparian-condition.netlify.app/.

How to use this report

This report is intended to be used in conjunction with the NEAP bank and riparian condition assessment dataset.

The dataset is comprehensive, containing reach-specific field-assessed attributes on bank erosion severity, erosion processes, contributing factors, observed impacts to environmental, infrastructure and amenity/safety values, data on riparian width, continuity, structure, diversity and integrity (weed incursion including presence/absence of important riparian weeds) and including a riparian condition score and rating, data on remediation works presence, effectiveness, and type, and recommendations from the DPIRD Fisheries DST for bank erosion management in NSW estuaries.

For the NEAP project, the dataset has been used specifically to generate a set of priorities for estuary management that reflect the NEAP goals, that is improving resilience and protecting estuary assets (broadly defined as public assets and infrastructure, important natural assets and cultural assets and values). These priorities are able to be adopted directly into estuary management or Coastal Management Programs. The management priorities have been purposefully broken into tables that broadly target common environmental funding opportunities through various programs (e.g. Coasts and Estuaries program, Recreational Fishing Trust, Flagship or Habitat Action Grants).

It is important to note that the management priorities presented within the NEAP report represent a system of using the data which is linked closely to the estuary management objectives outlined in the report. The great benefit of the system of data storage used in the NEAP project is that it can be repurposed towards other objectives or goals. Through the online web portal, or by incorporation of the NEAP dataset in desktop GIS, a vast combination of enquiries into the data are possible. For instance, the dataset can be interrogated and analysed for more specific analyses or other purposes including:

- Identifying project sites for projects targeting riparian vegetation improvement or restoration, biodiversity corridors or connections, and/or strategic riparian weed control activities.
- Developing community-based environmental programs which require the identification of suitable sites prior to accessing funding opportunities
- Developing collaborative projects between local councils and community-based organisations (e.g. Riverkeeper, Landcare, Ozfish, etc.)
- Developing collaborative projects for managing, restoring or protecting culturally significant areas with Local Aboriginal Land Councils and Traditional Owner groups.
- Investigating opportunities to participate in emerging nature repair markets including blue carbon.

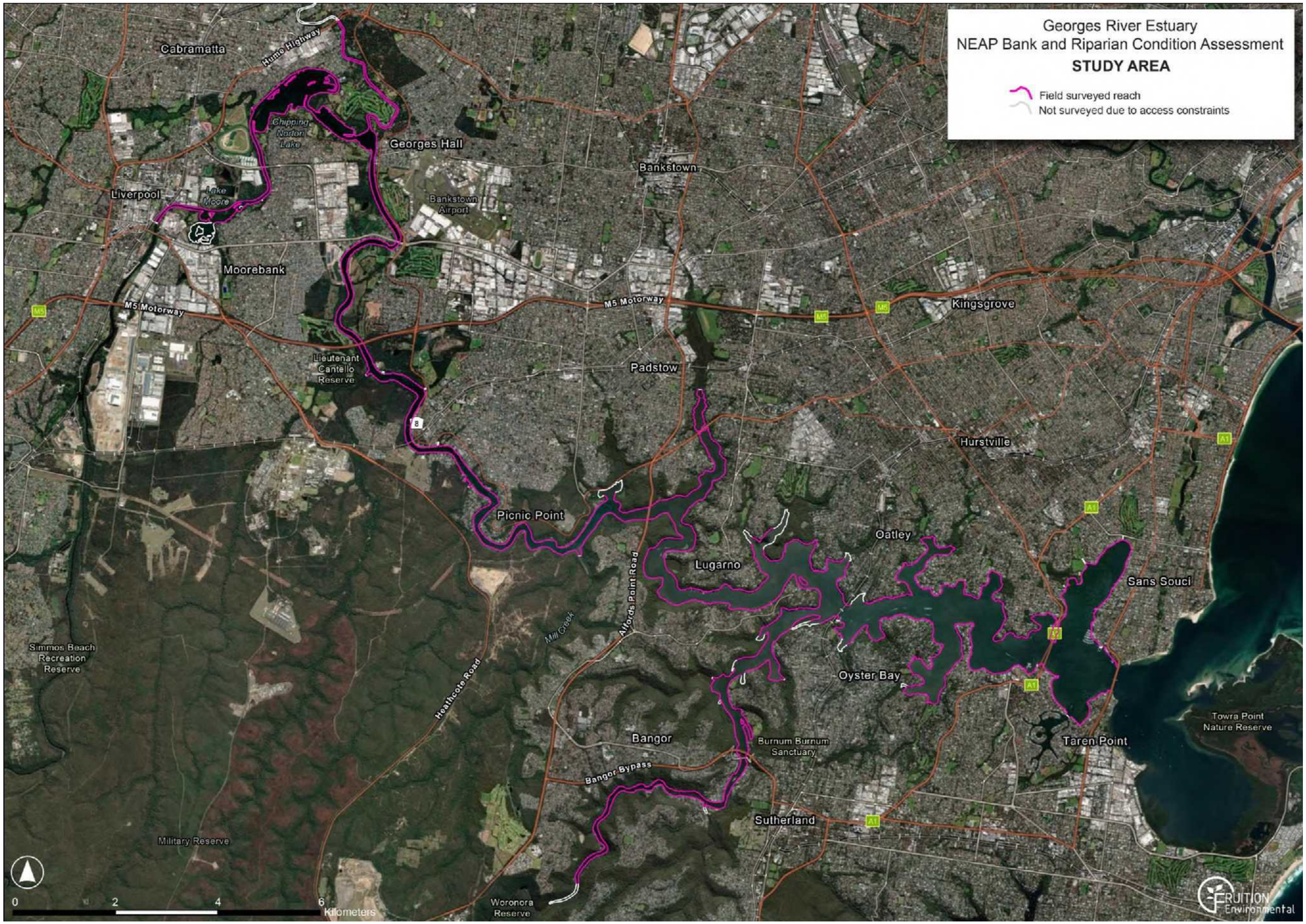

Figure 1 Georges River Estuary Bank and Riparian Condition Assessment Study Area, March 2025.

PART 1 – Existing Knowledge and Data

Literature Review

This section reviews the existing information and data that relate to the Georges River estuary physical processes and condition. There have been a number of studies and reports that have assessed to varying levels of detail the estuary processes, bank erosion distribution, estuarine vegetation, and potential estuary management strategies covering the study area. These include:

- Georges River Estuary Coastal Zone Management Plan (CZMP), 2013 (BMT WBM, 2013)
- Georges River Data Compilation and Estuary Processes Study 2010 (SMEC, 2010)
- Woronora River Estuary Processes Study (WBM, 2006)
- An Environmental Assessment of the Georges River (Albani & Rickwood, 2010)
- Sutherland Shire Watercourse Assessment & Rehabilitation Prioritisation (Applied Ecology, 2012)
- Regional Environmental Plan Georges River Catchment, 1999
- Canterbury Bankstown Urban Bushland and Biodiversity Strategic Plan, 2024–2034
- Fairfield City Biodiversity Strategy 2022
- Sutherland Shire Biodiversity Strategy, 2000
- Liverpool City Council Biodiversity Strategy, 2003.

A number of additional documents were identified that provide useful background and overview information for the Georges River Estuary study area. Most of these sources do not provide specific information or datasets of relevance to the NEAP Bank and Riparian Condition assessments but are nevertheless identified here for completeness. These include:

- Woronora River Estuary Management Study and Plan, 2008 (BMT WBM, 2008)
- Georges River Catchment Coastal Management Program Scoping Study (Salt, 2022)
- Woronora River Estuary – Data Compilation Study (WBM, 2004)
- Georges River Foreshore Study (MHL, 2002)
- Biodiversity of the Georges River catchment: Aquatic biodiversity (Williams et al., 2004)
- Georges River Biodiversity Study (Total Earth Care, 2021).

Much of the background information presented in these documents are still relevant to managing the estuary in 2024 including information pertaining to the prevailing climate (rainfall, temperature, wind environments), historical river flow records, estuary sedimentation and erosion processes, bed sediment distribution, and estuary hydrodynamics. It is not intended to repeat the information presented in the documents here, except to summarise some of the information that is specifically relevant to the current 2024–2025 assessment of bank and riparian condition.

In this context, the focus of the review will be on identifying existing information relevant to the determination of estuary geomorphic process zones, estuary erosion processes, historic bank erosion mapping, historic riparian vegetation mapping, sediment sources and processes, existing bank protection works, and bank erosion and riparian vegetation management priorities in the Georges River estuary.

Where relevant and appropriate, the information presented in this review will be compared to the contemporary bank and riparian condition assessment results in later sections of this report.

Estuary Process Zones

Estuary process zones are a useful way to describe estuarine geomorphic attributes, estuarine character, estuarine sedimentary and erosion processes and to some extent riparian and estuarine vegetation associations occurring in a specific estuary system.

Estuary process zones have initially been classified by Williams et al. (2004), using a combination of bathymetric data, bed sediment sampling and geomorphological interpretation, and further comprehensively discussed in the Processes studies for the Georges and Woronora Rivers. Both process studies have been based on compilation of existing data sources and studies to discuss the hydrodynamics and sedimentary processes in relation to their geomorphological evolution and more recent disturbance histories. Additionally, these studies surveyed existing bank erosion sites and foreshore structures (Georges River only). The information from these studies have been referenced in, and used as a basis for, estuary management plans (BMT WBM, 2008; 2013) and the recent Georges River Coastal Management Program Scoping Study (Salt, 2022).

Georges River Estuary Processes Study (SMEC 2010)

The modern-day estuary channel of the Georges River is considered a drowned river valley, whereby the present channel is constrained to a valley that has incised over the last 30 million years and then has subsequently inundated during sea level high stands. Throughout the Quaternary period, sea level changes associated with climatic cycles have dramatically altered the channel system and estuary zones across the continental shelf. The modern-day estuary occupied its approximate location 6000 years ago as sea level rise rose to its current level, forming a tide-dominated embayment in its lower reaches. Coastal processes, including wind and swell wave propagation, are largely restricted to Botany Bay downstream of the Georges River study area.

The estuary catchment is primarily dominated by two geological units. The upstream western catchment overlies Wianamatta Shales, while the lower Georges River estuary is predominantly underlain by quartz-lithic Hawkesbury Sandstone (*Figure 2*). The distribution of these units is important in terms of modern-day processes as they reflect major distinctions in geomorphic units, soils and processes that relate to issues of bank erosion dynamics within the Georges River estuary. The Wianamatta Shales are the source of most Quaternary soils and alluvial sediments along the channel. The modern channel has developed broad floodplains along the tidal margins upstream of East Hills, where this geological unit is present. This area also provides the fine sediment currently being transported to the lower delta and mud basin. Erosion concerns are primarily confined to these upper reaches of the estuary.

In contrast, the lower Georges River estuary and Woronora Estuary are underlain Hawkesbury Sandstone, with exposed bedrock occurring frequently along the foreshore. These rocky outcrops form steep, erosion-resistant valley margins and hydrological constriction points. Downstream of the Woronora River confluence, the foreshore is further stabilised by retaining walls associated with residential development, rendering the lower estuary largely resistant to bank erosion.

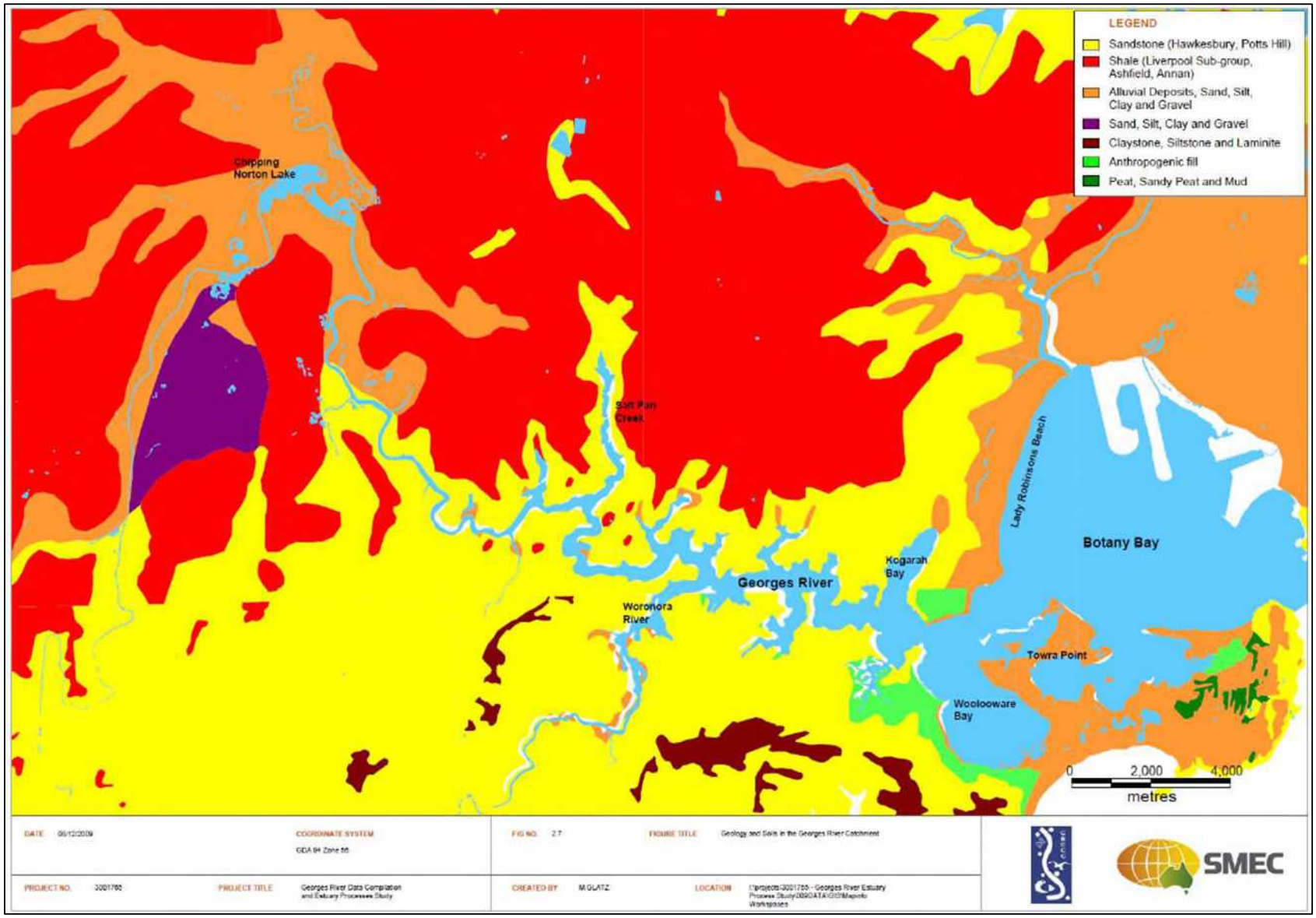

Figure 2 Underlying geology and soils of the Georges River catchment (source: SMEC, 2010).

The sediment transport regime through the estuary is dominated by the flood tide, while ebb-tide transport is significantly lower. Bed sediments of the Georges River estuary correspond to the fluvial and tidal hydraulic dynamics of the estuary (Munro et al., 1967) and relatively reflect the characteristics of distinct process zones. More recent bed sediment mapping indicates there has been little change to the depositional regimes (and hydraulic process zones) over the past 50 years aside from variations near the Chipping Norton lakes, associated with the formation of the lakes and discussed below (Albani and Rickwood, 2010). However, more in-depth information on these process zones are not fully explored in the SMEC (2010) report. These process zones include (*Figure 3*):

a. The main channel from Liverpool Weir downstream to Kyle Bay / Kangaroo Point where a strong fluvial regime is present, and the bed mostly consists of a downstream fining sequence of coarse to fine sands. A dominantly fluvial channel transitions to more tidally dominant delta downstream of East Hills. In the lower section, an increasing content of clays and silts demonstrate the downstream extent of the fluvial delta proximal to Kyle Bay.
b. Downstream of this point, a dominance of clays and silts in the bed highlight the transition to low-energy conditions of a mud basin in the central channel.
c. Large off-channel bay areas in the lower estuary (from Jewfish Bay to Kogarah Bay) have formed low-energy depositional zones dominated by flocculating silts and clays.

Dredging and sand extraction has had a major impact on the hydraulic and sediment dynamics of the Georges River, with both in-channel dredging and unregulated floodplain extraction occurring between the 1950s to 1970s (*Figure 4*). The major dredging activities occurred around Chipping Norton and Moorebank, with over 2.5 million cubic metres of material extracted from the floodplains and producing the lakes in this area. The formation of the lakes decreased the tidal range in this area of the channel network by 0.2 m and created extensive low-energy areas that have accumulated fine sediments. The redistribution of sediments through the lakes has increased sediment transport capacity upstream and downstream of the lakes and may be a contributing factor to erosion in these areas. However, an increase in tidal flows has changed the nature of bed scour and bed sediment mobilisation with the flood tides and across the range of flows in the flood regime. In-channel dredging in the mid reaches of the estuary at Milperra and upstream of Salt Pan Creek have also resulted in significant bed and bank erosion issues. Bed scour depths of 3–9 m have been predicted, with associated increases in channel width of up to 60% by the 1970s. While bank erosion sites were recorded (SMEC 2010), current historical channel width adjustments have not been adequately documented.

These anthropogenic disturbances have exacerbated the vulnerability of the channel, making it increasingly susceptible to further impacts from various environmental and human-induced factors. Bank erosion is influenced by multiple processes, including tidal undercutting, wind waves, flood events, boat wash, and the intensified influx of stormwater runoff (BMT WBM, 2013).

Flood events, in particular, play a significant role in erosion and sediment transport within the estuary. The Georges River is highly flood-prone and has experienced substantial modifications to its catchment hydrology and flood-risk over the past 150 years due to extensive urban development. Intensive urbanisation along the river and throughout the catchment has dramatically altered the river's hydraulic characteristics. The proliferation of impervious surfaces has led to increased runoff, which in turn has amplified flood velocities and exacerbated erosion, particularly in the upper reaches of the river. Undercutting, mass failure and slumping are all evident in the upper reaches. Some areas of the channel have been persistently eroding since the 1970s, with average bank retreat of 2–4 m and up to 10–15 m (SMEC, 2010). Localised erosion may also have been induced by inappropriate management actions or structures in some isolated areas.

Georges River Foreshore Study 2002

MHL (2002) undertook an assessment to identify the extent and causes of the existing bank stabilisation problems between Liverpool Weir and East Hills. The Foreshore Study provides a limited geomorphological assessment of the upper estuary.

The catchment area is characterised by two distinct physiographic regions, defined by the presence of Hawkesbury Sandstone and Wianamatta Shale geological formations. The diversity in soil types within the basin reflects this underlying geology, ranging from heavy clays to quartz-rich sands. Quaternary sedimentation is primarily confined to floodplain deposits, which are generally restricted to the reaches of the river near Liverpool, where the main channel transitions into the shale zone.

Within the upper estuary zone, the composition of the floodplain pockets varies, encompassing quartz sand, silty sand, silt, and clay. Downstream into the mid-reaches, there is an increase in finer sediments, resulting in the formation of sandy mud and muddy sand deposits. Notably, much of the left bank in the upper estuary consists of weathered Tertiary clayey quartzose sands and clays. The presence of dispersive clays in these riverbanks poses a significant challenge for erosion management. Generally, soils derived from shale are more susceptible to erosion and streams flowing through these areas tend to be more turbid due to the supply of fine sediments to the estuary during flood events, further exacerbated by urbanisation and development activities.

In the upper estuary, the bed sediments are primarily composed of coarse sands that, before the formation of the lakes, were largely immobile under tidal flow conditions. However, following dredging activities, the increase in tidal flow has facilitated minor reworking of these bed sediments, demonstrating the dynamic response of estuarine systems to anthropogenic modifications.

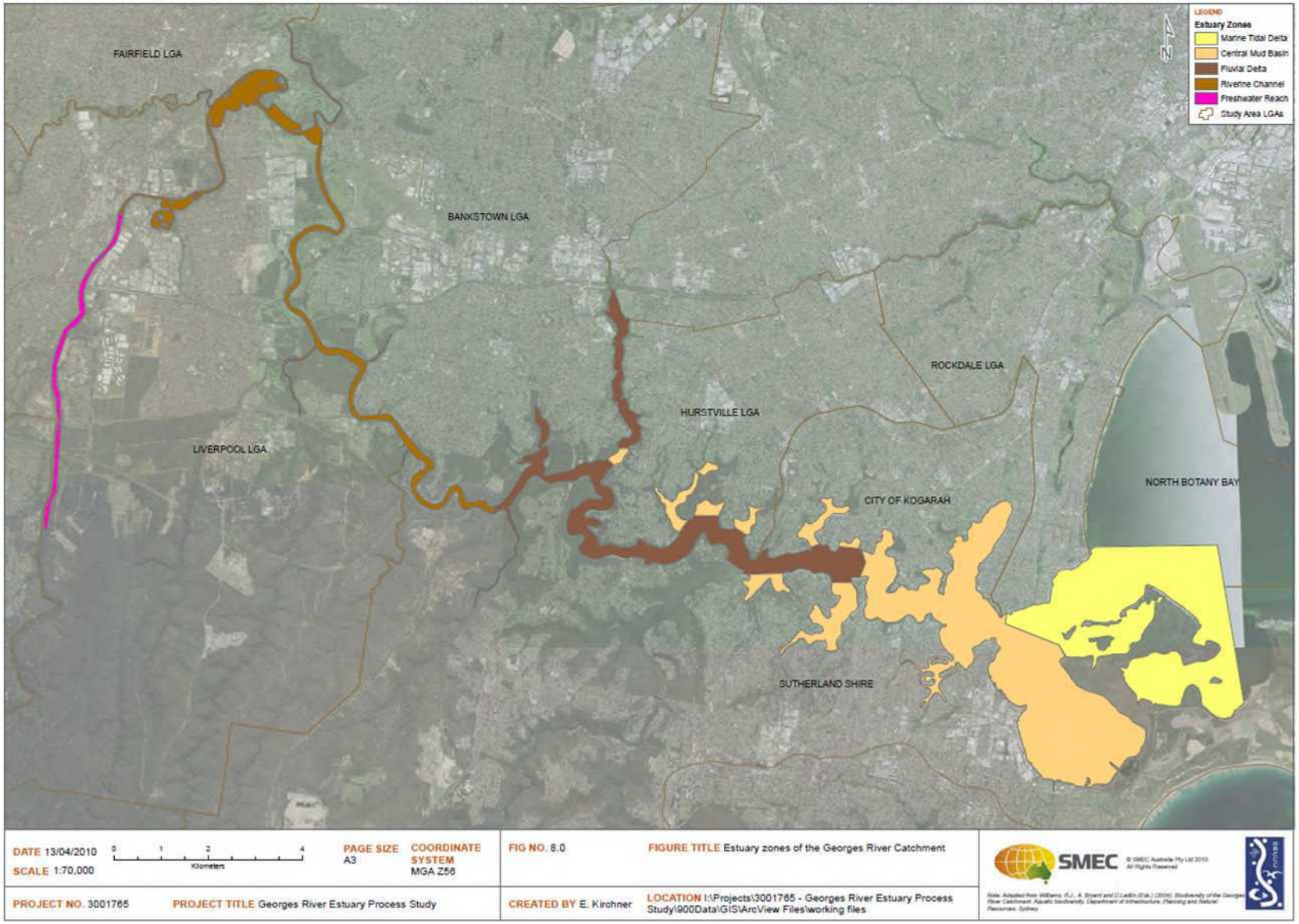

Figure 3 Map of estuary process zones of the Georges River Catchment (source: SMEC, 2010).

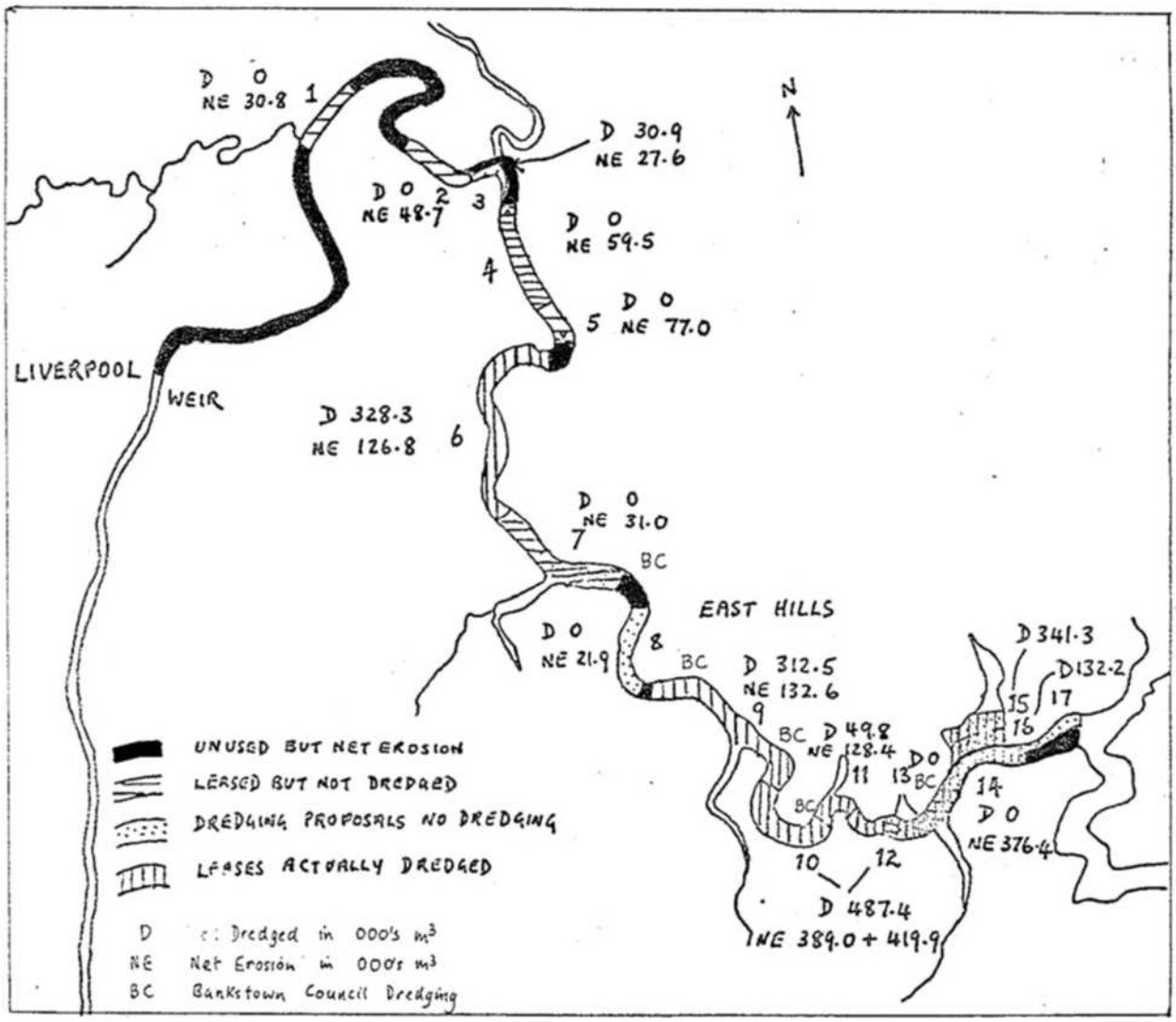

Figure 4 Areas dredged between 1959 and 1974 in the Georges River (Warner & Pickup, 1976).

Woronora River Estuary Processes Study 2006

The Woronora River estuary, a major tributary of the Georges River, is entirely situated on the Hawkesbury Sandstone and shares similar characteristics with the lower Georges River estuary. Like the latter, the Woronora River estuary is a drowned river valley, characterized by a deeply incised, narrow valley upstream that gradually widens as it approaches downstream areas. The headwaters of the Woronora River are regulated by Woronora Dam, which serves as drinking water supply for southern Sydney and the Illawarra. The estuary's catchment is defined by sandy soils, with the riverbed predominantly composed of sediments containing over 90% quartzose sands. Some low-energy areas, particularly in the lower estuary, exhibit a higher proportion of silt.

Geomorphologically, the Woronora River estuary can be divided into two process zones (*Figure 5*).

The first is a fluvial-dominated zone where the river channel intersects with the alluvial plain, extending to the upstream limit of brackish waters. The second zone, the fluvial delta, extends to the confluence with the Georges River and represents a significant depositional environment where the river's sediment load is deposited. This area features a complex array of physical habitats, ranging from terrestrial to intertidal and brackish subtidal zones. Extensive shoals are characteristic of this zone, and their formation, erosion, and reformation are believed to be a response to the dynamic equilibrium of sediment dynamics within the estuary. Historically, these shoals have been described as environmentally problematic, but such perspectives are likely outdated as reports from mid-1800s describe the naturally shallow character of the

estuary with a highly sinuous thalweg. These shoals have been influenced by anthropogenic activities such as dredging.

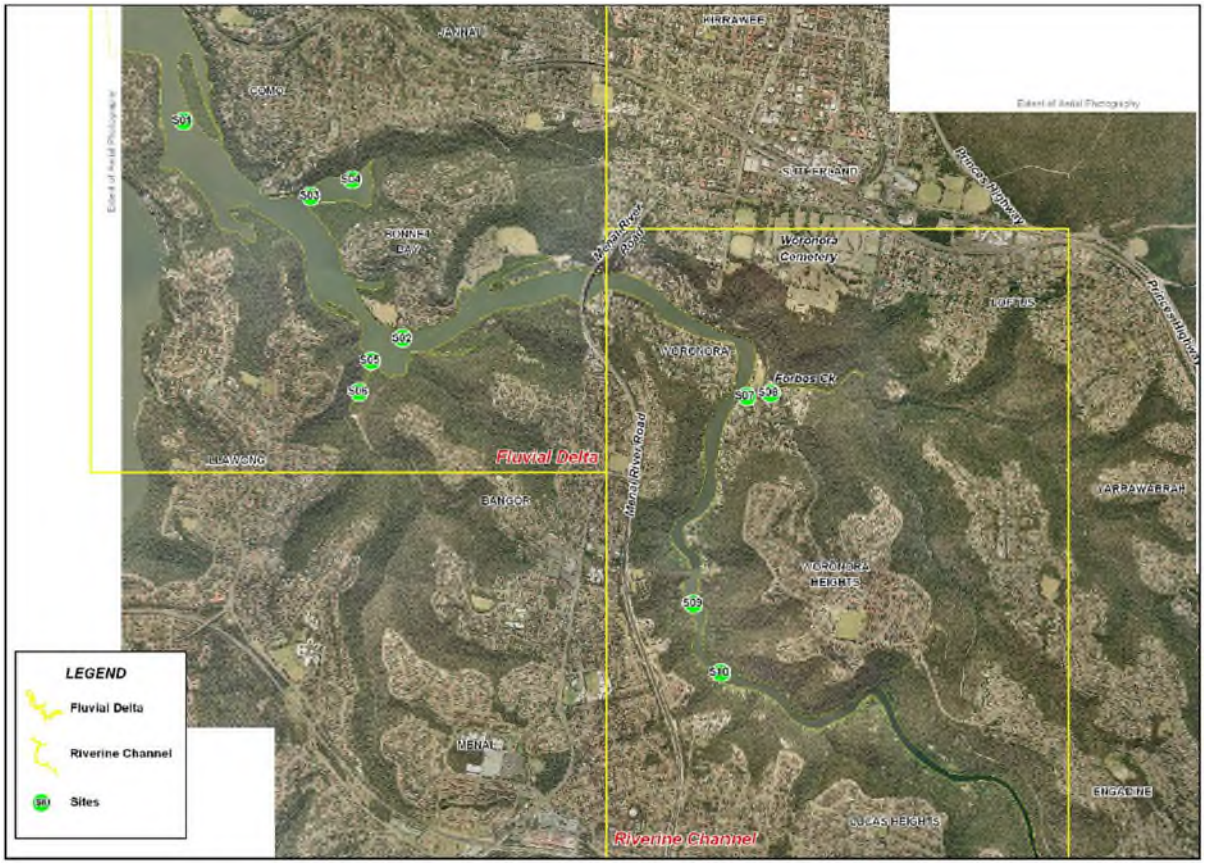

Figure 5 Distribution of process zones in the Woronora River estuary (source: WBM, 2006).

Historically, large portions of the Woronora River estuary were dredged in the late 1960s and early 1970s, with an estimated 400,000 m^3 of sediment removed, mostly in the middle reaches and at the estuary mouth. More recent residential development patterns have likely increased sediment loads, particularly within Forbes Creek and Loftus Creek catchments. But while sedimentation has remained a concern, mostly for recreational navigation, the rate of infilling has slowed considerably and has largely recovered from the impacts of dredging (*Figure 6*). As the estuary continues to evolve, it is anticipated to achieve a state of dynamic equilibrium, where the sediment budget becomes balanced over time. Sediment fluxes may fluctuate due to episodic events such as floods, but on average the sediment input from the catchment is expected to closely align with the sediment output from the estuary.

Bank erosion within the Woronora River is primarily attributed to boat wash, which is particularly severe in the downstream reaches due to larger and more frequent boat traffic. Upstream, erosion is not severe but extensive and is more likely related to infrequent flood events, exacerbated by the sandy soils prevalent in the adjacent floodplains. However, floods are likely to be partly mediated by Woronora Dam.

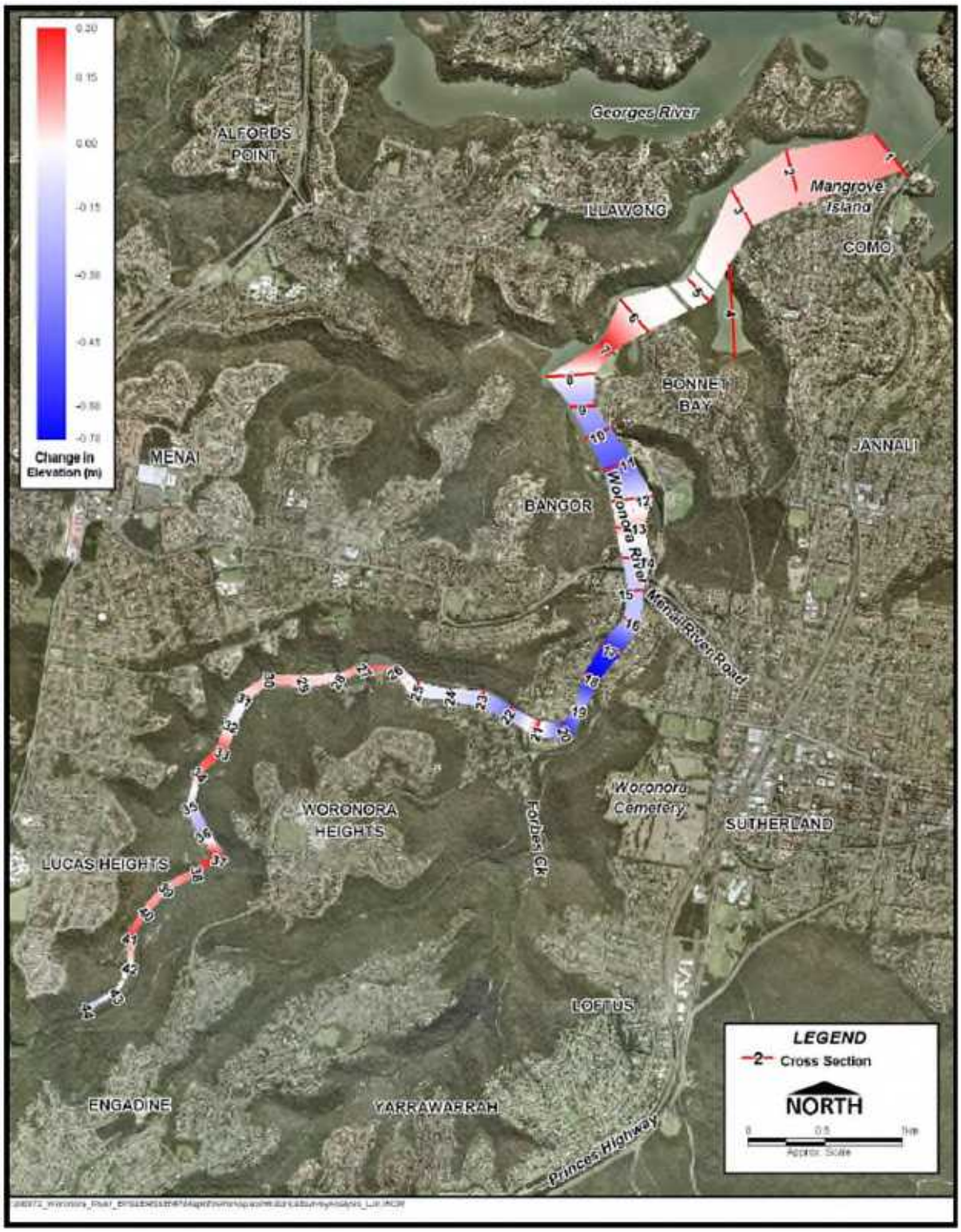

Figure 6 *Average changes in bed elevation in Woronora River, 1984–2005. Areas of Erosion (red) and Accretion (blue) (source: WBM, 2006).*

Estuary Bank Erosion Mapping and Estuary Bank Erosion Processes

Several studies and management reports have discussed issues of bank erosion and the causes and processes of erosion within the estuary. The most recent and relevant of these assessments occurred in 2009 as part of the Estuary Processes Study (SMEC, 2010) which investigated both past and current (at time of publication) erosion. A separate estuary processes study documented bank erosion in the Woronora

River estuary (WBM, 2006). Both of these studies collated and referenced earlier work undertaken in the 1970s, but few had documented or mapped erosion sites in detail. Other subsequent studies have primarily utilised information published within these reports.

Georges River Estuary Processes Study 2010

The most recent and comprehensive mapping of foreshore erosion sites on the Georges River were undertaken in late 2009 as part of field surveys undertaken in the Georges River Estuary Processes Study (SMEC, 2010). The area surveyed included the Georges River estuary downstream of Liverpool Weir and Prospect Creek. It is unclear whether Salt Pan Creek estuary was either not assessed or no sites were documented in that estuary, as it is not included in the surveyed site list and mapping. Woronora River estuary was not assessed as it has a separate estuary processes study and management plan.

Sites were mapped along the length of the bank where erosion was occurring and a bank erosion severity rating was attributed as either Light, Moderate or Severe erosion. No explanation for the erosion categories was provided but further details were collected for each site regarding the nature of erosion (e.g. undercutting, root exposure) and potential causes. Suggested relative costs, priority and management responses were also documented. An example of the mapping approach is shown in *Figure 7*. The mapping provides a useful comparative dataset as a baseline for current erosion severity throughout the estuary environment.

Figure 7 *Example of foreshore erosion and structure condition assessment undertaken as part of the Georges River Estuary Processes survey (source: SMEC, 2010).*

The report also suggested a number of key sites for management action, relative costs of intervention, and a general priority for management response. An example of sites identified is included in *Table 1*, with the identification of these sites used for comparative analyses of erosion later in this report.

Table 1 Key Management Action (erosion) sites for erosion identified in the 2010 Georges River Estuary Processes Study. Entries highlighted in RED were considered the highest priorities for erosion in the overall study area (excludes Woronora River).

Site (2010)	LGA	2009 Erosion Severity / Structure Condition	Priority
E1	Liverpool	Severe	High
E4	Liverpool	Severe	High
E21	Liverpool	Severe	High
E38	Fairfield	Severe	Med-High
E39	Fairfield	Light	High
E42	Fairfield	Severe	Med-High
E57	Canterbury-Bankstown	Severe	High
E58	Canterbury-Bankstown	Severe	High
E64	Canterbury-Bankstown	Severe	High
E88	Sutherland	Moderate	High
E90	Georges River	Severe	High
E91	Georges River	Moderate	High

SSC Watercourse Assessment & Rehabilitation Prioritisation 2012

Field surveys were undertaken at 1508 sample locations in 980 defined reaches of the Sutherland Shire LGA, of which 356 sites were surveyed in Georges River and 256 sites in the Woronora River estuary (Applied Ecology, 2012). The assessment only covered areas Sutherland Shire LGA which includes the lower right bank and foreshore of the estuary downstream of, Sandy Point, including Woronora River. Site locations were typically points located within the centre of a reach, but the number of points was scaled to the length of the reach.

Nine geomorphic indicators were assessed, which included categories of bank stability, bed stability, gully and rill erosion, depositional features, channel modification and excavation. These stream condition indicators were scored out of three for Assets and Problems (inverse ranking), where problem scores were:

- ***0*** – Nil
- ***1*** – Minor
- ***2*** – Moderate
- ***3*** – Extensive.

Further explanation or criteria to define each of these scores have not been documented in the report. *Gully* and *Rill* erosion were given a binary presence/absence score. At the reach scale, indicator scores were combined for the *Geomorphology* category and then ranked as either *Good* or *Bad*. Observations of the channel form, channel pattern, bed form and causes of erosion (if present) were also recorded for site specific points.

Woronora River Estuary Processes Study 2006

Estuary bank condition assessments were carried out in April 2005 as part of the Woronora River Estuary Processes Study (WBM, 2006). The survey recorded the structure and condition of the banks, the location of bank erosion and foreshore structures along the entire length of the estuary. In addition, a series of cross-sections were surveyed and compared with earlier cross-sectional data. This provided information on the dynamics and distribution of bed level variations and sediment volumes within the estuary (*Figure 6*).

While detailed foreshore assessment is mentioned as part of the survey, only summary information was included in the report and the detailed information could not be located. There was no categorisation of the scale or severity of the bank erosion in this summary data, only the presence of erosion was provided along with minor descriptions of some sites in the report body. Site specific processes were generally not identified although the assessment indicated that bank erosion was primarily related to boat wash and concentrated in reaches that have regular boat traffic. The most severe erosion was recorded between Burnum Burnum Sanctuary and the Bonnet Bay Boat Ramp (Sites 1–3; *Figure 8*). The data provides some opportunities to compare against survey data collected in this study.

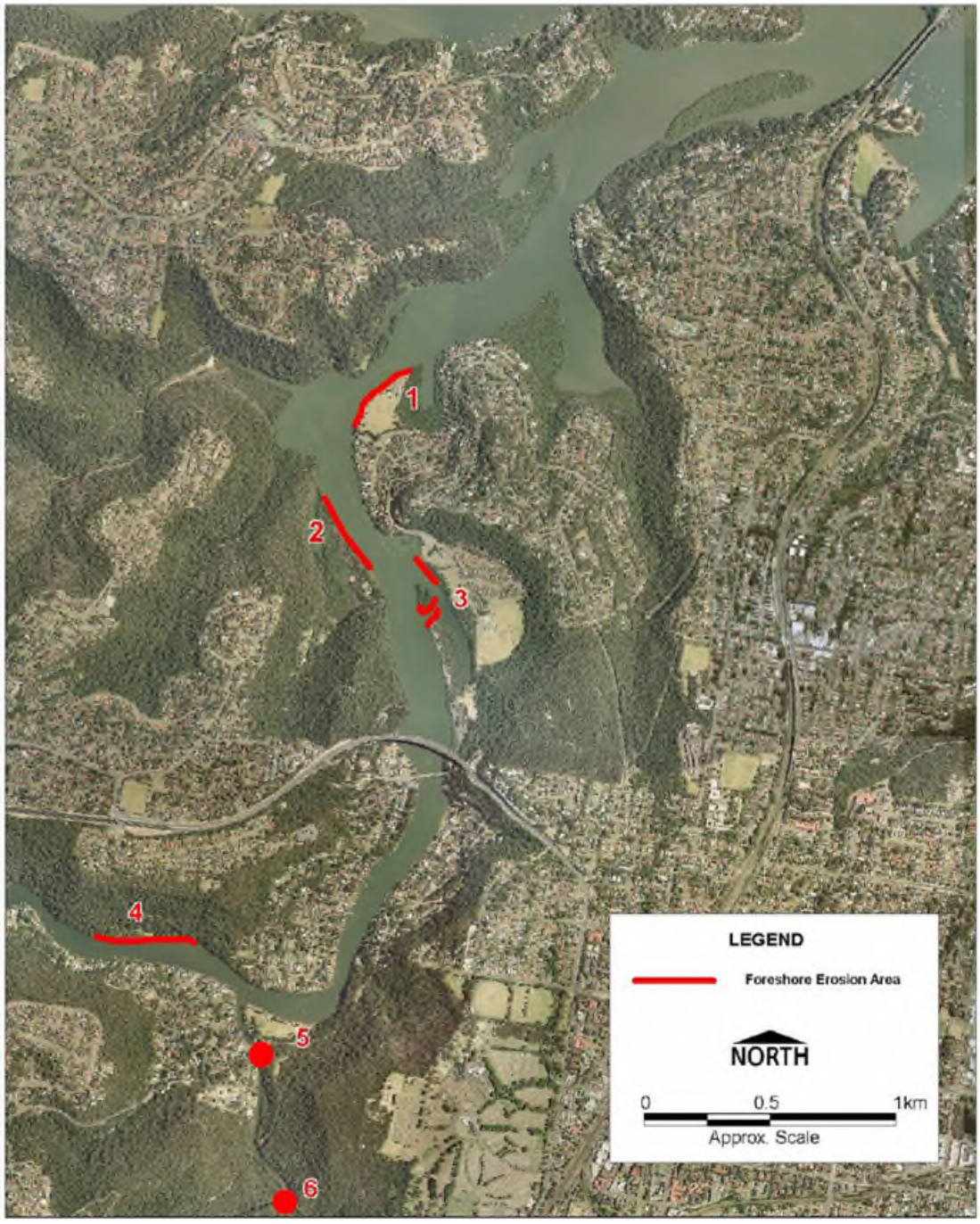

Figure 8 *Example of foreshore erosion assessment undertaken as part of the Woronora River Estuary Processes survey (source: WBM, 2006).*

Georges River Foreshore Study 2002

In February 2002 Manly Hydraulics Laboratory undertook field investigations of bank condition, erosion and protection in the upper Georges River estuary, from Liverpool Weir downstream to East Hills (MHL, 2002). Bank erosion locations were recorded and surveyed, along with repeat channel cross-section surveys to understand changes in channel dimensions from previous (1978–1989) surveys. Mapping of documented sites is not available and only qualitative comments provided in the report body and tables. Channel surveyed cross-sections are also not provided, only summary descriptions for each. The data is likely to be of limited practical value, and only if efforts are expended to locate and spatially reference the survey data.

Riverstyles® Assessment 2007

EarthTech consultants were initially engaged by Sydney Metro Catchment Management Authority in 2007 to undertake a Riverstyles® assessment and mapping in the Sydney Metro region (reported in EarthTech, 2007). Across NSW, River Styles data have recently been updated due to improvements in input data used for assessments and structural changes to align and produce a state-wide River Styles dataset (DPIE, 2023). In Georges River data, Assessment Confidence fields are incomplete, so it is unclear whether the data has been adjusted from the 2007 assessment.

The assessment describes the Georges River estuary study reach as a laterally unconfined, low sinuosity (tidal) channel in the upper reaches, transitioning to a partly confined, bedrock margin-controlled, low sinuosity (tidal) channel downstream of East Hills. The entire estuary is described as being in either Poor (upstream of Chipping Norton Lake) or Moderate geomorphic condition, with associated Low to Moderate recovery potential. The reasons for the classification include urbanisation of the catchment and river with extensive historical gravel mining leading to changes in channel areas and hydrology and reduced resilience. Woronora River has a Good to Moderate condition, broadly aligning with the Process Zone delineation. It is described as being intact upstream and a High recovery potential and priority for rehabilitation downstream. The ratings have limited practical management application, particularly at the reach scale.

Riparian Vegetation Condition Mapping

There have been several instances of comprehensive mapping of riparian vegetation condition undertaken for the Georges River Estuary study area over the last twenty years. The most recent broad scale mapping undertaken in the Georges River was in 2013, which updated 2009 vegetation mapping (OEH, 2016). Vegetation mapping also occurred in 2004 throughout the extent of the Georges River estuary in a focused study of the Georges River catchment (Williams et al., 2004). More limited investigations were undertaken by some councils within their LGA, with vegetation condition assessments covering a portion of the study area. The following documents contain some information on the distribution, composition and condition of riparian vegetation within the study area.

The Native Vegetation of the Sydney Metropolitan Area 2016

This GIS dataset is most comprehensive and broadscale vegetation mapping for the Georges River estuary and covers the complete extent of the study area (OEH, 2016). The dataset does not directly differentiate vegetation communities into riparian vegetation types but includes a diverse range of ecosystem Niches, which could be assessed as “riparian” (e.g. Estuarine fringes, Riverflats, Intertidal zone). Further, the mapping shows vegetation occurring adjacent to waterways and includes estuarine macrophyte communities (e.g. mangroves, seagrass meadows). *Threatened Ecological Communities* (TECs) have been identified as an attribute of the data, although this has not been segregated to identify the *Endangered Ecological Communities* subset of this data. The overall dataset builds on 2009 vegetation mapping of the Sydney Metro area (DECCW 2009) and was considerably revised and published in 2013, with further

updates in 2016. It is unclear the extent and capacity to which vegetation mapping was revised within the Georges River estuary.

In addition to mapping communities, the dataset includes categories of disturbance, with 27 qualitative disturbance types and a disturbance severity score based on spatial extent of disturbance within the mapped polygons:

- ***0*** – Not assessed
- ***1*** – Isolated disturbance (<10% polygon affected)
- ***2*** – Restricted disturbance (10–30% polygon affected)
- ***3*** – Broad disturbance (30–70% polygon affected)
- ***4*** – Extensive disturbance (>70% polygon affected)
- ***5*** – No visible disturbance

The initial mapping product was further used as a proxy for vegetation condition and prioritisation (SMEC, 2010).

Biodiversity of the Georges River Catchment 2004

Vegetation mapping of the Georges River estuary was undertaken in 2004 by the NSW Department of Infrastructure, Planning and Natural Resources. Reports of the data were split into two volumes, *terrestrial biodiversity* (DIPNR, 2004) and *aquatic biodiversity* (Williams et al. 2004). The mapping efforts and conclusions have been subsequently used by a number of subsequent studies and analyses, forming the basis for understanding of estuary processes in Georges River. It is clear the report and associated data were comprehensive. However, the full extent of the report, and associated data and mapping created as part of the study, could not be located for further analysis.

Woronora River Estuary Processes Study 2006

Field surveying and mapping of wetland and riparian vegetation was undertaken in 2005 in the Woronora River estuary in conjunction with bank condition assessment (WBM, 2006). The presence and boundaries of estuarine wetland vegetation (i.e. seagrass, mangrove, saltmarsh and Casuarina) as well as apparent degraded condition or health (e.g. canopy dieback). Mapping was combined with prior vegetation mapping (Williams et al. 2004), digitising a limited amount of new or unrecorded vegetation from 2005 high-resolution aerial photography. While vegetation mapping was undertaken in a GIS, no further digital record of this data could be located for comparative analysis with surveying undertaken in this project. The report contains figures showing the extent of estuarine vegetation, which could be digitised with concerted efforts, but this would not include any of the detailed condition assessment data. Further, the associated vegetation condition assessments could not be located.

Georges River Biodiversity Study 2021

The assessment was only undertaken in the extent of the Georges River LGA, which covers the lower left bank and foreshore of the estuary downstream of, and including, Salt Pan Creek (Total Earth Care, 2021). A range of spatial datasets were reviewed using a desktop assessment to identify priority sites for field assessment, with presented mapping utilising the OEH (2016) vegetation mapping. Sites were attributed with the areas of importance based on different criteria and values:

- ***Level 3*** – high importance to be focused on for targeted field surveys
- ***Level 2*** – moderate importance to be visited with no targeted surveys
- ***Level 1*** – low importance for desktop assessment only
- ***Street tree green corridors*** – street trees that form notable existing green corridors.

All foreshore vegetation communities, coastal wetlands and TECs were considered Level 3 (High importance). Rapid point condition surveys were undertaken for all Level 3 and Level 2 sites. Survey techniques were based on the NSW Biodiversity Assessment Method (BAM) (DPIE 2020) using survey plots with survey areas and condition was assessed on vegetation structure, native species diversity, presence of key native or weed species, as well as the degree of natural regeneration, fall timber, rock outcrops, cryptograms, mistletoe, hollow-bearing trees, grazing, erosion and fire or flood damage.

The study made management recommendations and priorities to a range of sites, which broadly included updating vegetation mapping, undertaking regeneration and weed removal works, implementing buffer planting around TECs and monitoring ongoing changes to Estuarine Saltmarsh communities at a number of sites.

SSC Watercourse Assessment & Rehabilitation Prioritisation 2012

612 field surveys were undertaken at representative point locations for mapped reaches in the Georges River and Woronora River estuary (Applied Ecology, 2012). The assessment only covered areas Sutherland Shire LGA which includes the lower right bank and foreshore of the estuary downstream of Sandy Point, including Woronora River. Site locations were typically located within the centre of a reach, but the number of points was scaled to the length of the reach.

The surveys included nine attributes of riparian habitat/vegetation condition and six attributes of in-stream habitat condition (which included mangroves and saltmarsh). As per the bank erosion assessment, indicators were scored out of three as either Assets (positive weighting) and/or Problems (negative weighting). The attributes include per cent cover, per cent native cover, per cent weed cover, vegetation structure, diversity, presence of threatened species and noxious weeds, in-stream vegetation health and habitat complexity. Each attribute was scored and then combined to give a single category condition score for each reach. The data was made available as an attributed point dataset with all the attributes and a reach polyline dataset that had the category scores used for rehabilitation prioritisation.

Existing Bank Protection Works

Both estuary processes studies (WBM, 2006; SMEC, 2010) have undertaken detailed assessments of the extent and range of bank protection works along the estuary foreshore. There is some limited information in the existing literature detailing the types of works and their effectiveness in controlling site erosion.

Georges River Estuary Processes Study

Comprehensive mapping and assessment of existing bank and foreshore protection works was undertaken in late 2009 as part of field surveys undertaken in the Georges River Estuary Processes Study (SMEC, 2010). Structure conditions were rated as followed:

- **Good**: the seawall is quite new or intact; it is properly engineered and does not need any maintenance or only minor maintenance.
- **Fair**: the seawall is in relatively good condition but would need maintenance or upgrades
- **Poor**: Dumped materials, collapsed seawall or seawall in need of major maintenance and upgrades

Details on the nature, purpose and additional comments were recorded for each structure, although these have not been attributed to the dataset. Where structures were rated poor, additional details relevant to further management were provided, including management options, relative cost (low to high) and priority rating (low to high). Summary guides are provided for the suggested management options, including example photos of each option. *Figure 9* provides an example of the mapping undertaken, showing the condition assessment and management recommendations.

Woronora River Estuary Processes Study

Bank protection structures were surveyed and assessed in 2005 as part of the Estuary Processes study (WBM, 2006). Mapping of bank protection has been relatively simple, stating whether structures are natural (e.g. rock outcrops) or engineered, which are primarily limited to waterfront residential properties (*Figure 9*). While detailed engineering assessments of foreshore structures is mentioned as part of the survey, only summary information was included in the report and the detailed information could not be located. The summary information within the report describes some structures as being inadequate or in a state of severe deterioration, but most are in reasonable condition.

Bank Erosion and Riparian Vegetation Management Priorities

The main documents which contain recommendations and priorities for the future management and protection of estuary banks and estuary bank vegetation in the study area are the Georges River Estuary Coastal Zone Management Plan (CZMP), 2013 (BMT WBM, 2013), Georges River Estuary Processes Study (SMEC, 2010), the Woronora River Estuary Management Study and Plan, 2008 (BMT WBM, 2008). In addition, the Georges River Catchment CMP Scoping Study identifies goals for deriving future management priorities within the catchment (Salt, 2022).

Georges River CMP Scoping Study 2022

Georges River Catchment Coastal Management Program Scoping Study provides the first stage of the CMP by determining the strategic context and establishing purpose, vision and objectives based on key management issues (Salt, 2022). The Scoping Study establishes the program of work to be completed for the CMP, particularly a range of actions to undertake in Stage 2 studies. It does not currently provide explicit priorities for estuary management, which are likely to emerge from the Stage 2 studies.

A first pass risk assessment undertaken as part of the study identified that the highest-ranking issue is *Riparian & Estuarine Condition and Habitat/Corridor Loss*, while *Catchment Runoff and Water Quality* was ranked second. Both issues had high environmental priority, and moderate-high social and economic priority.

Streambank Stability & Erosion, as well as *Foreshore Asset Management* were both considered low priorities to be addressed in the CMP, respectively ranking nineth and tenth out of twelve issues. It is not clear how these four issues are considered independent, as riparian condition, water quality and foreshore assets are strongly inter-related with streambank stability. Although the issues were further defined through a workshop conducted by Alluvium Consulting Pty Ltd, it is unclear what explicitly they encompass and how they have been compartmentalised.

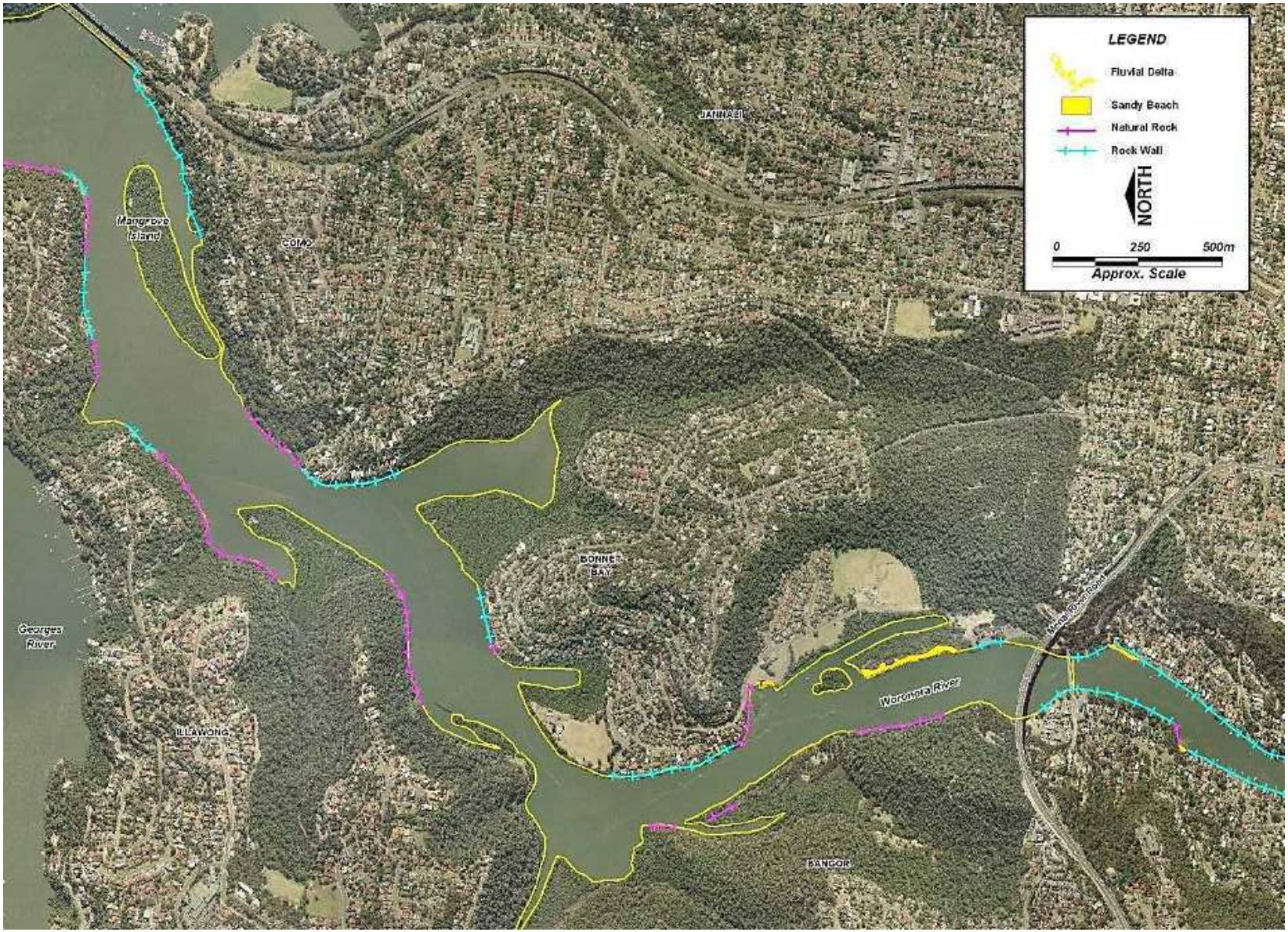

Figure 9 Natural and constructed attributes of river margins along the lower Woronora estuary (source: WBM, 2006).

Georges River Estuary CZMP 2013

The CZMP (BMT WBM, 2013) provides strategic direction and guidance on environmental management and planning within the estuary and its catchment. It also provides an action plan for undertaking targeted works to conserve and improve the existing natural environment, and to improve the water quality, of the Georges River Estuary. The plan identifies nine broad aims and 27 management objectives to address key issues within the estuary catchment. The relevant aims to this study include:

- Water quality: to optimise water quality within the Georges River Estuary and its tributaries
- Aquatic and Riparian Habitat: To protect, enhance and restore aquatic habitats and foreshore vegetation
- Recreation and Amenity: To protect and enhance public access to the foreshore
- Bank Erosion and Sedimentation: To actively manage bank erosion and sedimentation
- Foreshore Protection: To manage existing built foreshore assets while maximising environmental values

Actions and strategies have been recommended to address identified objectives of the plan, with each action typically addressing multiple objectives. Strategic locations have also been identified to achieve these objectives (*Figure 10* and *11*).

High priority management objectives within the CZMP relevant to this study include:

- **E1.** Reduce the extent and severity of bank and foreshore erosion while minimising the impacts on estuary health
- **E2.** Reduce the causes and impacts of sedimentation in the estuary
- **B3.** Protect and improve the extent and condition of estuarine and riparian vegetation
- **B2.** Minimise the cause and spread of invasive species in aquatic and terrestrial habitats

Further lower priority objectives within the CZMP that are relevant to this study include:

- **G1** To effectively manage threats to and to enhance the natural and cultural heritage values in the catchment and waterways
- **C3** To maintain and improve formal public access to the foreshore without compromising estuary health
- **C1** To maintain the varied legal recreational pursuits of the Georges River catchment without compromising estuary health and social amenity

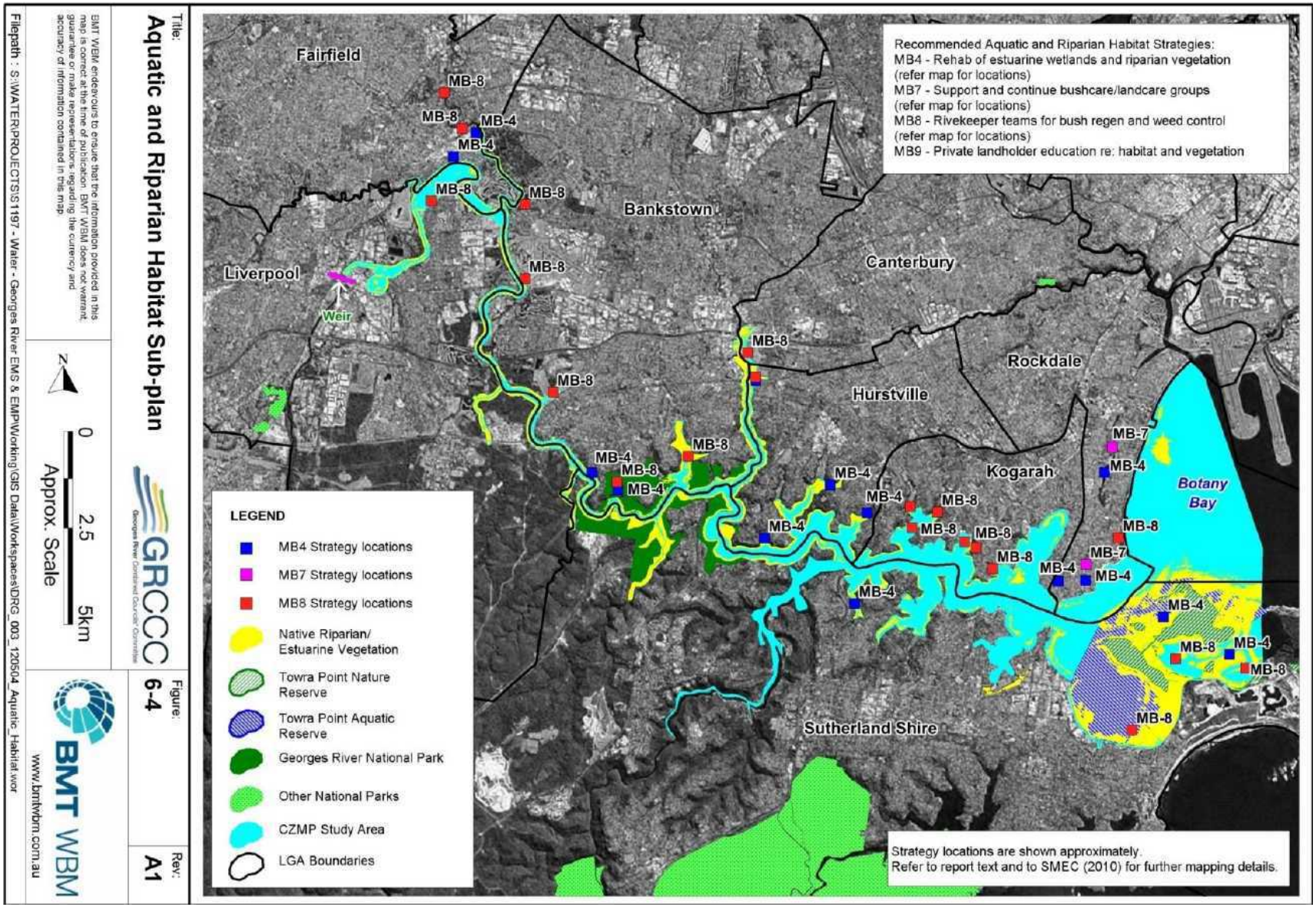

Figure 10 Strategies and locations identified in the Aquatic and Riparian Habitat Sub-plan from the Georges River Estuary CZMP (source: BMT WBM, 2013).

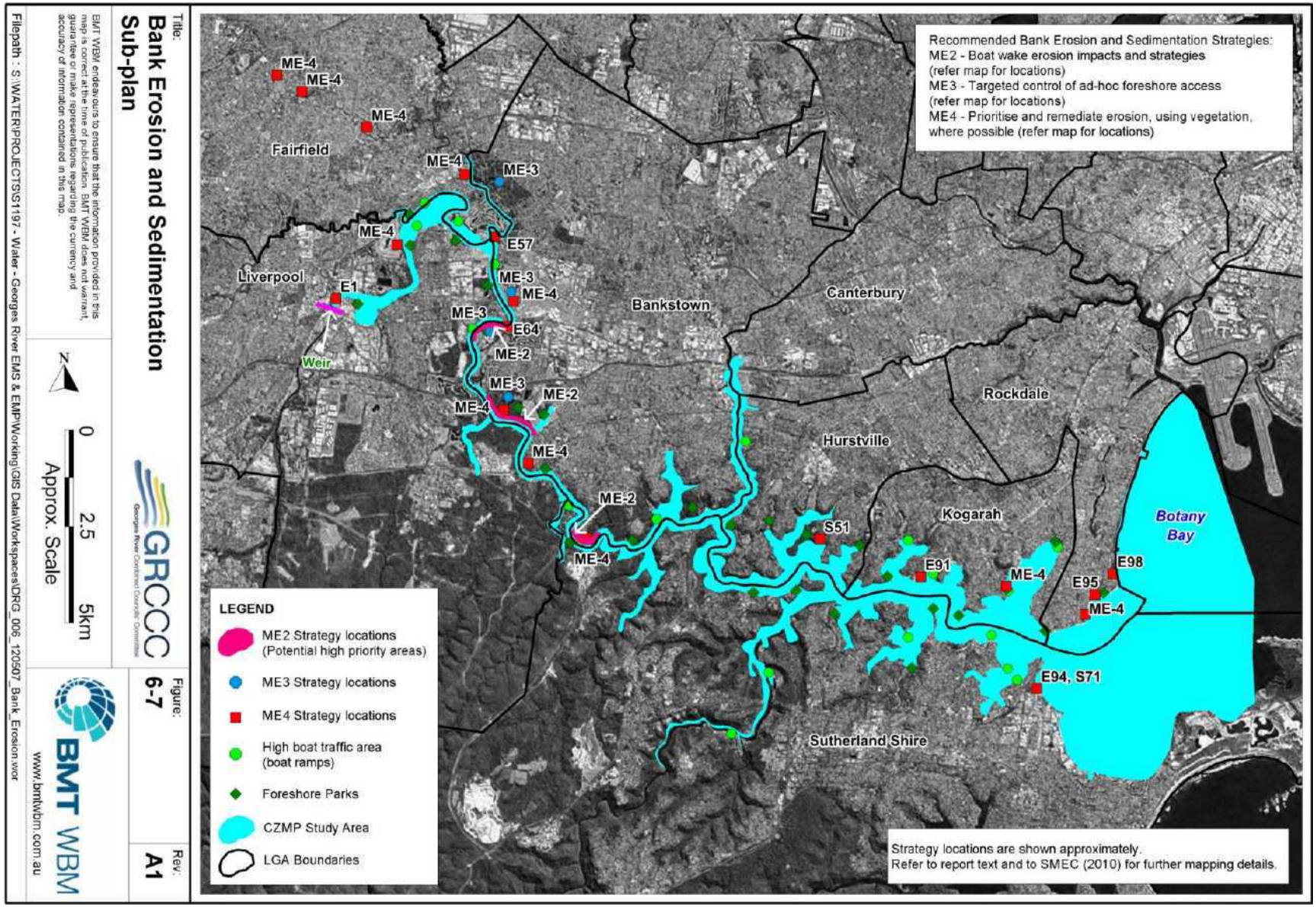

Figure 11 Strategies and locations identified in the Aquatic and Riparian Habitat Sub-plan from the Georges River Estuary CZMP (source: BMT WBM, 2013).

Relevant actions indicated in the CZMP that identify specific locations to improve estuary condition by addressing the above aims and objectives include:

- **Action MB-4: Identify locations for and undertake targeted rehabilitation, creation and enhancement of estuarine wetland communities (saltmarsh, mangrove, seagrass) and adjacent riparian vegetation**

  This action addresses Objective B3 at a range of strategic locations as part of an Aquatic and Riparian Habitat Sub-Plan (*Figure 10*) including:

  - Identifying and fill any gaps in ecological surveys undertaken to date.
  - Completing relevant design, assessments and construction of necessary works.
  - Establishing appropriate ongoing habitat monitoring programs.
  - Implementing management and restoration programs.
  - Monitoring growth of mangroves and control where they are encroaching into saltmarsh (where feasible and appropriate).
  - Monitoring the populations of other significant species associated with saltmarsh communities.
  - Investigating feasibility of levelling land to a suitable level for tidal inundation and saltmarsh establishment.
  - Integrating revegetation including invasive plant removal and replanting of saltmarsh species in areas where natural recovery potential (resilience) of saltmarsh is not possible.
  - Monitoring the integrity and condition of estuarine vegetation communities to determine dynamics, present and/or future anthropogenic impacts resulting in intra-specific competition between communities (e.g. Estuarine reedland and estuarine swamp oak forest).

- **Action ME-3: Control ad hoc access along the foreshore to limit vegetation trampling and bank destabilisation, targeting sites of high environmental significance**

  The action addresses Objective E1, C3 and B1 as part of a Bank Erosion and Sedimentation Sub-Plan (*Figure 11*), including:

  - Limiting access in areas where problems such as vegetation trampling and bank destabilisation are occurring.

- **Action ME-4: Prioritise active eroding foreshore areas and undertake erosion management works using techniques that maximise the use of riparian vegetation**

  The action addresses Objective E1 as part of a Bank Erosion and Sedimentation Sub-Plan (Figure 11) including:

  - Identification of key erosion sites
  - Prioritisation of erosion sites
  - Encourage natural solutions or environmentally friendly engineered solutions
  - Apply erosion and sediment controls in DCPs in areas prone to streambank erosion.

Georges River Estuary Processes Study 2010

The Estuary Processes Study uses mapping of bank erosion and structures, which includes a rapid assessment for particular management approaches, to develop a prioritisation for management actions (SMEC, 2010). A simple and subjective prioritisation approach for management actions at each site was based on a combination of relative cost and environmental benefit. The highest priorities were those which provide the greatest environmental benefit at minimum cost.

A final list of 31 key management actions were determined based on a selection of high priority ranking sites, aimed at providing a relative distribution across the estuary catchment. Ten sites were selected as the highest priority for the estuary study area. The selection of management priorities includes both erosion sites (*Table 1*, presented previously) and seawall structure sites (*Table 2*) but was not a comprehensive list of all sites ranked as high.

Table 2 Key management action (seawall) sites identified in the 2010 Georges River Estuary Processes Study. Entries highlighted in RED were considered the highest priorities for seawall maintenance in that report's estuary study area (excludes Woronora River).

Site (2010)	Survey ID (2025)	LGA	2009 Erosion Severity	Priority
S17	98	Fairfield	Poor	Med-High
S21	1041	Fairfield	Poor	High
S24	75	Canterbury-Bankstown	Poor	High
S28	43, 48	Liverpool	Poor	High
S36	314	Liverpool	Poor	High
S40	357	Canterbury-Bankstown	Fair	High
S42	351	Sutherland	Fair	High
S50	463	Sutherland	Fair	High
S51	717, 718	Georges River	Fair	Med-High
S56	831	Georges River	Poor/Fair	High
S60	949	Georges River	Fair	High
S63	975	Georges River	Poor	High

Woronora River EMP 2008

The EMP details objectives for long-term management of the Woronora River and recommends a series of detail prioritised and costed management strategies and actions. It identifies 19 objectives framed within four over-arching goals based on the values of the estuary and the issues/problems it is facing. The relevant objectives to this study include:

GOAL 1: Water quality of the Woronora Estuary should be suitable for a range of environmental and recreational uses

- **Objective 1:** Reduce the level of pollutant and sediment loads entering the Woronora Estuary from catchment runoff (Priority 1).

GOAL 2: Habitats of the Woronora River Estuary should support a diversity of estuarine species

- **Objective 7:** Identify, protect and enhance key habitat areas (Priority 7)
- **Objective 9:** Identify and minimise impacts of recreational activities on estuarine habitats and species (Priority 14)
- **Objective 10:** Remove weeds from bushland areas around the estuary (Priority 5).

GOAL 3: Appropriate use of the waterway and foreshores without compromising natural and cultural values of the Woronora Estuary

- **Objective 11:** Stabilise eroding foreshores, where necessary, to protect assets or infrastructure (Priority 6).
- **Objective 12:** Minimise bank erosion impacts of recreational and commuter boating (Priority 9).

- **Objective 13:** Improve and maintain amenity of foreshore reserves, where appropriate (Priority 12).
- **Objective 14**: Recognise Aboriginal and early European cultural significance of Woronora River Estuary and environs (Priority 18).

A total of 45 potential management options were formulated and considered to address the 19 management objectives. Effective policing of waterway users (W&F-7) was considered the highest priority action, while on-ground works in the form of protecting eroding foreshores (W&F-9) and Revegetation/ protection of eroding foreshores (Ecol-6) were the next highest priority actions.

Boat wake has been considered as the major cause of bank erosion in the Woronora Estuary. A number of specific actions and strategies were tabled for review and assessment that focus on removing processes more so that targeted management of eroding sites e.g. limited boat activities that induce erosion. However, high priority actions for both bank erosion and riparian vegetation management include:

- Hard protection/repair of existing foreshore structures. Specific areas included Janalli Reserve (Burnum Burnum Sanctuary) and Prince Edward Park
- Revegetation / Protection of eroding foreshores (identified in the Estuary Processes Study; WBM, 2006) using Bushcare Groups. Priority areas included sites 1, 2, 3 and 4 (northern estuary) and Site 7 (southern estuary), remediating eroding foreshore at:
    - Lakewood City Reserve
    - Bonnet Bay Boat Ramp
    - Opposite Bonnet Bay Boat Ramp
    - Scout Camp, Opposite Burnum Burnum Sanctuary
    - Scout Camp, West of Deepwater Estate.

Georges River Regional Environmental Plan 1999

The *Greater Metropolitan Regional Environmental Plan No 2—Georges River Catchment* (REP) influences the land use, environmental planning and management decisions of the Georges River catchment. Development undertaken within the catchment that is likely to affect the environment is subject to the provisions of the Plan.

The aims of the REP are:

- Maintain and improve water quality and river flows in the Georges River and its tributaries.
- Protect and enhance the environmental quality of the Catchment for the benefit of all users; and
- Ensure consistent delivery of Ecologically Sustainable development when assessing development and promote integrated catchment management policies.

More specifically, the REP notes the following relevant objectives for estuary management:

- to preserve and protect and to encourage the restoration or rehabilitation of regionally significant sensitive natural environments such as wetlands (including mangroves, saltmarsh and seagrass areas), bushland and open space corridors within the Catchment.
- to preserve, enhance and protect freshwater and estuarine ecosystems.
- to conserve, manage and improve the aquatic environment for the aquaculture industry by reducing pollution entering watercourses.
- To protect the safety and wellbeing of the local and regional community by improving water quality and river flows to enable recreation.

Council Biodiversity Strategies

Across the estuary study area, each Council has a Biodiversity Strategy ranging in age from 2000 to 2022. A strategic plan could not be identified for the Georges River Council but appears to be in development. Across the four strategies (Canterbury-Bankstown, Fairfield, Liverpool, and Sutherland Councils) there is a shared commitment to protecting and enhancing biodiversity through a mix of strategic planning, operational restoration, mapping, policy enforcement, and community engagement. None of the documents indicate protection of specific sites or vegetation communities, although there is a general direction towards Endangered Ecological Communities (EECs), threatened species of flora and fauna, as well as endangered populations. While the exact objectives and actions for each Council strategy vary, core themes emerge across the strategies and include:

Riparian Vegetation and Waterway Protection – All four councils prioritise the rehabilitation and protection of riparian corridors as essential components of biodiversity conservation. Actions include:

- Planning riparian corridors with a focus on vegetation rehabilitation and biodiversity enhancement (Canterbury-Bankstown – BP2).
- Rehabilitating creek banks, with measurable goals such as restoring 30% of both sides to natural condition (Fairfield – Action 2.6).
- Protecting, managing, and restoring riparian vegetation, including buffer zones and aquatic ecological values (Liverpool – 3.2.5).
- Protecting drainage lines, watercourses, and foreshores as natural soil stabilisers (Sutherland – Habitat Protection Objective).

Native Vegetation Management and Enhancement:

- Expanding native tree canopy and indigenous ecologies (Canterbury-Bankstown).
- Improving vegetation cover and condition in natural areas through maintenance and restoration programs (Fairfield – Action 2.7).
- Acquiring and managing land to restore native vegetation and habitat (Liverpool – LM1).
- Mapping and inventorying vegetation types and condition, with ongoing updates to inform planning (Sutherland – Habitat Action 1).

Habitat Connectivity and Corridor Creation:

- Establishing wildlife corridors and linking fragmented habitats (Sutherland – Corridor Actions).
- Locating restoration programs within mapped corridors and green grid links (Fairfield – Action 3.3).
- Preserving connectivity roles of remnant vegetation in riparian and regional areas (Liverpool – 3.2.3, 3.2.6).
- Mapping and updating biodiversity overlays to reflect corridors and habitat links (Canterbury-Bankstown – BP4).

Threatened Species and Ecological Communities:

- Protecting EECs in urban and riparian areas (Liverpool – Core Remnants, 3.2.5).
- Investigating and promoting Biodiversity Stewardship sites to secure significant patches of bushland (Canterbury-Bankstown – ER1).
- Preventing extinction and promoting recovery of threatened species and their habitats (Sutherland – Threatened Species Objectives).

Existing and Derived GIS Datasets used in this Assessment

Existing Spatial Datasets

The following existing spatial datasets have been used in this assessment:

- *NSW Crown Lands Parcels* accessed via the NSW Spatial Data portal at https://www.spatial.nsw.gov.au/products_and_services/spatial_data which allowed for the identification of Crown owned land during the field survey and later during the priority setting process.
- *NSW State Forest Parcels* accessed via the NSW Spatial Data portal at https://www.spatial.nsw.gov.au/products_and_services/spatial_data which allowed for the identification of State Forest owned land during the field survey and later during the priority setting process.
- *NSW National Parks Estate Parcels* accessed via the NSW Spatial Data portal at https://www.spatial.nsw.gov.au/products_and_services/spatial_data which allowed for the identification of National Parks estate during the field survey and later during the priority setting process.
- Council Owned Land Parcels accessed via the NSW Spatial Data portal at https://www.spatial.nsw.gov.au/products_and_services/spatial_data which allowed for the identification of Council owned land during the field survey and later during the priority setting process.
- *SEPP (Resilience and Hazards) 2021 Coastal Wetland Area, Coastal Wetland Proximity Area, Littoral Rainforest Area, and Littoral Rainforest Proximity Area* mapping accessed via the Seed Portal at https://www.seed.nsw.gov.au which was used as one of a variety of criteria which informed the determination of priorities for action relevant to the Coastal Management Act 2016.
- *Estuarine Macrophytes* accessed via the Seed Portal at https://www.seed.nsw.gov.au which was used during the priority setting process.
- *Aquaculture Lease Areas, Priority Oyster Aquaculture Area* and *NSW Oyster Reefs* datasets accessed via the NSW DPIRD Fisheries portal at https://www.dpi.nsw.gov.au/fishing/fisheries-research/spatial-data-portal which was utilised during the field survey and later during the priority setting process.
- *Native Vegetation of the Sydney Metropolitan Area – Version 3.1* (2016) accessed via the Seed Portal at https://www.seed.nsw.gov.au which allowed for the identification of areas of high conservation value vegetation during the field survey and also informed the priority setting process for riparian management actions.
- Various layers relating to asset and infrastructure locations were provided by participating Councils including Canterbury Bankstown, Georges River, Liverpool and Fairfield Council.

Spatial Datasets Derived from Existing Sources for the Field Survey

The following spatial datasets were created to facilitate the field survey component of this assessment:

- *Georges River Estuary Bank Reference Layer* was onscreen digitised at 1:2000 scale off February 2023 Worldview Imagery. This line feature allowed for the accurate mapping of survey reaches with each reach “snapped” to the digitised bank location to ensure accuracy.

Community, Industry and Stakeholder Consultation

A targeted community consultation process was undertaken to assist in identifying bank and riparian issues affecting the estuary from an industry and recreational use viewpoint. The consultation was undertaken by telephone interview and email, targeting estuary users and land managers identified by early-stage consultation with local and state government stakeholders, during the interviews themselves and through online research. The consultation was supplemented by conversations with estuary users during the field mapping exercise.

Interviews were undertaken with:

- St George Power Boat Club
- Transport for NSW Maritime
- St George & Sutherland Shire Anglers Club

Some other members of the community, including representatives from Ozfish, Marine Rescue, Sutherland Shire Canoe Club, Bass Sydney Fishing Club, Woronora River RSL Fishing Club, Sydney Waterski Club, and the Oatley Flora and Fauna group were contacted but either did not wish to comment or were not able to respond to calls or emails.

Transport for NSW Maritime

Fiona Thomson the Senior Boating Safety Officer for Port Hacking and Botany Bay was interviewed by telephone to gain her perspective on bank erosion in the Georges River Estuary. Fiona identified the Milperra reach as an area of erosion, particularly around the golf course. She also had some concerns about the Meriton housing and marina development that is under construction off Newbridge Rd in the same area, but to date these have not had impacts as it has not been opened up to the river. She considered erosion due to boat wash having greater impact in areas of restricted speed zones. Fiona also expressed a general concern about hazards to navigation with shallowing of the river as a result of sedimentation. *Figure 12* shows the areas identified by Fiona Thomson.

St George Power Boat Club

Mitch Pratt, the vice-commodore of the St George Power Boat Club was interviewed by telephone to gain an insight into bank erosion in the areas in of the Georges River they are familiar with. Mitch made reference to the area from Alford Pt Bridge to Milperra and noted that areas of 4 knot zones show higher erosion than open speed limit areas because vessels create greater wash travelling at low speed than when on the plane. He also made note that inside bend seawalls around Milperra are causing wave reflection resulting in erosion of opposite bank. *Figure 12* shows the broad areas identified by Mitch Pratt.

St George & Sutherland Shire Anglers Club

Emails were exchanged with club representative Phil Targett regarding the clubs' environmental concerns relating to sediment movement and erosion in the Georges River. A telephone interview was also conducted with Simon Gosby, the club president. Issues of concern raised were all related to areas downstream of Captain Cook Bridge which is beyond the scope of this study, however they expressed the view that what occurs upstream is directly relevant to these areas. Sand buildup and navigation restriction in relation to the boat ramp on Smith Street at Taren Point which is 1 km downstream of Captain Cook Bridge was a significant concern as it impacts their access to the waterway. They were also very concerned about habitat degradation, due to sand migration and associated impacts on seagrass, mangroves and general riparian zones.

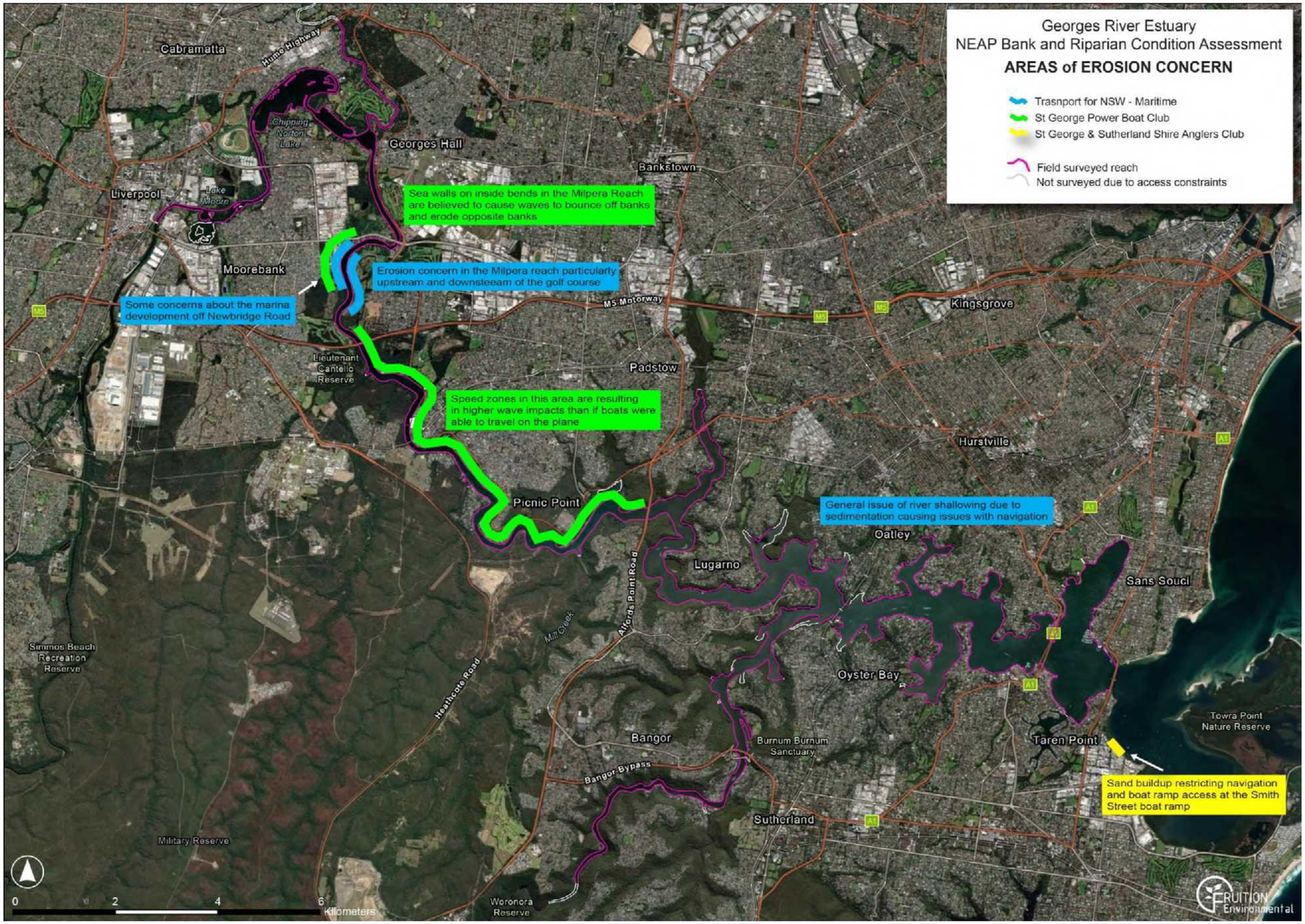

Figure 12 Areas of perceived bank erosion concern as identified by targeted consultation with members of the Georges River Estuary.

Cultural Engagement – Gamay Sea Country Plan Linkages

The peoples of the Gadigal, Bidjigal and Gweagal clans have been custodians of Sydney Coast, Gamay (Botany Bay) and the Georges River for millennia. The Gamay Sea Country Plan continues this tradition and defines the way in which the traditional owners will maintain their voice for and stewardship of Country.

The Sea County Plan includes priorities and objectives for management and protection, some of which overlap the areas focused upon in the NEAP Bank and Riparian Condition Assessment (specifically the Georges River from Rocky Point Road bridge to Affords Point Road bridge, and the tidal sections of Saltpan Creek and Woronora River).

A cultural engagement activity was undertaken on the lower Goerges River and parts of Gamay (Botany Bay) on the 16th June 2025. The activity was attended by representatives of the La Perouse Local Aboriginal Land Council (LALC) and Gamay Rangers including Bryce Liddell, Robert (Bintar) Cooley and Robert Russell. The intent of the engagement activity was to:

- Gain an appreciation of areas of cultural importance within the estuary to the traditional peoples.
- Understand Indigenous cultural perceptions of the estuary and cultural management practices.
- Where possible and appropriate, identify linkages between the ongoing cultural caring for Country projects run or proposed by traditional owners under the Gamay Sea Country Plan and the NEAP Bank and Riparian Condition Assessment project outcomes.

The entire area of the Georges River is significant to the traditional peoples after millennia of cultural connection and use. Several important areas were identified during the day including an area of Saltpan Creek which was an earlier camp before mob were moved to La Perouse, and an area around Mill Creek which has important art sites. These areas do not correlate neatly with the NEAP assessment project as they are generally outside the riparian zone of the estuary. There are also numerous burial sites, resource sites, artefact sites, and other areas of cultural importance, understandably held closely by the community.

Gamay or Botany Bay is of particular importance, and it is in this area (which again is outside the NEAP Assessment study area) that draws the most interest and focus in the Sea Country Plan. There are many projects looking after Country that are undertaken collaboratively and in partnership with University of NSW, Sydney Institute of Marine Science, University of Technology, and others. These include seagrass harvesting and re-planting, marine mammal monitoring, and the installation of seahorse hotels under the Sydney Seahorse Project. Bryce Liddell commented that the Rangers are very busy with these projects and that there is not much capacity for focusing on estuary work, but they are interested all the same.

In terms of erosion, the main area of concern is erosion at Towra Point. At this location, an important freshwater wetland habitat has had the bank separating it from the bay breached and is now infiltrated by salt water. There is also an important repatriation site near this location so ongoing erosion is of great concern. There are many recent tree falls in this area, ongoing active erosion (primarily related to coastal wave penetration into the bay), and failing geotextile sand bags at the breakthrough point to the wetland. Although the site is outside the NEAP Assessment Study Area, the primary recommendation stemming from this engagement day is to support the investigation into the causes of erosion at this site and engage with La Perouse LALC representatives with the intent of generating a sustainable solution to protect the important cultural values at this location.

Thanks to the La Perouse LALC and Gamay Rangers for their participation and the sharing of knowledge on the day.

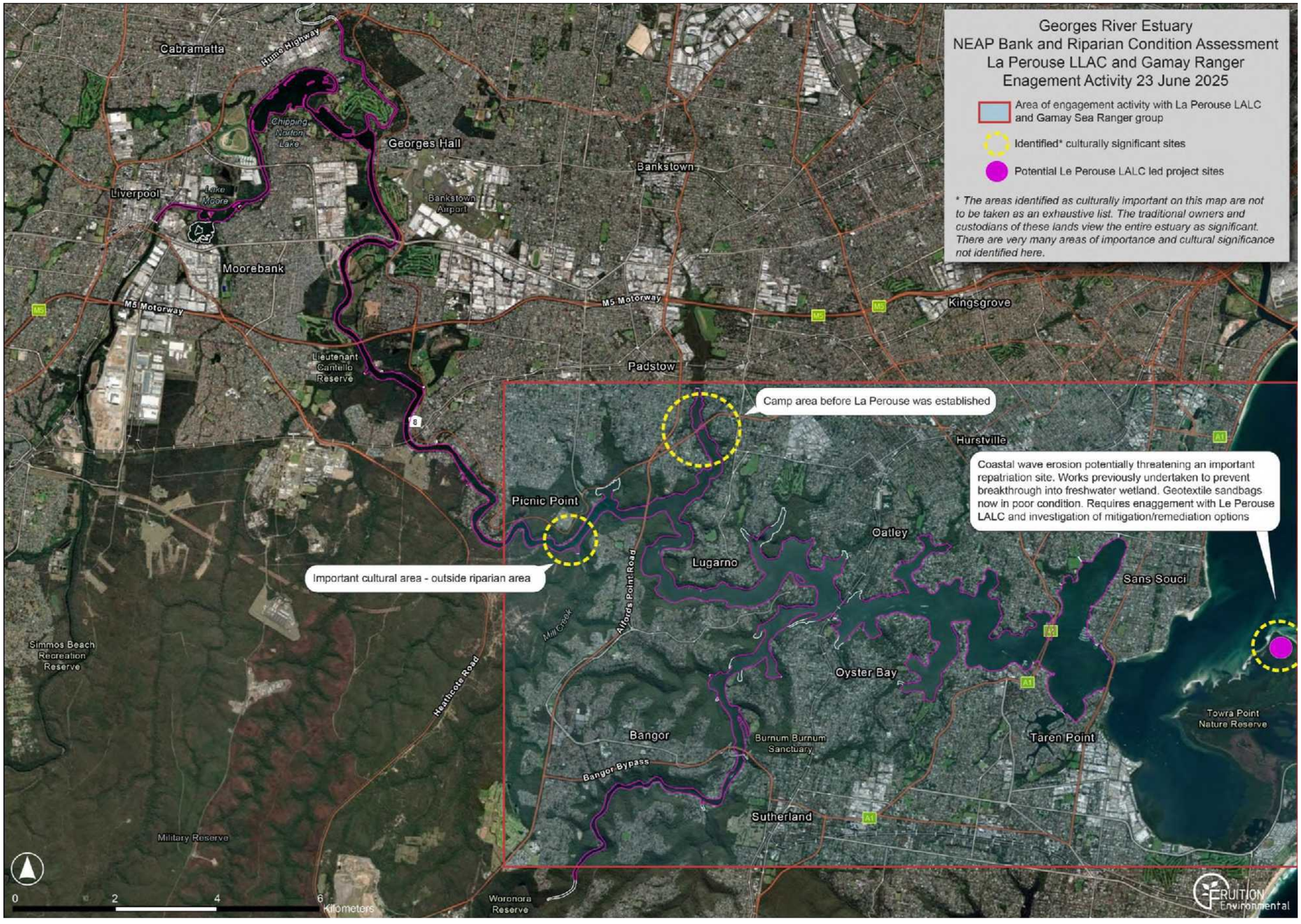

Figure 13 La Perouse LALC and identified areas of cultural importance and potential cultural restoration activities compatible with the Gamay Sea Country Plan within the Georges River Estuary study area.

PART 2 – Georges River Estuary Process Zones

To support an improved understanding of the dominant factors influencing erosion processes within the estuarine system, geomorphic process zones have been identified based on the sediment dynamics and the morphological characteristics of the banks, channel, and floodplain. The distribution of these zones was initially established in the Georges River Estuary Processes Study (SMEC, 2010) and has been modified based on upon additional hydrodynamic and sediment distribution data from the Georges River Foreshore Study (MHL, 2002) and the Woronora River Estuary Processes Study (WBM Oceanics Australia, 2007). These have been further supported by geomorphic insights derived from the NSW Coastal Quaternary Geology mapping (Troedson et al., 2016).

The distribution of the estuary process zones adopted for this study are shown in *Figure 14*.

Process Zone Descriptions

Fluvial Dominated Process Zone

This process zone occurs in the upper Georges River, approximately upstream of Milperra (*Figure 14*).

The zone is characterised by a single thread channel with low sinuosity bounded on each side by extensive, continuous alluvial plains 1.5 to 2 km wide. The zone roughly corresponds with the outcropping of the Wianamatta Group shales, which have eroded down to form broad, undulating hills in the surrounding landscape. The alluvial plains consist variously of mid-Holocene to mid-Pliocene fluvial-derived silt, clay and sand and have been heavily developed with urban and industrial infrastructure. Tertiary-aged terraces are present in the upper estuary reaches upstream of Chipping Norton Lake. Banks sediments range from heavy clays to silty sands.

The channel bed sediments of the Georges River predominantly exhibit a longitudinal downstream fining sequence, transitioning from coarse sand and fine gravel in the upper reaches to fine silty sands and muds closer to the estuary mouth. This gradient reflects a strong fluvial regime upstream of East Hills, with increasing tidal influence downstream of this point. In many reaches, a thin veneer of fine mud overlies coarser sands indicating reduced tidal velocities and intermittent flows, but also likely reflecting an increase of fine sediment input to the catchment from upstream disturbances. Historical sediment studies have also identified elevated concentrations of heavy metals in the upper estuary attributable to legacy industrial discharges and reduced flushing due to floodplain dredging. These contaminants are often bound within fine sediments.

As the name implies, Fluvial Dominated process zones are defined by riverine erosion mechanisms, with bank instability primarily driven by high-energy flow conditions. These zones typically experience fluvial scour, lateral channel migration, and episodic mass failure, including bank slumping, particularly during high-flow or flood events. While these processes often result in progressive channel adjustment, disturbance can accelerate responses, leading to abrupt morphological changes such as rapid channel widening. Bank erosion in these areas is most commonly initiated by hydraulic shear stress exceeding the resistance of unconsolidated alluvial bank materials, resulting in progressive retreat and morphological adjustment of the channel margin.

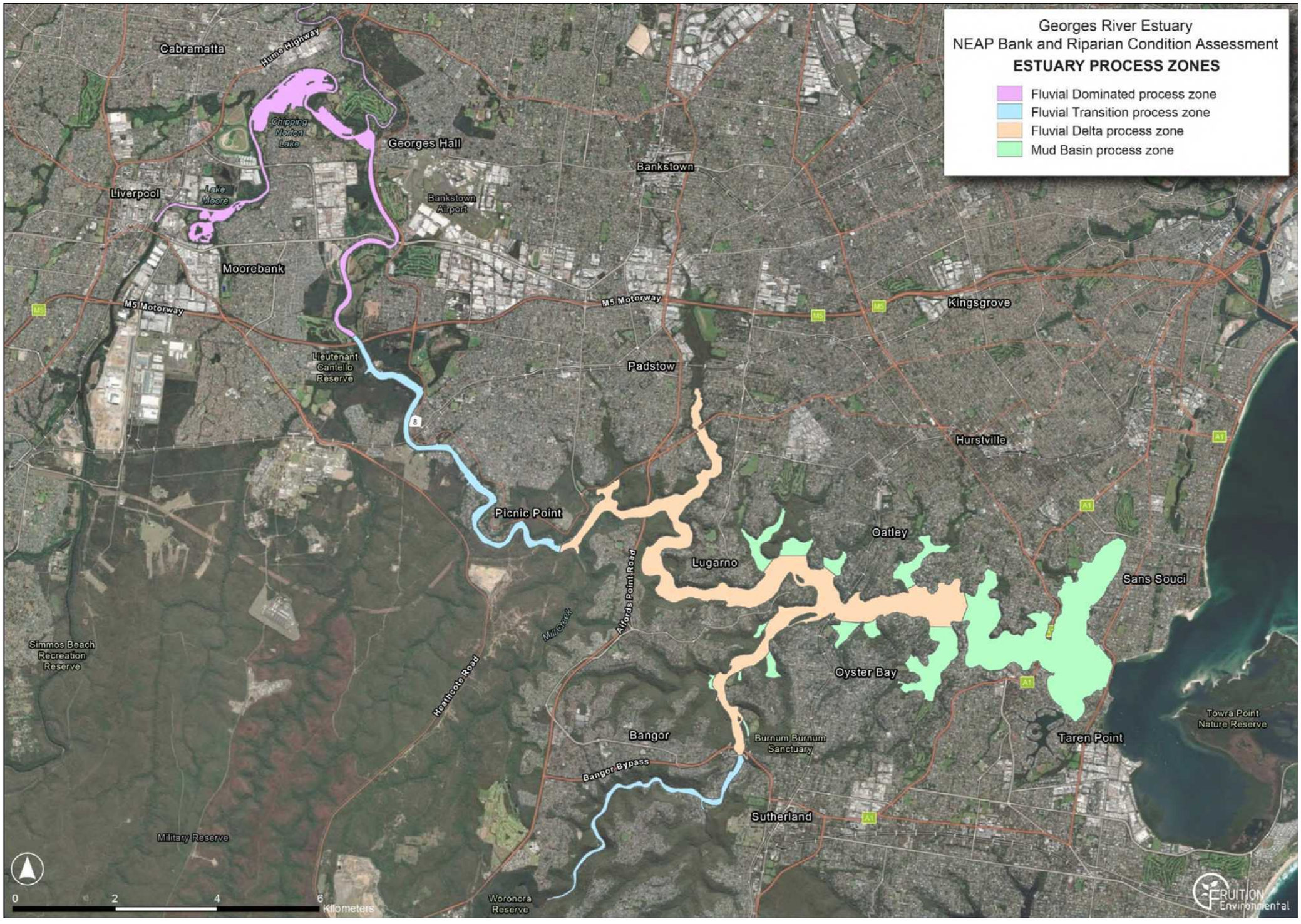

Figure 14 Distribution of geomorphic process zones in the Georges River estuary study area.

As is typical of many NSW estuaries, this upper estuary process zone exhibits the highest incidence of High severity erosion across the estuarine system. This is partly due to the greater erodibility of alluvial bank materials compared to the bedrock-constrained lower reaches but also factors relating to stream energy and estuary use. For instance, the Fluvial Dominated zone has the high stream energy compared to other estuary zones due to channel slope and confinement, further intensified by urbanisation in the catchment. Erosion risk associated with stream energy (i.e. fluvial scour) is exacerbated by the fact that impervious surface cover has increased by 200% resulting in increased runoff and flood discharge but reduced time of concentration (SMEC, 2010).

Additionally, boat wake erosion is prevalent in this zone (*Plate 1*) with the persistent wave impacts exacerbating susceptibility to other forms of erosion. While most observed erosion is classified as low to moderate in severity, it commonly results in undercutting and destabilisation of the lower bank profile and also impacting bank vegetation.

Riparian vegetation in this zone is less tolerant of saline conditions and there is an increased dominance of native freshwater riparian vegetation species. Remnants of candidate River Flat Eucalypt Forest EEC are common on alluvial flats but are often highly disturbed. Typical species observed include forest red gum (*Eucalyptus terreticornis*), Sydney blue gum (*Euclayptus saligna*), blackbutt (Eucalyptus pilularis), rough-barked apple (*Angophora floribunda*), paperbark (*Melaleuca* spp.), and wattles (*Acacia* spp.). Mangroves, most notably river mangrove and grey mangrove were recorded above Chipping North Lake and were often occurring on the intertidal bench below fringing swamp oak (*Casuarina glauca*) forest where low alluvial plains were present or eucalypt woodlands and forest where higher elevation floodplains occurred.

Plate 1 *From left to right: boat wave wash erosion is common in the Fluvial Dominated process zone particularly around Milpera (upper Georges River Reach 250); bank toe scour and slumping and typical processes occurring in the Fluvial Dominated process zone.*

Fluvial Transition Process Zone

The fluvial transition process zone represents a section of the estuary study area where tidal/marine influence is evident, yet the system retains a fluvial morphological character.

On the Georges River, estuarine dynamics progressively transition to a tidally dominated deltaic environment downstream of Milperra. Between East Hills and Picnic Point, the channel morphology shifts from dominantly alluvial margins to intermittent bedrock-confined margins as the Hawkesbury Sandstone formation becomes increasingly exposed (*Plate 2* left image).

Plate 2 *Bedrock outcropping is common in the valley confined sections of the Fluvial Transition process zone in both the Georges River (left: Reach 400) and Woronora River (right: Reach 603).*

Historically, estuarine processes downstream to East Hills were driven predominantly by a fluvial regime. However, extensive dredging and channel modification, particularly associated with the construction of the Chipping Norton Lake system, have significantly altered the hydrodynamics and sediment transport regime. Modelling and bedform analysis indicate pronounced flood-tide sediment transport processes extending upstream to Milperra with limited evidence of ebb-tide transport. The geomorphology of the estuary, with its progressively widening downstream form, contributes to tidal amplification within this zone, concentrating flood-tide flows through a relatively narrow (upstream) channel cross-section.

From a geomorphological perspective, the bed and banks of this zone reflect a legacy of fluvial dominance. The low-lying floodplains consist predominantly of clay with generally low dispersivity, though zones of dispersive clays do occur. Bed sediments are composed of brown silty fluvial sands, containing medium sand grains with minor mud fractions. Surface fine sediments suggest altered hydrodynamics and reworking by tidal flows. Nevertheless, sediment input and erosion processes remain episodic and flood-driven. High sediment sorting further indicates significant mobility under tidal action.

Erosion within the Georges River is largely attributed to fluvial processes, with historical evidence of channel widening and bank retreat due to fluvial scour and bank slumping, particularly during high-flow events. There is minimal evidence of toe scour from either tidal or fluvial currents. However, wave-induced erosion is prevalent, especially along outer channel bends where the navigation channel concentrates boat traffic near the banks.

The Woronora River is characterised by a tidal-dominated hydrodynamic regime, with no clearly defined fluvial process zone. While sediment dynamics are primarily governed by episodic flood events, freshwater inflows are relatively limited, estimated at approximately 34,000 m^3/day. The construction of the Woronora Dam has further reduced base flows and enhanced tidal influence, altering the longitudinal salinity profile and reducing estuarine freshwater input. The tidal range observed at the upstream estuarine boundary is equivalent to that at the confluence with the Georges River, indicating negligible attenuation. Previous studies have noted that the tidal prism is large relative to total estuary volume, suggesting tidal processes play a dominant role in estuarine flushing, despite generally low tidal velocities.

The Woronora River flows through a laterally confined valley bordered by steep forested slopes underlain by Hawkesbury Sandstone (*Plate 2* right image). Bedrock confinement dominates the channel margins, with limited and discontinuous floodplain development at minor tributary junctions. Downstream, floodplain continuity increases, although bedrock bluffs remain a prominent morphological feature. The estuary is considered geomorphically mature, with its accommodation space largely infilled by sediment. Given the dominance of sandstone geology, bed and bank sediments are primarily sandy with low fines content (*Plate*

3 left). Sediment transport is episodic and driven by high-flow events, though there is evidence of ebb-tide sediment redistribution. Erosion dynamics in the Woronora River reflect both fluvial and tidal influences, occurring under relatively low-energy conditions. Boat wake erosion is considered the principal driver of erosion along eroding bank sections downstream of Loftus Creek.

Plate 3 *Bed and bank material is predominantly fine sands in the Fluvial Transition process zone: for example Woronora River Reach 575; greater development of low alluvial floodplains has resulted in more extensive swamp oak floodplain forests, for example Reach 256 Georges River.*

The riparian vegetation in this process zone is similar to the upstream Fluvial Dominated process zone, with many areas of eucalypt woodland and river flat eucalypt forest, although often impacted by urban development and extensive clearing. With greater development of low lying alluvial floodplains, swamp oak (*Casuarina glauca*) floodplain forests fringing with mangroves are more extensive than in the upstream Fluvial Dominated process zone (*Plate 3 right*), although again often highly disturbed. The most upstream occurrence of coastal saltmarsh in the Georges River estuary also occurs in this process zone with pockets on low supratidal flats common from East Hills downstream. Coastal saltmarsh does not occur in the Woronora until downstream of the Burnum Burnum bridge which has been classified as Fluvial Delta for this study.

Fluvial Delta Process Zone

The fluvial delta process zone represents a major depositional environment within both the Georges and Woronora estuaries. Morphologically, this zone continues the pattern of the drowned river valley, with channel width increasing in the downstream direction. As the basin deepens and widens, the development of alluvial features along the valley margins is inhibited. In the Georges River, this process zone is typified by a lack of floodplain development and the frequent occurrence of bedrock outcrops along much of the estuarine length. While the Woronora estuary exhibits similar morphological constraints, it also contains a greater extent of low-lying floodplains and intertidal flats (*Plate 4*).

Plate 4 *Bedrock outcropping is common in the valley confined sections of the Fluvial Transition process zone in the Georges River: image left Reach 460 and image right Reach 723).*

Bed sediments within both estuaries predominantly consist of silty sands, with a downstream increase in fines content. In the lower reaches of the Georges River proximal to Kyle Bay, 50–70% silt-clay content demonstrates the downstream extent of the fluvial delta. In the Woronora River, bed sediments are primarily composed of medium-grained grey-brown sands. Silt-clay content ranges from 2–25% in the upper estuary, increasing to approximately 45% in the lower reaches. Limited sampling has identified underlying basal silty clays in some areas, indicative of low-energy depositional embayments.

The Georges River remains in an early stage of sedimentary infilling and retains a relatively deep channel profile. While there is limited historical evidence of channel deepening due to bed erosion, there are localised areas of bank deposition and siltation. In contrast, the Woronora River exhibits extensive shoaling and sedimentation, consistent with a more geomorphologically mature estuary. This condition reflects a combination of episodic sediment delivery during high-flow events and continuous tidal reworking.

Within the Georges River, localised wind-wave erosion occurs in isolated pockets of alluvium, along with some tidal scour. However, the dominance of bedrock outcrops and extensive bank protection works mean there is limited opportunity for erosion to occur in this zone. By contrast, the Woronora River, with its confined valley geometry and limited wind fetch, experiences only a minimal wind-wave climate. Fluvial processes are also minimal, and tidal velocities remain low. As previously discussed, the primary mechanism driving bank erosion is boat wake wash despite the presence of extensive speed restrictions in the lower estuary. Nonetheless, the confined nature of the estuary limits the spatial extent of erosional impacts.

In the Fluvial Delta process zone, the riparian vegetation is variable depending upon whether the substrate is bedrock or alluvium flats, with the vegetation composition on alluvial flats depending upon floodplain height and soil composition. Bedrock outcrops are characterised by Sydney Hinterland Exposed Sandstone Woodland including scribbly gum (Eucalyptus racemosa), smooth barked apple (Angophora costata), grey gum (Eucalyptus punctata), red bloodwood (Corymbia gummifera) and red mahogany (Eucalyptus resinifera). Restricted areas of low-lying alluvial floodplain support Swamp Oak Floodplain Forest (Casuarina glauca) and paperbark swamp forest, while intertidal flats feature both mangrove forest and isolated pockets of saltmarsh. Mangroves also extensively fringe sandstone outcrops along the waterfront. Weed presence is typically low (<10%), mostly consisting of lantana but also coastal morning glory, madeira vine and prickly pear.

Mud Basin Delta

The most downstream process zone of the estuary is defined by an extensive mud basin, which occurs downstream from Oyster Bay to the estuary's outlet at Taren Point into Botany Bay. Similar mud basin environments occur within several smaller off-channel embayments throughout the lower estuary. Unlike many barrier and wave dominated estuaries, a Marine Tidal delta process zone is not present with the Georges River instead flowing directly into Botany Bay.

The Mud Basin Delta process zone is characterised by the deposition of fine-grained, flocculating silt and clay bed sediments. These sediments accumulate under low-energy hydrodynamic conditions, primarily influenced by tidal action, with minimal input from fluvial or wave-driven processes. Most areas within the zone experience relatively effective tidal flushing, although the upper reaches of some embayments exhibit restricted tidal exchange, resulting in periodic nutrient enrichment and depleted dissolved oxygen levels leading to ecological 'dead zones'.

Owing to the long history of urbanisation, much of the immediate estuarine foreshore is now intensively developed for residential land use. The banks are predominantly composed of bedrock outcrops or modified with bank or foreshore protection structures. As a result, active erosion is generally limited across the zone. Where localised erosion does occur, it is typically attributed to boat wash, wind wave action, or, in some cases, current-induced scour associated with tidal flows.

Extensive urban development along the estuary foreshore of the Georges River has significantly degraded riparian vegetation, resulting in its widespread poor condition. However, intact vegetation bordering the Woronora River estuary and isolated remnant pockets indicate the riparian margin mostly consisted of Coastal Enriched Sandstone Dry Forest, dominantly composed of grey gum (*Eucalyptus punctata*), Sydney red gum (*Angophora costata*), Sydney peppermint (*Eucalyptus piperita*) and bloodwood (*Corrymbia gummifera).* Broad, fringing mangrove forests consisting of river mangrove (*Aegiceras corniculatum*) and grey mangrove (*Avicennia marina*) have been preserved in many side embayments but have been degraded by foreshore development elsewhere (*Plate 5*). Large expanses of seagrass meadows have also been considerably reduced and/or fragmented, with significant reductions in the distribution and abundance of Zostera observed over the last 20 years (Cardno, 2019).

Plate 5 Many of the embayments in the Mud Basin process zone have intact fringing mangrove communities at least in the upstream extents (left image: Oyster Bay Reach 948), however there are many areas where foreshore development and clearing has significantly degraded this important estuarine habitat (e.g. right image: Georges River Reach 979).

PART 3 – 2024 Bank and Riparian Condition Survey

Georges River NEAP Online Estuary Condition Mapping Database

Approximately 144.9 km of the Georges River Estuary was surveyed via boat in March 2025. The survey area included the navigable reaches of Prospect Creek, Salt Pan Creek, Woronora River and the Georges River main arm and various connected bays (where accessible).

Data was entered directly into Fruition Environmental's field maps application, which allowed for survey segments (reaches) to be drawn as a line feature along the bank based in the field. Reaches were defined based on a change in either erosion severity, riparian vegetation condition, or existing controls. Each new reach segment was snapped onto the previous line segment and the survey was repeated.

Except where survey bank length was very small, a minimum of two photos were taken of each segment: one downstream looking upstream, and one upstream looking downstream. Any features of interest within the section were also photographed (i.e., existing controls, erosion, etc.).

One thousand and fifty-two (1052) reaches were surveyed. Each reach had up to one hundred and six (106) attributes recorded. The recorded attributes primarily focused upon:

- Bank erosion severity
- Riparian vegetation continuity, width, structure, diversity and weed presence (used to generate the riparian vegetation condition ratings)
- Presence of existing erosion control works, proportion of segment with works, style of works and works effectiveness.
- Criteria relevant to the NSW Fisheries Decision Support Tool for Bank Erosion Management, 2024 version (the "DST"; developed by Hydrosphere Consulting for DPIRD Fisheries under the Marine Estate Management Strategy Initiative 2, see Hydrosphere Consulting, 2020 and 2020b).

Appendix A and the methodology descriptions in the following section provide further detail on the criteria assessed.

The Fruition Environmental Web App

The Fruition Environmental Web App holds the full database of survey records including all attributes for each segment surveyed and any photographs taken of the reach. The records are current as at 10 March 2025 but are able to be updated in the field using ESRI Field Maps and an appropriate login if required.

How to Access the Online Bank and Riparian Condition Database

The custodian for the estuary condition survey database is Department of Primary Industries and Regional Development – Fisheries. Requests to use the GIS database should be made directly to the Senior Fisheries Manager – NEAP. A public viewable version of the dataset is available at https://nsw-neap-bank-riparian-condition.netlify.app/.

Georges River Estuary Bank Condition

Method

Attributes related to bank condition were mapped directly into ESRI Field Maps via the Fruition Environmental online mapping tool. This ensured a standardised collection methodology across all areas of the estuary surveyed and also between survey personnel.

A component of the project was to allow for the bank condition dataset to be compatible with the 2024 draft of the DPI Fisheries DST for bank erosion management. Accordingly, the methodology for recording bank condition incorporated the data attributes and definitions used in the DST manual (Hydrosphere Consulting, 2020) in addition to other project attributes specific to this project.

Bank erosion severity was the primary attribute for the differentiation of bank segments for the bank condition assessment. The bank segments represent relatively homogenous reaches of similar attributes so where bank erosion severity was homogenous but riparian vegetation condition changed the segment was broken to allow the different vegetation condition to be represented despite the erosion severity being recorded as the same. The degree of bank erosion present in the segment was recorded as either Negligible, Low, Moderate, High or Extreme.

The definition for each erosion severity category were adopted from the DPI Fisheries DST (see Hydrosphere, 2020) and as follows:

- NEGLIGIBLE: currently aggrading or stable – no erosion
- LOW: some erosion occurring but considered within natural parameters OR occurring at a scale and rate not considered to be of management concern
- MODERATE: rate or scale of erosion is considered more than natural
- HIGH: rate and scale of erosion is significant
- EXTREME: erosion occurring with significantly accelerated rate and scale

Examples of reaches with Extreme to Low erosion severity are shown in *Plates 6 to 9*.

Plate 6 *Examples of Extreme erosion severity in the study area, from left to right: upper Georges River Reach 264; mid Georges River Reach 250.*

Plate 7 *Examples of High erosion severity in the study area, from left to right: upper Georges River Reach 180; and mid Georges River Reach 26.*

Plate 8 *Examples of Moderate erosion severity in the study area, clockwise from top left: upper Georges River Reach 180; and mid Georges River Reach 26.*

Plate 9 *Examples of Low erosion severity in the study area, from left to right: Woronora River Reach 595; and mid Georges River Reach 358.*

In addition to the severity of erosion, a number of other attributes were recorded to maintain compatibility with the DST and provide additional factors relevant to bank condition at the site.

The following additional information were recorded for all segments surveyed (see *Appendix A* for category definitions):

- Presence or absence of **bedrock** in the segment (Yes/No).
- The **estimated future trajectory** of erosion being either *not occurring not likely*, *not occurring but likely*, *occurring and continuing,* or *occurring and accelerating* (only one selected).
- **Water depth** (measured by a staff at 5 m from the mean high tide mark on the bank), being a surrogate measurement for the question of what types of erosion control works could potentially be practical at the site if required: *shallow* (less than 0.8 m), *moderate* (0.8 to 1.5 m), *deep* (>1.5 m).
- A subjective assessment of the **impact of erosion** upon perceived environmental, infrastructure/commercial, and amenity/safety values of the segment or broader estuary (see Hydrosphere Consulting, 2020 for more detail). Ratings of *negligible*, *low*, *medium*, or *high* could be assigned (one to be selected for each of the three values category). To assist this assessment, a number of existing datasets were available within the Field Maps app to help inform the surveyor of known issues in the reach. These included NSW Endangered Ecological Vegetation Community mapping, aquatic vegetation mapping, and Crown/council/NPWS land parcels.
- The **location** of any erosion occurring was recorded as either one or a combination of: *top of bank*, *upper bank*, and/or *lower bank*.
- The c**ontributing causes** of erosion for each segment were documented with one or more causes selected from: *ocean waves*, *public access*, *river flood or tidal flows*, *sediment extraction*, *stock access*, *vessel waves*, and/or *wind waves* (Yes/No required for each cause for DST compatibility).

Overview of Results

Figure 15 shows the spatial distribution of bank erosion severity within the different process zones of Georges River estuary, while *Table 3* summarises the proportions of estuary bank of each category of erosion severity for the whole estuary study area (depicted graphically in *Figure 15*). The overall extent of erosion observed is low by regional standards with *Table 3* showing that the vast majority of the estuary banks in the study area have either Low or Negligible erosion (94.3%). A major factor is the very high proportion of banks protected by either bedrock or foreshore protection works. Half of the total area surveyed had either bedrock substrate or completely effective protection works (70.1 km or 49.9% of the surveyed reaches).

However, localised instances of active erosion were identified in discrete reaches, as well as broader low-level erosion issues. Less than one per cent of the estuary is currently experiencing severe erosion, with 576 m (0.4%) of the mapped banks featuring Extreme erosion, while 741 (0.5%) show High erosion.

Table 3 Bank erosion severity in the Georges River Estuary study area.

Bank Erosion Severity	Length of Bank (m)	% of Overall Estuary Bank Mapped
Extreme erosion	576	0.4%
High erosion	741	0.5%
Moderate erosion	6,903	4.8%
Low erosion	24,795	17.1%
Negligible erosion	111,844	77.2%

Table 4 summarises the bank erosion survey results, presenting the proportion of estuarine bank length classified by erosion severity across each geomorphic process zone and estuary location.

A clear downstream reduction in erosion frequency and severity is evident in the Georges River, while in the Woronora River, the distribution of erosion is relatively uniform across its two defined process zones (*Figure 16*). Surveyed reaches of Salt Pan Creek exhibited minimal erosion, with 98% of bank length classified as Negligible. This pattern is likely attributable to the resistant geological composition of the mid and lower estuary, while the subdued flood history in recent decades may account for the limited erosion observed in upstream areas.

Negligible to Low erosion dominates across all process zones, accounting for 85–100% of the mapped bank lengths. Of these, negligible erosion is the most widespread classification across the estuary. *Low* erosion is the most frequently observed active process across all zones. While driven by a range of contributing disturbance factors, this level of erosion remains within the expected natural variability of estuarine dynamics and is not typically of management concern.

Moderate erosion was observed along 4.8% of the total mapped estuarine banks and was more broadly distributed across multiple process zones. In the Georges River, Moderate erosion was recorded along 2.6 km (8%) of the bank length in the fluvial-dominated zone, and 1.7 km (10.1%) of the fluvial transition zone. Some of these areas may represent reaches recovering from earlier high severity erosion events—such as flood-induced slumping—where natural stabilisation processes are evident. In the Woronora River, Moderate erosion was mostly restricted to isolated upper reaches, totalling approximately 890 m (7.8%), and in proximity to boat ramps at Bonnet Bay and Burnum Burnum. These moderately eroded reaches typically exhibited minimal toe scour, with bank instability primarily associated with riverine or tidal flows and boat wake, leading to wave notching and subsequent bank slumping.

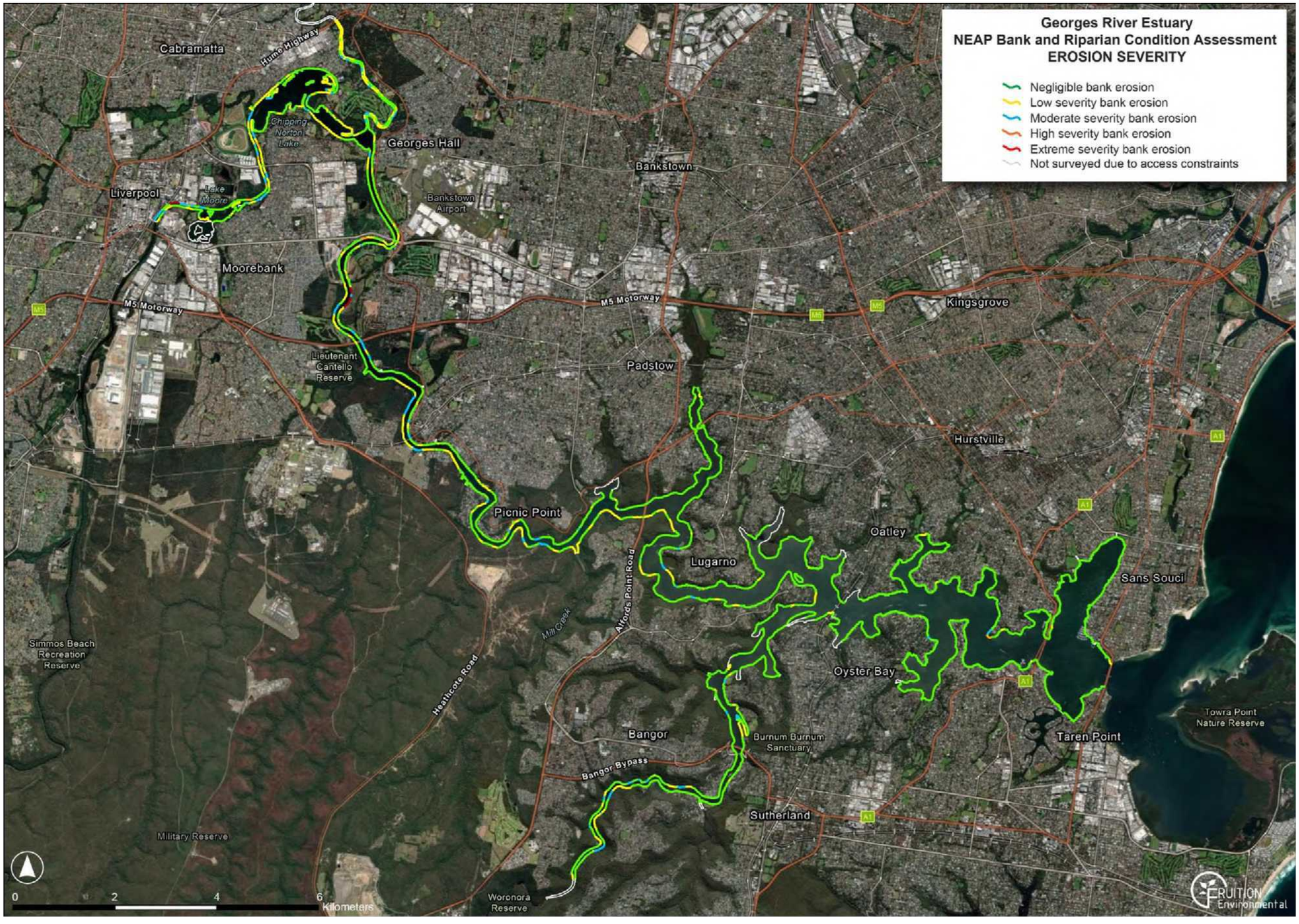

Figure 15 Distribution of mapped bank erosion severity across the Georges River Estuary Study Area.

Table 4 Distribution of bank erosion severity by estuary process zone and location: summary statistics.

	Total (m)	Negligible (%)	Low (%)	Moderate (%)	High (%)	Extreme (%)
Fluvial Dominated Process Zone						
Georges River	32,110	57	31.6	8	1.6	1.8
Prospect Creek	6,929	40.3	48.9	10.7	-	-
Other	181	44.2	55.8	-	-	-
TOTAL	39,220	54.0	34.8	8.4	1.3	1.5
Fluvial Transition Process Zone						
Georges River	16,379	65.7	23.6	10.1	0.6	-
Woronora River	11,486	75.3	17	7.8	-	-
Other	179	100	-	-	-	-
TOTAL	28,044	69.9	20.7	9.1	0.3	-
Fluvial Delta Process Zone						
Georges River	24,647	83.1	15.1	1.8	-	-
Woronora River	8,082	85.3	9.8	4.9	-	-
Saltpan Creek	6,054	97.8	2.2	-	-	-
TOTAL	38,783	85.8	12	2.2	-	-
Mud Basin Process Zone						
Georges River	35,193	97.8	1.2	0.6	0.3	-
Woronora River	3,619	93.5	6.5	-	-	-
TOTAL	38,812	97.4	1.7	0.6	0.3	-

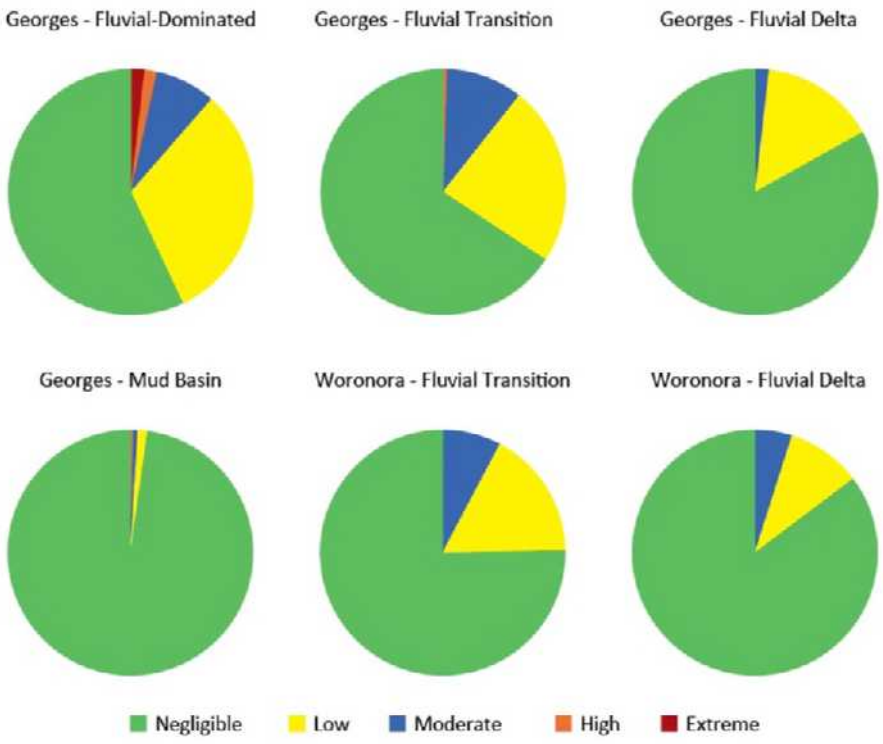

Figure 16 Proportional distribution of bank erosion severity within each estuary of the Georges River study area.

Instances of High and Extreme erosion are primarily confined to the fluvial-dominated process zone of the upper Georges River estuary. These reaches are underlain by erodible alluvial bank materials and are more susceptible to fluvial erosion processes during high-flow or flood events. Extreme erosion was predominantly observed along outer channel bends, consistent with the fluvial dynamics of this zone. However, a notable reach of approximately 400 m at Milperra, which was in the early stages of remediation at the time of survey, exhibited Extreme erosion likely heavily impacted by boat wake rather than fluvial processes. Downstream, only isolated occurrences of High erosion were identified and there was no Extreme erosion. Specifically, one reach was identified within the fluvial transition zone (92 m) and one reach in the mud basin process zone (123 m). No High or Extreme erosion was recorded in the Woronora River or in the fluvial delta process zone.

Comparison of 2009 and 2025 erosion sites

The 2009 estuary condition survey undertaken by SMEC (2010) provides a useful baseline of erosion severity to compare against the current 2025 field survey results. Such a comparison can provide an indication of changes in bank condition across the extent of the estuary study area over the last 15 years and help identify key areas and persistent issues throughout the Georges River estuary, particularly regarding severe (High and Extreme) erosion. The comparison requires some qualification:

- There are key differences in the survey methods and erosion categories that limit direct comparison. The 2009 survey adopted four erosion severity classes (including negligible) and provided no definition for erosion categories.
- The process for describing bank protection works was fundamentally different. In 2009, no identification of erosion was provided for banks containing protection works. Rather these were described as *good* to *poor* condition with no definition of condition categories.
- The 2009 survey data was not available in a digital format. Erosion categories were manually digitised onto the 2025 estuary outline within the Fluvial Dominated Process Zone, based on visual interpretation of maps in Appendix 2 of SMEC (2010).

The spatial distribution of bank erosion in the 2025 survey is broadly consistent with the 2009 results and earlier assessments (MHL, 2002). Erosion remains concentrated in the upper estuary, primarily within the fluvial-dominated reaches upstream of East Hills. These reaches are underlain by erodible alluvial materials and are subject to fluvial scour and episodic slumping during high-flow events. Downstream of Picnic Point, erosion is limited and generally of low severity, typically associated with localised failures of degraded foreshore protection structures. Many of the priority erosion sites identified in 2009 appear to have received no management intervention.

In the upper estuary, a marked reduction in active erosion has occurred between the two survey periods. The 2009 assessment recorded approximately 4.9 km of Severe erosion and 1.6 km of Moderate erosion, mostly concentrated upstream of Chipping Norton Lake. Although the erosion severity classifications between the 2009 and 2025 surveys are not directly comparable, many of the reaches previously assessed as Severe now fall into Low to Moderate categories, with some showing Negligible erosion. In 2025, only 1.2 km of banks within the Fluvial Dominated and Fluvial Transition Zones were classified as High or Extreme erosion. This represents an approximate 76% reduction in severe erosion extent, assuming a consistent interpretation of category thresholds.

Some of this improvement is attributable to targeted remediation efforts, such as the construction of a rock revetment along the railway corridor downstream of Liverpool Weir (Reach 225). However, other areas without visible intervention now exhibit signs of natural stabilisation. This underscores the potential for passive recovery, particularly where vegetation has successfully established and provides root reinforcement. While instability may be initiated by the absence of vegetation and external disturbances,

the findings suggest that many flood-induced mass failures do not progress in the manner typical of fluvial bend migration or widening processes.

Despite these improvements, several areas remain actively eroding or have worsened in severity. *Table 5* outlines the status of Key Management Action sites identified by SMEC (2010), while *Table 6* identifies reaches where erosion has persisted or intensified since 2009.

Table 5 Status of Key Management Action erosion sites identified in the SMEC 2010 report. Sites in red were considered the highest priorities for the overall study area.

Site (2010)	Survey ID (2025)	LGA	2009 Erosion Severity	2025 Erosion Severity	Status
E1	225	Liverpool	Severe	Negligible	Rock armouring has effectively treated erosion issues
E4	223	Liverpool	Severe	Moderate	No action – apparent natural stabilisation
E21	171	Liverpool	Severe	High	No action
	174, 184			Low	Some apparent natural stabilisation and some minor lengths of rock armouring protection
E38	150	Fairfield	Severe	Low	No action – apparent natural stabilisation
E39	142	Fairfield	Light	Low	No action
E42	117	Fairfield	Severe	Low	No action – apparent natural stabilisation
E57	74	Canterbury-Bankstown	Severe	Negligible	No action – apparent natural stabilisation
E58	70	Canterbury-Bankstown	Severe	Low	No action – apparent natural stabilisation
E64	13	Canterbury-Bankstown	Severe	Low	No action – apparent natural stabilisation
E88	463	Sutherland	Moderate	Moderate	No action
E90	858	Georges River	Severe	Negligible	Stabilisation of bank with rock armouring and building rubble
E91	878	Georges River	Moderate	Low	No action

Table 6 Sites that have demonstrated a significant increase in erosion severity between the 2009 and 2025 bank condition surveys

Survey ID	Location	2009 Severity	2024 Severity	Length	Site Notes
26	Opposite Vale of Ah Reserve	Negligible	High	119	-
171	Warwick Farm Racecourse	Light/severe	High	87	-
180	South Park, Chipping Norton	Severe	High	140	Unresolved high erosion site
224	Downstream from Liverpool Weir	Negligible	Extreme	192	Erosion of outside bend with existing adjacent erosion and pressure
250	Milperra	Light	Extreme	132	Sites identified by Council for erosion management, under construction
254	Milperra	Light	Extreme	252	Sites identified by Council for erosion management, under construction
925	Bald Face Point Reserve	Negligible	High	190	Likely ignored in 2009 as a natural erosion process

Some notable observations on the comparison include:

- Many of the high priority sites identified in 2009 have not had no apparent remediation works undertaken. Despite the lack of action, during the 2025 survey most were observed as having Negligible to Low erosion, demonstrating some apparent natural stabilisation over the past 15 years.
- **Chipping Norton / Warwick Farm:** Both banks exhibited widespread Severe erosion in 2009. While large-scale instability has reduced, some areas of High erosion including significant mass failure remain. Some areas of erosion show vegetation recruitment, mostly where the dominant erosion processes are episodic (related to flood events) and some level of stabilisation occurs between events. Nevertheless, the fact that erosion persists may suggest that further monitoring and potential pre-emptive actions such as bank stabilisation and revegetation may be required to alleviate erosion in these reaches.
- **Riverlands Golf Course / Wurrungwuri Reserve:** Previously mapped with Negligible to Low erosion, both sites now show significant deterioration. Extreme erosion is evident at Riverlands, while Wurrungwuri Reserve has Moderate erosion affecting Swamp Oak Floodplain Forest EEC. Most reaches are located on outside bends and are also highly susceptible to boat wake impacts.
- **Deepwater Park:** This reach was identified with Severe erosion in 2009. Despite visible bank protection works, it continues to experience Moderate to High severity erosion, with both slumping and wave wash contributing to ongoing instability.
- **Picnic Point:** Several new areas now exhibit Low to Moderate erosion where no erosion was recorded in 2009. This erosion is likely driven by boat wake, a relatively low intensity but persistent disturbance mechanism resulting in gradual bank retreat.

Georges River Estuary Riparian Vegetation Condition

Method

Riparian Vegetation Condition was assessed using a multi-metric index of riparian condition. The index has been modified from previous methodologies utilised by Fruition Environmental in other estuarine assessments and studies (e.g. The Bellinger Kalang estuary study undertaken by Cohen and Telfer in 2010). The method has proved suitable for whole of estuary studies where each segment needs assessment (i.e. where the length of bank being assessed precludes more detailed assessments such as those undertaken under the Ecohealth Monitoring Project by Ryder et al., 2017).

Again, the attributes collected included those required to ensure compatibility with the DPI Fisheries DST methodologies. To this end the DST attributes of riparian vegetation continuity and width have been adopted with the criteria for assessment for these two attributes adopted from the DST assessment method (Hydrosphere Consulting, 2020). Specifically:

- **Riparian Vegetation Continuity** was recorded as either *negligible*, *low*, *medium*, or *high*
- **Riparian Vegetation Average Width** was recorded as *<2 m*, *<5 m*, *<10 m*, *<20 m* and *>20 m*.

In addition to the DST compatible attributes, three additional attributes were adopted to assist in determining riparian condition. The additional attributes adopted were:

- **Riparian Vegetation Structure** which was recorded as either *very poor*, *poor*, *medium*, *good* or *very good* (see Appendix A for descriptions of each category for this attribute). Again, a number of existing datasets were available within the Field Maps app to help inform the surveyor of what vegetation communities could be expected in the segment. These included the identification of High Conservation Value (HCV) vegetation types from the Native Vegetation of the Sydney Metropolitan Area – Version 3.1 (2016) dataset and aquatic vegetation mapping (mangrove, saltmarsh and seagrass communities). For instance where the riparian vegetation was a coastal saltmarsh community then the riparian vegetation structure value reflected what would be expected for a vegetation community of that type.
- **Riparian Vegetation Diversity** which was recorded as either *very poor*, *poor*, *medium*, *good* or *very good* (see Appendix A for detail). Again the value recorded was measured against the level of diversity expected for a vegetation community of the type that would naturally occur in that segment, informed by vegetation mapping layers loaded into field maps.
- **Exotic Weed Presence** which was recorded as either *nil observed*, *low* (<10% FPC), *moderate* (10–25% FPC), *high* (25–50% FPC), or *very high* (>50% FPC).

Upon completion of the field mapping exercise, the results of each segment's survey against the five sub-indices were used to compute a riparian condition index score using a simple algorithm (sum of attribute scores). The attribute scores used to convert the field records into the condition score is shown in *Table 7*.

Table 7 Riparian Condition Index attributes and values used in calculation the Riparian Condition Index Score for each field surveyed bank segment in the Georges River Estuary.

Attribute	Value	Score
Riparian Vegetation Continuity	Negligible	0
	Low	1
	Moderate	5
	High	9
Riparian Vegetation Average Width	Less than 2 m	0
	Less than 5 m	2
	Less than 10 m	5
	Less than 20 m	9
	Greater than 20 m	12
Riparian Vegetation Structure	Very poor	0
	Poor	2
	Moderate	5
	Good	9
	Very Good	12
Riparian Vegetation Diversity	Very poor	0
	Poor	2
	Moderate	5
	Good	9
	Very Good	12
Weed Presence	Nil observed	5[1]
	Low (<10% FPC)	3
	Moderate (10–25% FPC)	1
	High (25–50% FPC)	0
	Very High (>50% FPC)	0
	Maximum Score	**50**

[1] Note: if Riparian Vegetation Continuity <3 then weed presence score was set at 0 regardless of the weed presence entry. This was because if there was "no" to "low" vegetation continuity then there was likely also no weeds present so without this adjustment the condition score would be artificially high due to the 5 scored against "nil observed".

The condition score was then converted to a **Riparian Vegetation Condition** Rating which represents 5 condition bands ranging from *very poor*, *poor*, *moderate condition*, *good condition* through to *very good condition*. The bands used to convert the condition score to the Riparian Condition Ratings are shown in *Table 8* with the definition for each category as follows:

- VERY POOR CONDITION: no to very little riparian vegetation.
- POOR CONDITION: discontinuous riparian vegetation of narrow width with poor diversity and structure, exotic weeds may be present.
- MODERATE CONDITION: medium to high vegetation continuity, width greater than 2 m and with variable structure and diversity, weeds may be present.
- GOOD CONDITION: medium to high vegetation continuity, width greater than 5 m and with structure and diversity generally medium to good, weeds may be present but not dominant.
- VERY GOOD CONDITION: high vegetation continuity with width greater than 10 m, very good vegetation structure and diversity, and low to no weed presence.

Table 8 Riparian Vegetation Condition Ratings derived from the Condition Index Scores used in the Georges River Estuary assessment.

Riparian Vegetation Condition Rating	Riparian Condition Index Score
Very Poor Condition	0–5
Poor Condition	6–10
Moderate Condition	11–25
Good Condition	26–40
Very Good Condition	41–50

In addition to the five attributes which combine to form the Riparian Vegetation Condition rating, more detailed presence/absence of important individual **environmental weed species** were recorded. These included presence/absence within the segment of *bitou bush*, *Broad-leaved privet*, *camphor laurel*, *coastal morning glory*, *ground asparagus*, *groundsel bush*, *lantana*, and *small-leaved privet*. The records of observations are available through the online mapping database.

Examples of reaches with Low to Extreme erosion severity and shown in *Plates 10* to *14*.

Plate 10 *Examples of Very Good condition riparian vegetation within the study area, clockwise from top left: upper Georges River Reach 89; mid Georges River Reach 265; lower Georges River Reach 910; and Woronora River Reach 531.*

Plate 11 *Examples of Good condition riparian vegetation within the study area, from left to right: upper Georges River Reach 50; and Woronora River Reach 650.*

Plate 12 *Examples of Moderate condition riparian vegetation within the study area, from left to right: Woronora River Reach 540; and mid Georges River Reach 333.*

Plate 13 *Examples of Poor condition riparian vegetation within the study area, clockwise from top left: Woronora River Reach 601; mid Georges River Reach 404; upper Georges River Reach 129; and Woronora River Reach 574.*

Plate 14 *Examples of Very Poor condition riparian vegetation within the study area, clockwise from top left: Woronora River Reach 589; mid Georges River Reach 250; lower Georges River Reach 908; mid Georges River Reach 397.*

Overview of Results

Figure 17 shows the distribution of riparian vegetation condition within the Georges River estuary study area. *Table 9* highlights the proportions of surveyed estuary bank which were mapped against each category of riparian vegetation condition. The survey data shows a broad spread of condition of riparian vegetation throughout the estuary. Approximately half of the estuary, 53.4% of reaches surveyed equating to 77.4 km, was classified as having riparian vegetation in Good to Very Good condition. Considerable lengths of the estuary have intact remnant riparian vegetation communities, particularly along steep sandstone valley margins. This vegetation includes several EEC communities, providing considerable ecological and aesthetic value to the estuary.

However, 31% (or 44.9 km) was classified as being in a Poor to Very Poor condition. Most of these reaches have been heavily modified by urbanisation, with residential developments along the immediate foreshore. In many cases, seawalls have been constructed to the exclusion of any vegetation. Reaches with Very Poor vegetation condition is particularly apparent downstream of Como Bridge and in Woronora.

A total of 15.5% of assessed riverbank was recorded as having Moderate condition, indicating that a notable proportion of banks may be in a transitional state where condition could either improve or deteriorate depending on future management interventions. In reaches with Very Poor to Moderate condition vegetation, a major factor in the rating is narrow riparian width. Almost half of the surveyed

estuary length (43%) featured average riparian widths of less than 5 m wide, while a further 14.5% were recorded as under 10 m wide.

Table 9 Riparian Vegetation Condition in the Georges River Estuary study area.

Riparian Vegetation Condition	Length of Bank (m)	% of Overall Estuary Bank Mapped
Very Poor Condition	33,904	23.4%
Poor Condition	11,018	7.6%
Moderate Condition	22,511	15.5%
Good Condition	37,579	25.9%
Very Good Condition	39,847	27.5%

Table 10 and *Figure 18* illustrate the distribution of riparian vegetation condition by process zone and estuary location, demonstrating the variation in vegetation quality throughout the estuary. Overall, the results indicate that riparian vegetation across the estuary is generally healthy and of significant ecological value. Most process zones exhibit riverbanks with 60% or greater of riparian vegetation in Good to Very Good condition.

In the Fluvial Dominated process zone of the Georges River, riparian vegetation is primarily in Good condition (46.1%). Approximately one-quarter of this zone was in Moderate condition (24.4%) with the main degradation related to urban development and historical clearing. While only 12.5% of riparian zones were classified as Poor or Very Poor, these areas are often characterised by narrow vegetation buffers with poor canopy structure, diversity and continuity. This Fluvial dominated process zone also exhibited the highest density of weeds, accounting for 69% of all reaches with more than 25% weed cover. Weed infestations were most prominent in the upper Georges River near Chipping Norton, where species included lantana, small-leaved privet, madeira vine, and cockspur coral tree.

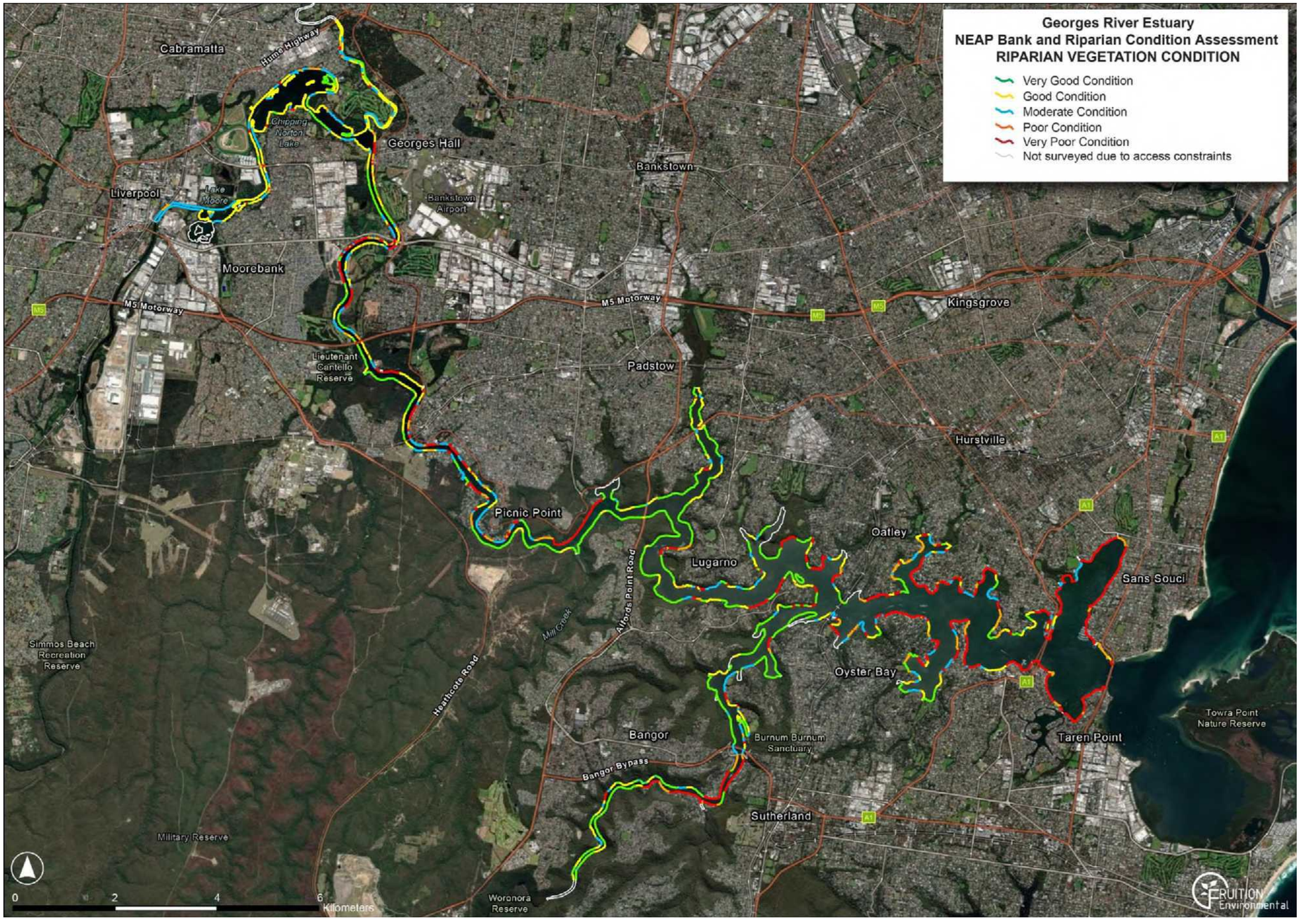

Figure 17 Distribution of riparian vegetation condition across the Georges River Estuary Study Area.

Table 10 Distribution of riparian vegetation condition ratings in the Georges River estuary by process zone and location: summary statistics.

	Total (m)	Very Poor Condition (%)	Poor Condition (%)	Moderate Condition (%)	Good Condition (%)	Very Good Condition (%)
Fluvial Dominated Process Zone						
Georges River	32,110	8.3	5.7	24.7	46.1	15.1
Prospect Creek	6,929	2.2	3.4	23.7	62.8	7.9
Other	181	-	-	-	100	-
TOTAL	39,220	7.2	5.3	24.4	49.3	13.8
Fluvial Transition Process Zone						
Georges River	16,379	17.8	11.3	21.9	20	29
Woronora River	11,486	28.6	6.8	6.1	18.9	39.6
Other	179	70.9	29.1	-	-	-
TOTAL	28,044	22.5	9.6	15.3	19.4	33.2
Fluvial Delta Process Zone						
Georges River	24,647	31.8	3.6	6.4	14.4	43.8
Woronora River	8,082	9.6	3.8	21.2	15.7	49.8
Saltpan Creek	6,054	1.3	-	8.2	37.1	53.4
TOTAL	38,783	22.4	3.1	9.8	18.2	46.5
Mud Basin Process Zone						
Georges River	32,729	26.3	4	10	14.7	45.2
Woronora River	3,619	-	3.6	2.6	17	76.8
TOTAL	38,812	41.4	13	12.5	15	18.3

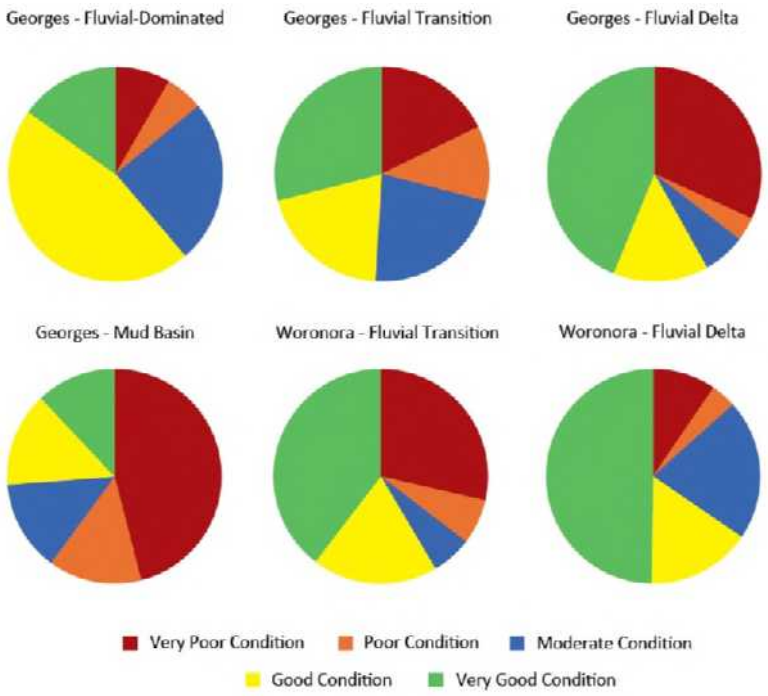

Figure 18 Proportional distribution of riparian vegetation condition severity within each estuary of the Georges River study area.

Downstream in the Fluvial Transition zone, there is an increase in both Very Good and Very Poor vegetation condition, resulting in a relatively even distribution across all condition classes (*Table 10*). This pattern reflects the mix of residential development and parkland along the estuary foreshore. In developed areas, riparian vegetation has often been entirely removed, with foreshore protection structures replacing natural banks. Conversely, parklands and national parks contribute substantial areas of healthy vegetation communities. These include fringing mangroves, sandstone hillslopes with dry sclerophyll forest, and alluvial flats supporting swamp oak floodplain forest or saltmarsh.

This trend continues in the Fluvial Delta zone, where vegetation is either largely intact or highly modified or almost absent. Riparian vegetation in the Georges River fluvial delta zone is in Good or Very Good condition along nearly two-thirds of riverbanks (58.2%), although the proportion of Very Poor vegetation also nearly doubles (*Figure 16*). Notably, some areas – such as Burrawang Reach Picnic Area – were classified as Very Poor despite the apparent proximity of high-quality vegetation. These areas are separated from the bank by open parkland and roads and feature artificial foreshore protection with no riparian vegetation present.

The Woronora River shows similar spatial trends. In the upper estuary, over one-third of riverbanks (35.4%) are in Poor to Very Poor condition, primarily due to residential development. However, two-thirds of the riverbanks feature Good or Very Good condition riparian vegetation (65.4%). In contrast, vegetation condition improves in the Fluvial Delta of the Woronora River, where 49.8% of riverbanks are in Very Good condition and an additional 15.7% are in Good condition. Vegetation along Salt Pan Creek is particularly healthy, with 90.5% of banks in Good or Very Good condition.

In the lower estuary, vegetation condition is significantly degraded. Nearly half of the riparian areas in the Mud Basin process zone (45.6%) are in Very Poor condition, which corresponds to the high degree of foreshore urbanisation. Many properties have entirely cleared riparian and fringing vegetation for access and amenity purposes. Only 26.8% of this zone retains Good or Very Good condition vegetation, typically consisting of mangrove forests in off-channel embayments and patches of Coastal Dry Sclerophyll Forest on steep sandstone slopes. Weeds such as lantana and ground asparagus are present in this zone, though their coverage is generally low (<10%).

The major impacts on riparian vegetation condition observed during the field assessment included:

- Clearing associated with urbanisation and foreshore access.
- Loss due to erosion processes including bank undercutting or stripping of intertidal benches under mangrove habitat due to persistent wind or boat wave effects, particularly where only a narrow fringe of vegetation exists on the bank.
- Weed incursion, particularly in the upper reaches between Liverpool Weir and Chipping Norton Lake, as well as Prospect Creek. Elsewhere typically had Low (<10%) weed cover observed. The most extensive weeds identified included lantana, ground asparagus, coastal morning glory, cockspur coral tree and madeira vine.

Existing Estuary Erosion Control Works

Method

The presence or absence of existing erosion controls on the bank was recorded for each surveyed section. The methodology broadly followed the DPI Fisheries Draft Decision Support Tool methodology (Hydrosphere Consulting, 2020) with some modification. Compatibility with the DST was maintained although extra information was recorded to assist in the more accurate determination of existing control statistics (percentage of bank treated with control) and a number of additional control types were added (i.e. gabions, jetty/wharf structures).

If existing erosion control works were present the following information were recorded:

- The type of control/s (i.e., rock revetment, revegetation, building rubble, etc.) were recorded using a yes/no data field against each potential control listed (multiple selections possible),
- the percentage of segment with an existing control/s was recorded to allow more accurate determination of length of works as the control length does not always correlate with the segment length as it is not the primary determinant of the segment. The options for this field were *nil existing*, *less than 10%*, *10–25%*, *25–50%*, *50–75%*, and *75–100%* of the segment length (only one selected).
- Finally, the effectiveness of the existing control/s was recorded. The options for this field were *Ineffective*, *Partial (Condition)*, *Partial (Design)*, *Completely*, *Under Construction*, or *Redundant*. The DST descriptions of the works effectiveness categories were adopted for this assessment (see Hydrosphere Consulting, 2020).

Types of Works Present

Of the total length of individual bank field surveyed in the Georges River estuary (144.9 km), 60.3 km or 41.6% of riverbank had some form of existing bank protection (*Table 11*).

The most prevalent form of bank protection observed was seawalls (as either sandstone or concrete blocks, walls or slab) which comprised 60% (36.3 km) of all works recorded, representing 25% of the total surveyed length of estuary bank in the study area (*Table 11*). The next most prevalent types of bank protection included rock armouring along 20.5 km (34% of works) and building rubble, bricks and broken concrete along 2.6 km (4.3% of works) of riverbank.

All other works types have been used minimally throughout the estuary, each representing < 1% of total works and include foreshore habitat, gabion baskets, rock groynes, sheet piles, timber walls. Sand bags, cobble beaching and tyres have been used in single, small reaches.

Several sites had works in the early stages of construction, but the type of remediation could not be determined. Several areas of foreshore habitat reconstruction have been undertaken using environmentally friendly and aesthetic landscape design principles, integrating sustainable principles with rock armouring or sandstone seawalls. No other active revegetation for bank protection purposes were identified throughout the estuary.

Examples of the types of erosion protection works present in the Georges River Estuary study area are shown in *Plates 15* to *18*.

Table 11 Total length of each existing bank protection works style, the percentage of each style of the overall total length of bank protection measures, and the percentage of each style of the total length of estuary bank surveyed in the Georges River estuary

Control Type	Total Length of Bank (m)*	% of Overall Works	% of Surveyed Bank
Seawall	36,344	60.2%	25.1%
Rock armouring	20,481	34%	14.1%
Building rubble	2,587	4.3%	1.8%
Rocky foreshore habitat	1050	1.7%	0.7%
Under construction (unknown)	445	0.74%	0.31%
Gabion baskets	188	0.31%	0.13%
Other	132	0.22%	0.09%
Rock groynes	66	0.11%	0.05%
Timber wall	58	0.10%	0.04%
Geotextile sandbags	20	0.03%	0.01%
Cobble beaching	17	0.03%	0.01%
Tyres	16	0.03%	0.01%
Rock fillets	-	-	-
Revegetation	-	-	-
Log wall	-	-	-
Natural logs on bench	-	-	-
Oyster shells	-	-	-
Entrance training wall	-	-	-
Trial	-	-	-
Total bank treated	**60,354**	**100%**	**41.7%**

* *Note: the total length of works may exceed the length of bank treated where works types overlap, such as rock armouring of the bank toe and revegetation of the mid and upper bank.*

Plate 15 *Examples of effective bank protection works in the Georges River estuary, clockwise from top left: sandstone block wall and rock armour toe on the mid Georges River Reach 291; upper Georges River Reach 162; geotextile sandbags used in a public access location on the mid Georges River at Reach 426; and rocky foreshore habitat restoration at Carss Park Reach 989.*

Plate 16 *Examples of partially effective bank protection works in the Georges River estuary, clockwise from top left: failing timber wall in Prospect Creek Reach 1093; failing rock wall adjacent to public park area in mid Georges River Reach 416; failing gabions and concrete wall in the lower Georges River Reach 463; and failing rock wall in the Woronora River Reach 636.*

Plate 17 *Examples of ineffective bank protection works in the Georges River estuary, from left to right: failed gabion structures on the upper Georges River Reach 26; and failed rock works with concrete capping on the mid Georges River Reach 394.*

Plate 18 *Examples of inappropriate bank protection works in the Georges River estuary, from left to right: dumped concrete slabs on the mid Georges River Reach 9; and building rubble used for bank protection in the upper Georges River Reach 35.*

Condition of Works

The condition or effectiveness of bank protection measures installed in the Georges estuary was recorded wherever works were identified. *Table 12* provides the summary statistics on works condition whilst *Figure 19* shows the distribution of works and their effectiveness throughout the estuary (with the occurrence of bedrock and thus erosion-resistant banks also indicated).

Table 12 *Total length of each category of works effectiveness for bank erosion protection measures surveyed and percentage of each category of the total length of surveyed bank protection measures in the Georges River estuary.*

Works Effectiveness	Total Length of Bank (m)	% of Overall Works
Completely	52,897	87.6%
Partial (Condition)	4,833	8.0%
Partial (Design)	244	0.4%
Ineffective	707	1.2%
Redundant	1,082	1.8%
Under construction	590	1.0%
TOTAL	60,353	100%

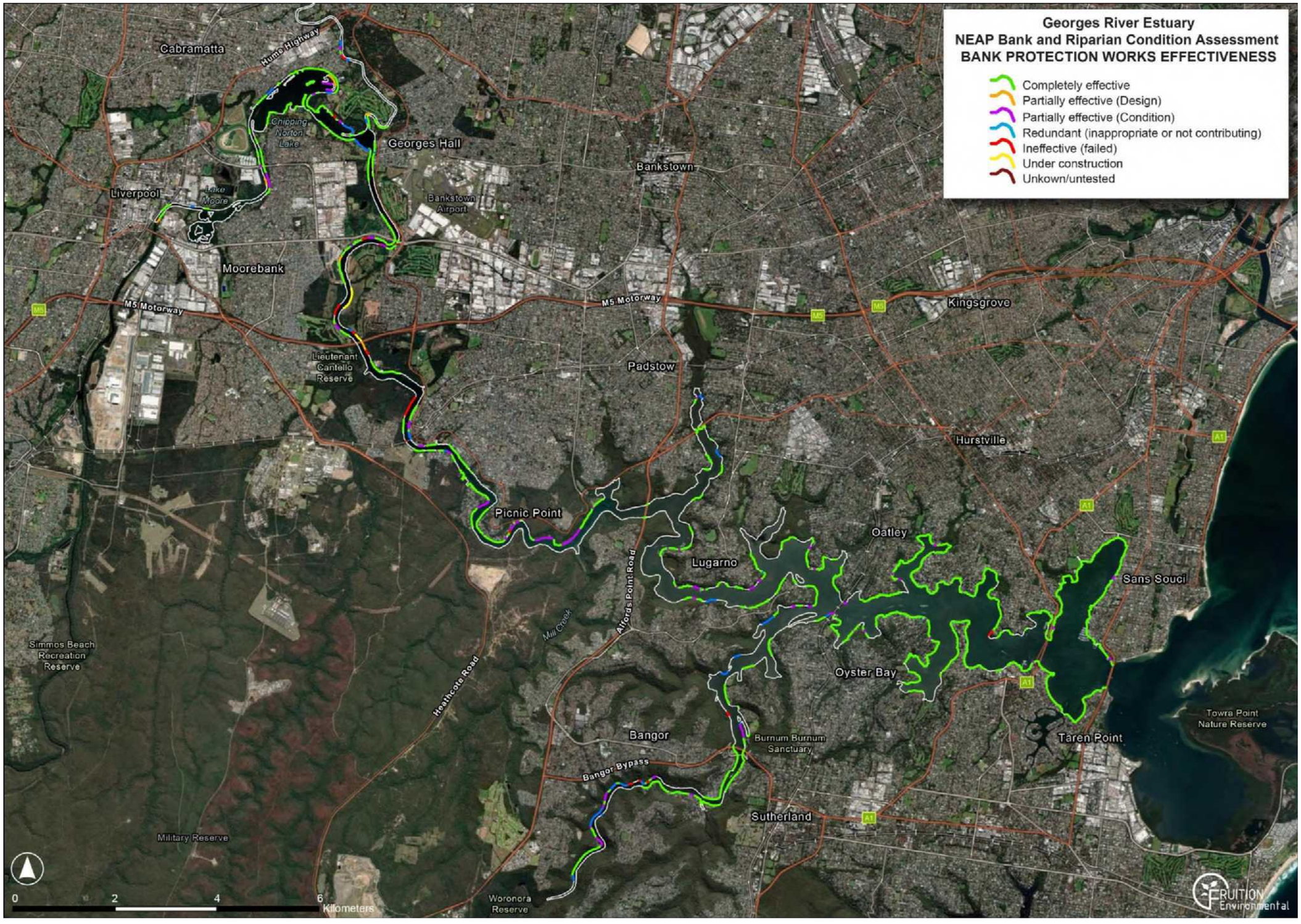

Figure 19 Distribution of bank protection works effectiveness within the Georges River estuary study area.

Comparison of Priority Works Sites

The Estuary Processes Study (SMEC, 2010) included an assessment of seawall structural condition to identify and prioritise sites for management intervention. Twelve sites were designated as Key Management Actions due to seawalls being assessed in Poor or Fair condition, with recommendations for replacement or repair. As of the 2025 survey, approximately half of these sites have not undergone any maintenance and remain in similar condition to their 2009 assessment (*Table 13*). These structures show varying levels of effectiveness, with some still partially mitigating erosion despite evident structural degradation.

One structure (S21 / Reach 1041) appears to have completely failed, with active erosion now present, or may have been removed without replacement works.

One site (S40 / Reach 314) includes a rock groyne that does not appear to function as a bank protection structure. Although its removal and replacement with riparian vegetation was recommended (SMEC, 2010), the structure has since been reinforced with a concrete slab and now serves as estuarine recreational infrastructure. No structural or functional issues were identified at this location. The remainder have been repaired and are currently providing effective protection against erosion (*Table 13*).

Additional sites throughout the estuary were previously ranked as high priority, though not designated as Key Management Actions, based on the use of inappropriate construction materials, such as building rubble, bricks or broken concrete. These sites were recommended for future upgrade to more habitat-sensitive solutions, including rock armouring and riparian revegetation. In the 2025 survey, most of these structures were assessed as completely or partially effective, despite their materials, and have not been prioritised for further management. Some locations, such as Carss Bush Park, have undergone retrofitting with environmentally sensitive designs, even though their condition was considered Good in the 2009 assessment.

*Table 13 Status of Key Management Action seawall sites identified in the SMEC 2010 report. Sites in **red** were considered the highest priorities for the overall study area.*

Site (2010)	Survey ID (2025)	LGA	2009 Structure Condition	Priority	2025 Effectiveness	2025 Status
S17	98	Fairfield	Poor	Med-High	Completely effective	Existing structure repaired with rocky habitat landscaping and rock armouring
S21	1041	Fairfield	Poor	High	**No existing control**	Unclear – timber wall no longer exists, low-level undercutting of bank
S24	75	Canterbury-Bankstown	Poor – abandoned structure	High	**Redundant**	No action undertaken
S28	43, 48	Liverpool	Poor – dumped material	High	Completely effective – concrete rubble	No action undertaken. Reach 48 now fringed with Phragmites
S36	314	Liverpool	Poor	High	<10% completely effective works	No action undertaken
S40	357	Canterbury-Bankstown	Fair	High	Structure appears structurally sound	No action undertaken
S42	351	Sutherland	Fair	High	Partial (condition)	No action undertaken
S50	463	Sutherland	Fair	High	Partial (condition)	No action undertaken
S51	717, 718	Georges River	Fair	Med-High	Completely effective	Existing seawall maintained and repaired to good condition – no apparent issues
S56	831	Georges River	Poor/Fair	High	Completely effective	Existing seawall maintained and repaired to good condition – no apparent issues
S60	949	Georges River	Fair	High	Completely effective	No issues identified
S63	975	Georges River	Poor	High	Completely effective	Replacement of existing seawall with effective rock armouring

DST For Bank Erosion Management in NSW Estuaries – Summary of Recommendations

Method

The Decision Support Tool for Bank Erosion Management in NSW Estuaries (the "DST") is an excel-based tool developed by Hydrosphere Consulting for NSW Department of Primary Industries and Regional Development – Fisheries under the NSW Marine Estate Management Strategy. The tool is designed to contribute to the development of estuary bank management strategies which are consistent with best management practices.

The main output of the tool is the DST Recommendation. This recommendation is made up of the primary recommendation determined by the DST macros plus any additional recommendations related to riparian management, fencing, or other management actions (e.g. boating controls). The primary recommendation may be a recommended treatment type where bank erosion and erosion impact thresholds are exceeded or may be a recommendation to undertake maintenance on existing controls. Shortlisted treatment types are also provided.

The method by which the DST determines bank erosion treatments and riparian/estuary management actions are detailed in the DST's supporting documentation (see Hydrosphere, 2020 and 2020b). It is important to review these documents before using the DST outputs as they provide important context and explanatory notes on the outputs. As examples:

- Fencing will be recommended where stock access or public access is identified as contributing to erosion in a specific reach
- Riparian vegetation management will be recommended where the average width of riparian vegetation in a surveyed reach is less than 10 m, or where the vegetation is patchy (i.e. "continuity" is negligible or low), unless there is a landward constraint such as a road or other infrastructure that would prevent improvement.
- Other management controls are recommended where vessel wave wash is identified as a contributing factor or public access is a consideration.

It is explicitly acknowledged in the DST documentation that social and economic impacts of the recommendations have not been considered at this stage and that consultation with relevant stakeholders would be required before implementation.

Importantly also, the primary recommendation and shortlisted options provided by the DST are based on the data collected during the field survey which due to the scale of assessment are not necessarily of the detail that would normally be required for developing site specific remediation recommendations. As such there may be reasons why the DST recommendation may not be the most suitable option for the bank segment and these reasons may not be captured by the input data. Hydrosphere, in its documentation on the tool explicitly states that "*It is crucial that the DST recommendations are further investigated…to assess whether they are indeed applicable or if other techniques could be more suitable*" (Hydrosphere, 2020, p.18).

Overview of Results

Figure 20 shows the distribution of DST Primary Works Recommendations within the Georges River estuary study area.

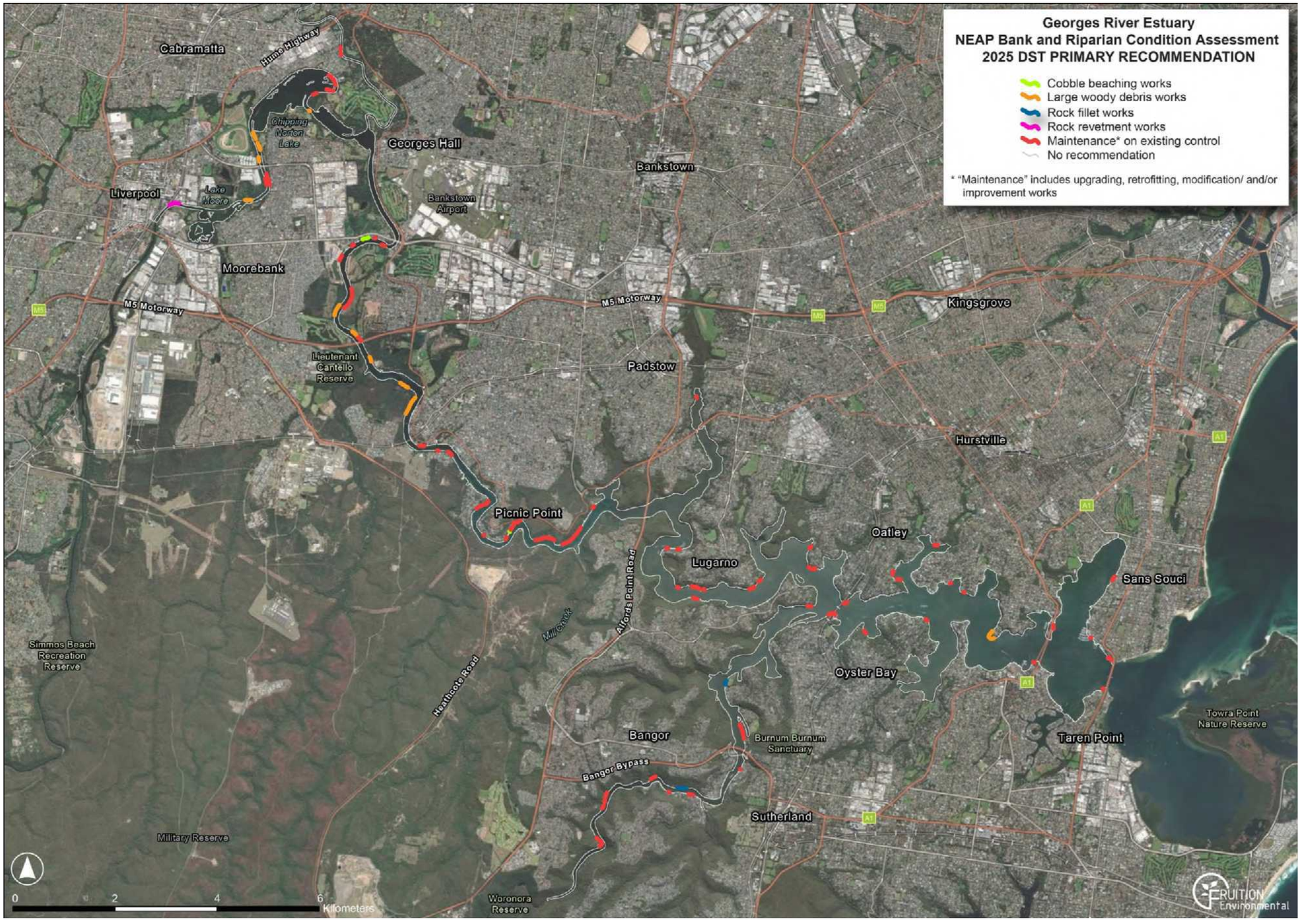

Figure 20 Primary DST recommendations in the Georges and Woronora River estuaries based on the NSW Fisheries Decision Support Tool for Bank Erosion Management in NSW Estuaries (Hydrosphere, 2020).

As mentioned previously, the DST recommendations are made on the basis of the field data in accordance with the tool's macros and are designed to give a first cut assessment of best practice works types suitable for the estuary location and the processes and impacts recorded during the field survey. The DST primary recommendation is either a main works type or a recommendation to maintain the existing controls present where appropriate. A summary of the range of Primary DST Recommendations made for the Georges River estuary study area is included in *Table 14.*

Table 14 Summary of primary recommendations from the DPIRD Fisheries Decision Support Tool for Bank Erosion Management in NSW for the Georges River estuary.

Control type	Length of Works Recommended (m)	Proportion of Surveyed bank (%)
Maintenance on existing control	6,259	4.3%
Large Woody Debris works	1,733	1.2%
Rock Fillets works	240	0.17%
Rock Revetment works	192	0.13%
Cobble Beaching works	170	0.12%
Total works	**8,594**	**5.9%**
No recommendation	**136,265**	**94.1%**

It should be noted that the fact that a surveyed reach attracts a recommendation for works or maintenance within the DST does not infer that the reach is a priority for management action. This is because the DST does not include any consideration of overall objectives for estuary management beyond bank erosion control using best practice (the prioritisation of reaches for management intervention is covered separately in Part 4 of this assessment report). For example, the DST does not consider the broader estuary management objectives, the context of the specific reach in that broader management context, ownership of the land or assets, funding availability, approvals required, or other related strategies or policies. However, where a reach is separately assessed to be a priority for intervention, the DST provides a reasonably objective and standardised approach to determining which treatment options should be first considered.

Across the study area, only 8.5 km (5.9%) of surveyed banks received a primary DST recommendation for intervention. The most common recommendation was Maintenance on Existing Control, accounting for 72.8% of primary recommendations. This was advised for 75 reaches, covering 6.3 km of the estuary study area. A recommendation for Maintenance is typically made where an appropriate treatment/control is in place but is only partially effective at erosion control. Maintenance is generally not recommended where the existing works are inappropriate, such as the use of tyres or building rubble for erosion control, but may be considered where inappropriate elements are part of otherwise functional control works. In such cases, maintenance should involve the removal of unsuitable materials and the application of current best practice methods.

The second most common recommendation was the installation of Large Woody Debris structures, representing 20.2% of all primary recommendations. This treatment was advised for 13 reaches, covering 1.7 km of the study area.

Lastly, it should be noted that the DST Final recommendation may also include management actions such as fencing, riparian vegetation management or other management controls (managing public access or implementing boating speed restrictions, etc.). The complete NEAP Georges River Estuary Condition Survey dataset should be reviewed to understand Final DST Recommendations within the study area.

Future Works

It is clear from the existing works statistics that the predominant forms of bank erosion protection used in the estuary to date rely on rock, sandstone and concrete seawalls in varying forms of direct bank protection. These methods account for over 94% of the bank protection methods found in the Georges and Woronora River estuaries and more than 57 km of bank length equating to more than 39% of the length of estuary bank surveyed. This is a relatively common occurrence in NSW estuaries where the preference for hard engineering solutions often reflects the setting, that is where public infrastructure or public access are requiring protection.

Both the Georges River Data Compilation and Estuary Processes Study (SMEC, 2010) and the more recent Georges River Coastal Zone Management Plan (BMT WBM, 2013) identified the extensive use of seawalls throughout the estuary and noted the varying condition of these assets. The NEAP assessment has confirmed the full extent and updated the effectiveness status for all bank protection types in the estuary study area.

Both earlier reports also promoted the future use of "environmentally friendly seawalls" and these approaches have subsequently been used in various formats within the lower estuary including at Carrs Park, Dover Park, Claydon Reserve, Kwannicle Reserve, and other locations. The approaches adopted conform to a large extent with the *Environmentally Friendly Seawalls* (EFS) guide produced by the Sydney Metropolitan Catchment Management Authority and Office of Environment and Heritage (2012).

Where existing seawalls are present but requiring repair or maintenance the techniques outlined in that guide provide options for improvement of the ecological values at those sites.

Of course, remediation and bank protection works must deal with the erosion processes that are occurring at the specific site and issues related to risks to and value of assets to be protected. Where deep near-bank water channel profiles exist then modified seawalls may be the only practical solution.

However, in some cases it is worth considering whether seawalls are in fact an appropriate solution at that location. In the Georges and Woronora there is a great deal of existing rocky foreshore habitat, both naturally occurring as a result of the extensive bedrock outcropping which occurs in these systems, and artificially, as a result of the extensive use of seawalls and rock revetment in response to long-term erosion issues. This is particularly the case in the mid to lower Woronora estuary and mid to lower Georges estuary including the many bays such as Oyster Bay and Kogarah Bay which have seen very extensive foreshore development and reclamation. In essence what has been lost, although not quantified in this study, is the vegetated riparian fringe. In areas where intertidal or supratidal benches occur this has resulted in a loss of mangrove forest and coastal saltmarsh which is not easily re-established if seawalls are maintained.

In many areas of the lower Georges and Woronora, wave wash erosion (including both wind and boat wave wash) is a major issue which although is generally of low intensity is persistent across the full tidal range. Under these conditions, even established mangrove forests can be gradually undermined through the persistent erosion of the intertidal bench and some method of stabilisation of the bench is required.

Of note, the EFS guide does include options for re-establishment of fringing vegetation communities such as mangroves using techniques such as rock fillets, constructed embayments of varying heights and temporary fencing (although temporary fencing and the use of coir logs have proven in other estuaries to be very short-lived). Other suitable works in these locations include hybrid log/rock fillets potentially with the addition of cobble beaching and/or oyster shell or even innovative oyster modules to restore intertidal bench height and encourage mangrove colonisation. These are often referred to as soft engineering approaches or "living foreshores" and there are many sites where such approaches are suitable, constructable, and likely to be cost-effective. These options should be pursued when the opportunity for

maintenance or replacement of existing bank protection works occurs and wherever intertidal benches occur.

The NEAP assessment revealed that most bank erosion of management concern is concentrated in the upper fluvial dominated reaches of the Georges River (although still only affecting less than 12% of this part of the estuary). Where erosion has been addressed, the approaches used have tended to be harder engineering approaches including rock armouring, stone walls, concrete blocks and slabs, and some ad hoc works using inappropriate materials (e.g. building and construction waste). Where inappropriate works types have been used and the land is Crown or Council owned, a potential future action could be the targeted removal of inappropriate works and replacement with more appropriate works types which contribute to bank stability and estuarine and riparian habitat in these reaches.

In these upper estuary reaches, bank protection approaches that seek to address bank stability issues whilst also improving estuarine habitat are available and should be investigated for potential use. These include the use of hybrid works approaches that incorporate large wood. An example of these works are the large woody debris structures installed in the upper Clarence River estuary above Seelands which were constructed under an NSW Transport and Local Land Services partnership to deal with wake board erosion. These works are generally successful having been appropriately used in a part of the estuary less susceptible to marine borers and worms and utilising appropriate hardwood species of substantial dimensions. In general, wood elements permanently in contact with mid-estuary waters are the most susceptible to borer and worm attack and at least part of the structures are likely to have a limited life span. Provided the finished heights of the wave dissipation/protection structures is sufficient, the slow decomposition of timber elements is not an issue. However, where the wood elements failure results in slumping of the crest height of the structures, erosion is often observed of the mid to upper bank due to waves overtopping.

In most cases of bank protection and certainly where objectives included riparian vegetation improvement, active revegetation is an important component. However, in the Georges Estuary study area there were few instances of active bank revegetation noted during the NEAP survey. The exceptions were incorporation of low estuarine vegetation plants into the environmentally friendly seawall projects and some obvious cases of assisted natural regeneration of riparian vegetation in some areas of parkland associated with bush regeneration efforts. Future projects could include improvements to riparian vegetation in targeted reaches in addition to direct bank protection to improve estuarine habitat outcomes.

Lastly, management controls are also important, particularly where boat wave impacts have been identified. There is a very high recreational use of the Georges and Woronora estuary including many types of craft, some of which are able to minimise waves under the indicated speed restrictions whilst others probably produce greater waves at those speeds than when on the plane. Potentially the replacement of vessel speed signs with no wake zones coupled with compliance activities in areas susceptible to wave erosion could assist, noting that many areas of the estuary are already protected via works and foreshore development.

PART 4 – Priorities for Action and Investment

This part of the bank and riparian condition assessment report outlines a priority system designed to identify and rank priority reaches for management, remediation, protection and investment. The multicriteria analyses used to determine the priority reaches draws the criteria from the objectives of a number of foundational documents relevant the management of the estuary. These include the NSW Coastal Management Act 2016, the Marine Estate Management Strategy 2018–2028, the Coastal Crown Lands Guidelines 2023, the Georges River Coastal Management Plan Scoping Study 2022 (Salt, 2022), the Georges River Estuary CZMP (BMT WBM, 2013), the Woronora River Estuary Management Plan 2008 (WBM, 2008), and to a lesser extent the various member Council Biodiversity strategies (see *Appendix C*).

The Management Context

Coastal Management Act No 20 2016 (NSW)

The *Coastal Management Act 2016 No 20* NSW (CMA 2016) identifies the management objectives for coastal management areas in New South Wales. The objects of the CMA 2016 include (s3):

> *to manage the coastal environment of New South Wales in a manner consistent with the principles of ecologically sustainable development for the social, cultural and economic well-being of the people of the State*, and of particular relevance to this assessment:
>
> *(a) to protect and enhance natural coastal processes and coastal environmental values including natural character, scenic value, biological diversity and ecosystem integrity and resilience, and*
>
> *(b) to support the social and cultural values of the coastal zone and maintain public access, amenity, use and safety, and*
>
> *(c) to acknowledge Aboriginal peoples' spiritual, social, customary and economic use of the coastal zone, and*
>
> *(d) to recognise the coastal zone as a vital economic zone and to support sustainable coastal economies, and*
>
> *(f) to mitigate current and future risks from coastal hazards, taking into account the effects of climate change, and*
>
> *(h) to promote integrated and co-ordinated coastal planning, management and reporting, and*
>
> *(i) to encourage and promote plans and strategies to improve the resilience of coastal assets to the impacts of an uncertain climate future including impacts of extreme storm events, and*
>
> *(m) to support the objects of the Marine Estate Management Act 2014.*

The CMA 2016 breaks the coastal zone into management areas with identified management objectives. Under Part 2 Section 8 the management areas include *wetlands and littoral rainforest areas* and *coastal environment areas*. These areas are defined within the State Environmental Planning Policy (Resilience and Hazards) 2021 (SEPP(R&H) 2021) and associated mapping (SEPP(R&H) 2021, s2.4). Coastal environment areas are defined in the CMA 2016 as the coastal waters of the State, estuaries, coastal lakes, coastal lagoons and land adjoining those features, including headlands and rock platforms. Wetlands and littoral rainforest areas are defined as land which displays the hydrological and floristic characteristics of coastal wetlands or littoral rainforests and land adjoining those features.

The entire area of this assessment constitutes *coastal environment area*, however only a small proportion of the assessment area constitutes *wetland and littoral rainforest* areas. The CMA 2016 proscribes a hierarchy that operates where a parcel of land is mapped as more than one management area (s10(3)). In the context of this assessment that hierarchy operates to ensure that the management objectives for the wetland and littoral rainforest areas are given priority over the management objectives for coastal environment areas wherever an inconsistency arises. The management objectives for the two management areas are generally consistent, however one practical outcome of this hierarchy is that in areas of the Georges River estuary where wetlands or littoral rainforests occur, management efforts should include promoting the rehabilitation and restoration of degraded wetlands and littoral rainforests (CMA 2016 s6(b)).

In all other areas assessed in this study, the management objectives for *coastal environment areas* can be reasonably adopted and include (CMA 2016 s8(2)):

(a) to protect and enhance the coastal environmental values and natural processes of coastal waters, estuaries, coastal lakes and coastal lagoons, and enhance natural character, scenic value, biological diversity and ecosystem integrity,

(b) to reduce threats to and improve the resilience of coastal waters, estuaries, coastal lakes and coastal lagoons, including in response to climate change,

(c) to maintain and improve water quality and estuary health,

(d) to support the social and cultural values of coastal waters, estuaries, coastal lakes and coastal lagoons,

(e) to maintain the presence of beaches, dunes and the natural features of foreshores, taking into account the beach system operating at the relevant place,

(f) to maintain and, where practicable, improve public access, amenity and use of beaches, foreshores, headlands and rock platforms.

NSW Marine Estate Management Strategy 2018–2028

In terms of the State-wide perspective, the NSW Marine Estate Management Strategy 2018–2028 identifies a number of Management Initiatives relevant to this assessment including:

- Under *Management Action 1.3*: Facilitate and deliver on-ground activities that reduce diffuse source water pollution through investigation and provision of funding programs and financial incentives.
- Under *Management Action 2.3*: Develop marine vegetation management plans that maximise resilience…address key threats…facilitate rehabilitation opportunities. Also, to investigate estuary-wide bank protection options to inform the assessment of bank protection work proposals and facilitate rehabilitation opportunities.
- Under *Management Initiative 3*: Note that on-ground activities and habitat protection and rehabilitation that will help mitigate the impacts of climate change are to occur via actions under Initiative 1 and 2 and will include rehabilitating coastal wetlands, revegetating riparian areas, and protecting river banks.

Coastal Crown Lands Guidelines 2023

The Coastal Crown Lands Guidelines were released by the NSW Department of Planning and Environment in October 2023. The Guidelines apply generally to the administration of Crown land where that land occurs within the "coastal zone" within the meaning of section 5 of the Coastal Management Act 2016. This includes lands mapped under the SEPP (Resilience and Hazards) 2021 as coastal wetlands and littoral rainforest area, coastal vulnerability area, coastal environment area, and/or coastal use area.

The Guidelines focus on aligning decisions made under the Crown Land Management Act with the objects and principles of the Coastal Management Act and promote the integration of Crown land management with CMPs.

Of particular relevance to this report and its future use in the Georges River Coastal Management Program (CMP), any actions proposed on Crown Lands within the CMP must be referred to Crown Lands before the CMP is adopted. If this process is followed and the CMP is then certified, then applications for dealings or authorisations under the Crown Land Management Act will be streamlined.

Georges River CMP Scoping Study, 2022

Georges River Catchment Coastal Management Program Scoping Study (Salt, 2022) provides the first stage of identifying key issues to be addressed through the CMP process. It does not specify explicit objectives and actions, but highlights the following broad issues to be targeted for management in latter stages in the CMP development:

- Riparian & Estuarine Condition and Habitat/Corridor Loss
- Catchment Runoff and Water Quality
- Streambank Stability & Erosion
- Foreshore Asset Management

Georges River Estuary CZMP, 2013

The Georges River CZMP provides strategic management approaches and planning within the estuary and its catchment. It identifies several objectives and actions or strategies specifically aimed at managing bank erosion, and protecting foreshore assets and riparian habitat. These have been summarised in the literature review above and include objectives:

- **E1.** Reduce the extent and severity of bank and foreshore erosion while minimising the impacts on estuary health
- **E2.** Reduce the causes and impacts of sedimentation in the estuary
- **B3.** Protect and improve the extent and condition of estuarine and riparian vegetation
- **B2.** Minimise the cause and spread of invasive species in aquatic and terrestrial habitats
- **G1** Effectively manage threats and enhance the natural and cultural heritage values in the catchment and waterways
- **C3** Maintain and improve formal public access to the foreshore without compromising estuary health
- **C1** Maintain the varied legal recreational pursuits of the Georges River catchment without compromising estuary health and social amenity

Relevant actions within the CZMP that relate to the following priority analyses and rankings include:

- **Action MB4:** Rehabilitation of estuarine wetlands & riparian vegetation
- **Action ME2:** Boat wake erosion impacts and strategies
- **Action ME3:** Targeted control of ad hoc foreshore access
- **Action ME4:** Prioritise & remediate erosion, using vegetation, where possible

Woronora River EMP, 2008

The EMP provides objectives for long-term management of the Woronora River. While the area related specifically to the Woronora River, the relevant objectives within the Plan overlap with those of the Georges River CZMP and are summarised as:

- **Objective 1:** Reduce the level of pollutant and sediment loads
- **Objective 7:** Identify, protect and enhance key habitat areas
- **Objective 9:** Identify and minimise impacts of recreational activities
- **Objective 10:** Remove weeds from bushland areas around the estuary
- **Objective 11:** Stabilise eroding foreshores, protect assets or infrastructure
- **Objective 12:** Minimise boating-related erosion
- **Objective 13:** Improve and maintain amenity of foreshore reserves
- **Objective 14**: Recognise cultural significance

Georges River Regional Environmental Plan, 1999

The Georges River REP impacts environmental development and planning within the Georges River catchment. The Plan provides policy to:

- Preserve, protect and encourage the rehabilitation of regionally significant sensitive natural environments including wetlands (including mangroves, saltmarsh and seagrass), bushland (such as EECs); and
- Preserve, enhance and protect freshwater and estuarine ecosystems

Council Biodiversity Strategic Plans

Each Council has developed a Biodiversity Strategy to guide the protection and enhancement of biodiversity, including EECs and threatened species of flora and fauna. While these strategies are implemented at the local government level, their relevance extends beyond individual boundaries due to overlapping ecological values and shared natural systems. For the purposes of this prioritisation, the strategies have been considered collectively across the estuary study area. A summary of each Council's relevant objectives and strategic actions is provided in the literature review and detailed in Appendix C, and include:

Canterbury-Bankstown Council

- **Action BP2 –** Ensure vegetation rehabilitation and biodiversity enhancement is a primary focus within riparian corridors.
- **Action BP8 –** Focus on impacts to intertidal ecosystems such as riparian vegetation, wetlands, saltmarsh and mangroves.
- **Action ER1 –** Protect our most significant patches of remnant bushland
- **Ongoing action –** Conservation management in Council Reserves

Fairfield City Council

- **Action 2.6 –** Prioritise planting along creek banks, with 30% of both sides of creek banks rehabilitated to natural condition
- **Action 2.7 –** Improve native vegetation cover and condition in natural areas.
- **Action 3.1 –** Protect and enhance bushland in good condition
- **Action 3.3 –** Enhance and restore wildlife corridors

Liverpool City Council

- **Strategy LM1 –** Protect and restore native vegetation communities and species habitat
- **Strategy LM5 –** Improve water quality and habitat for aquatic biodiversity
- **Strategy LM8 –** Protect and enhance biodiversity values on Council lands

Sutherland Shire Council

- Retain bushland to enable survival of existing plant and animal communities
- Protect the habitats of native flora and fauna, including threatened species
- Protect wildlife corridors and vegetation links
- Protect bushland along natural drainage lines, water courses and foreshores
- Protect the recreational and educational value of bushland.

Priorities for Intervention

The priorities for intervention outlined below reflect the management objectives in the *Coastal Management Act 2016*, the key issues outlined in the Georges River Coastal Management Program Scoping Study 2022, the MEMS 2018–2028, and the bank and riparian management strategies identified in the various CZMP, EMP and Strategic Plans outlined above.

Priority Reaches and Priority Focus Areas

As part of the Georges River Estuary Bank Condition and Riparian Condition Assessment, a draft list of priority reaches for protection, enhancement and/or remedial intervention is to be produced.

In this context, an estuary "reach" refers to an individually mapped segment of bank which have been assessed during the field survey as being relatively homogenous in terms of either bank erosion severity and/or riparian vegetation condition.

One thousand and fifty-two (1052) individual reaches were mapped during the field survey. However, where appropriate, a number of adjacent reaches have been grouped and targeted as a priority on the basis that the same or similar strategies would be applied to address issues common to all the reaches in that grouping. To avoid confusion, where several reaches are combined to strategically address an identified issue, the combined reaches will be referred to as a "priority focus area".

The bank erosion severity and riparian vegetation condition are the primary fields upon which the estuary banks have been segmented into reaches. However, each reach also has a number of additional data fields recorded. This allows reaches to be identified on the basis of other attributes besides erosion severity or riparian condition. These additional attributes may include for example physical features (e.g. Presence of bedrock), vegetation characteristics (e.g. Presence of HCV vegetation communities), and/or man-made influences (e.g. the presence of existing control works and their effectiveness/condition at the time of survey).

The recording of field data in this way allows the interrogation of the field data sets using multicriteria analyses which in turn allows reaches with certain sets of attributes to be extracted from the field dataset and supplemented with other existing datasets to produce subsets which form either potential priority reaches or potential priority focus areas for further assessment.

Table 15 describes the analyses adopted for this assessment to develop the subset of reaches where further investigation as to whether protection, enhancement, or remediation is warranted. The analyses have been separated into the three primary areas of interest to this assessment: bank condition, riparian vegetation condition, estuarine habitat and existing works condition.

Table 15 Reach analyses outcomes based on the field data collected and multi-criteria analyses, supported by existing GIS datasets as described. These reaches form the pool of mapped estuary reaches to which the priority ranking criteria are to be applied to determine priorities for estuary bank and riparian vegetation remediation/protection actions.

ID	Analyses	Description	Notes
Bank Condition			
BC1	Reach mapped with at least "High" erosion severity and associated with at least "Good" riparian vegetation condition.	These are reaches where bank remediation measures would protect existing riparian vegetation that has been mapped as being in good to very good condition.	MEMS Action 2.3. CZMP 2013, Objective B3 CBC Biodiversity Strategy Action BP8; FCC Biodiversity Strategy Action 3.1; LCC Biodiversity Strategy LM1, LM8. 4 reaches identified. (Segments 171, 183, 191, 925)
BC2	Reach mapped with at least "High" erosion severity and also containing existing bank protection works which have been identified as partially effective, ineffective, or redundant.	These are reaches where erosion severity was classified as "high" based on field assessment and the DST criteria, but which landholder interest can be inferred by the presence of existing erosion protection works (which were not mapped as effective).	MEMS Action 1.3. 1 reaches identified. (Segment 26)
BC3	Reaches mapped with at least "high" erosion severity but also mapped as having "Medium" to "High" environmental, infrastructure/commercial, or Amenity/safety impact rating	These are reaches where high erosion severity is causing medium level impacts to environmental, infrastructure, commercial, amenity or safety values as defined in DPI Fisheries Decision Support Tool for bank erosion.	CMA 2016 s3(b). Woronora EMP 2008 Objective 11. 4 reaches identified. (Segments 26, 171, 180, 191)
BC4	Reaches mapped with at least "Moderate" erosion severity and also important for public access	These are reaches where public access is established but where high erosion is potentially compromising public safety	CMA 2016 s8(2)(f). CZMP 2013 Objectives C1 & C3; Woronora EMP 2008 Objective 9. 6 reaches identified. (Segments 5, 26, 394, 416, 1018, 1034)
BC5	Reaches mapped with at least "High" erosion severity and also containing riparian vegetation in moderate condition	These are reaches where bank remediation measures would protect existing riparian vegetation that has been mapped in moderate condition.	MEMS Action 2.3. CZMP 2013 Objective B3. FCC Biodiversity Strategy Action 3.3; LCC Biodiversity Strategy LM8 2 reaches mapped. (Segments 180, 224)

ID	Analyses	Description	Notes
Riparian Vegetation Condition			
RC1	Reach containing or immediately adjacent to a mapped littoral rainforest community and threatened by at least moderate erosion severity.	These are reaches that correspond to the SEPP (Resilience and Hazards) 2021 Littoral Rainforest area mapping and are threatened by erosion processes which are considered above natural rates.	CMA 2016 s6(b) promotes promotion of rehabilitation and restoration of degraded littoral rainforests. No reaches identified. Littoral rainforest has been mapped near Great Moon Bay but erosion severity is negligible.
RC2	Reach containing or immediately adjacent to a mapped coastal wetland and threatened by at least "Moderate" erosion severity with "Medium" environmental impact rating.	These are reaches that correspond to the SEPP (Resilience and Hazards) 2021 Coastal Wetlands Area mapping and are threatened by erosion processes which are considered above natural rates.	CMA 2016 s6(b) promotes promotion of rehabilitation and restoration of degraded coastal wetlands. CZMP 2013 Objective B3, Action MB4. 6 reaches identified. (Segments 191, 249, 269, 290, 292, 597)
RC3	Reach immediately adjacent to a candidate High Conservation Value riparian vegetation community (excluding estuarine macrophyte communities) and threatened by at least "Moderate" erosion severity with "Medium" environmental impact rating.	These are reaches where the estuary bank vegetation forms part of a mapped candidate NSW Endangered Ecological Community which is threatened by erosion processes which are considered above natural rates. NOTE: The riparian vegetation condition rating of at least "Moderate" filters out reaches with very poor to poor condition vegetation condition.	CZMP 2013 Objective B3; Woronora EMP 2008 Objective 7. CBC Biodiversity Strategy Actions BP8 & ER1; FCC Biodiversity Strategy Action 3.1; LCC Biodiversity Strategy LM1, LM8; SSC Biodiversity Strategy 12 reaches identified. (Segments 93, 171, 177, 183, 191, 224, 249, 269, 283, 290, 292, 597)
Estuarine Habitat			
EH1	Reach containing or immediately adjacent to a mapped coastal saltmarsh community and threatened by at least "Moderate" erosion severity.	These reaches are where coastal saltmarsh is threatened by erosion processes which are considered above natural rates.	MEMS Action 1.3. CZMP 2013 Objective B3 & Action MB4; Woronora EMP 2008 Objective 7. Georges River REP, 1999 3 reaches identified (Segments 292, 376, 561)

ID	Analyses	Description	Notes
EH2	Reach containing or immediately adjacent to mapped mangrove habitat and threatened by at least "Moderate" erosion severity with "Medium" environmental impact rating.	These reaches are where mangrove habitat is threatened by erosion processes which are considered above natural rates.	MEMS Action 1.3. CZMP 2013 Objective B3 & Action MB4; Woronora EMP 2008 Objective 7. Georges River REP, 1999. 4 reaches identified. (Segments 249, 290, 292, 1069)
Existing Control Works Condition			
EC1	Reach identified as having "Medium" to "High infrastructure/commercial impacts or amenity/safety impacts and also have existing works in ineffective or partially effective condition.	Identifies reaches where failing works are contributing to impacts to infrastructure, commercial, amenity or safety values.	CMA 2016 s3(b). CZMP 2013 Objective C1 & C3; Woronora EMP 2008 Objective 11. 6 reaches identified. (Segments 26, 351, 373, 416, 502, 1018)
EC2	Reach mapped as at least "Moderate" erosion severity and also containing existing bank protection works adjacent to public land.	Public land is defined as Council-owned land, Crown reserves, or Crown land parcels. This criteria identifies reaches that have existing works but where erosion is continuing and is affecting a public land asset/public foreshore area NOTE: Reaches required at least "Low" infrastructure/commercial impact or amenity/safety impact rating to filter out reaches with negligible public foreshore impact.	CMA 2016 s3(b). CZMP 2013 Objective C3; Woronora EMP 2008 Objectives 11 & 13. 12 reaches identified. (Segments 15, 26, 276, 310, 320, 615, 622, 624, 640, 923, 1086, 1018)

Rankings

A simple weighted scoring system has been adopted to rank the priority reaches and focus areas identified using the above analyses. Higher rankings are allocated to higher scoring reaches. Higher ranking indicates greater justification for investment to meet the objectives outlined under the Coastal Management Act, MEMS, and other foundation documents that guide the objectives of estuary management in the Georges and Woronora Rivers.

Table 16 outlines the criteria used.

Table 16 Criteria and associated weightings used to rank the list of priority reaches and focal areas for potential investment in remediation/enhancement/protection.

ID	Criteria	Description	Weighting	Notes
A	Public assets or infrastructure at high risk	Primarily proximity to road, boating, or other public infrastructure. Applied where erosion severity was recorded as at least high, the DST infrastructure/commercial impact was recorded as medium or high OR the asset has been recorded as a high value asset at risk.	+5	CMA 2016 Object 3(b) and (d). Reaches where works are currently being implemented will be excluded.
B	Intervention likely able to address suite of estuarine natural values including bank stability, estuarine and riparian vegetation, estuarine habitat, and water quality	Reaches which intervention is likely to address a suite of estuary values are ranked more highly than those which address only a single value (such as bank stability).	+5	CMA 2016 Object 3(a). MEMS Management Initiative 1,2 and 3.
C	Reach is an important public access location	Proximity to a public access location and requiring considerations of safe access	+5	CMA 2016 s8(2)(f).
D	Intervention likely to improve future flood resilience of built assets	Interventions likely to improve the resilience of coastal built assets (private or public) to the impacts of extreme events (e.g. Storm or flooding events) are given more weight.	+5	CMA 2016 Object 3(f) and (i). This criterion is primarily focused on built assets as criteria B focuses on natural assets although the two are not mutually exclusive.
E	Reach is identified within a previous report as a priority area and has not yet been addressed through an appropriate management action	Reaches in the priority pool which are also identified in previous estuary management strategies and reports have already undergone assessment through an existing planning process and, if not already addressed, are ranked more highly in the priority system.	+3	CMA 2016 s3(a), (h) and (i) The previous strategies and reports referenced are the Georges CZMP (BMT WBM, 2013), Georges River Data Compilation and Estuary Processes Study (SMEC, 2010) and Woronora River EMP (WBM 2008).

ID	Criteria	Description	Weighting	Notes
F	Indigenous Cultural Heritage values at the site	A consultation process has been initiated with the La Perouse LALC to identify reaches of significance in terms of Indigenous cultural heritage and ongoing use in the Georges River estuary upstream of Rocky Road bridge (Captain Cook Bridge). Where this process results in the identification of areas of particular importance/significance, the weighting will be applied either positively or negatively to reflect either support for remediation/ intervention or a desire from the TO group for no disturbance to occur.	+5 or -5	CMA 2016 Object 3(c) and s8(2)(d) and MEMS Management Action 4.2.
G	Landholder support known or likely	Landholder support is generally crucial to the successful implementation of most interventions on estuary banks or in the riparian zone. Where landholder support is known or can be inferred from previous works or communications then potential interventions in those reaches will scored more highly.	+4	In the Georges River Estuary study area, reaches adjacent to Crown Land, NPWS estate, Council owned or managed land, and road reserves are assumed to meet this criterion.
H	Intervention likely to have a high degree of success	Site factors, erosion processes, recommended methods, and constructability are considered to have a high probability of achieving and maintaining site stability over the medium term (~10 years).	+4	Based on expert opinion.
I	Access is straight forward and is via existing all-weather private road/track, Crown Land or Council owned land	Ease of access reduces intervention costs	+4	Straightforward access will reduce implementation costs.

ID	Criteria	Description	Weighting	Notes
J	Intervention likely to protect/enhance important natural or aesthetic values	Factors include proximity to good to very good riparian vegetation, style of likely intervention, existence of redundant materials (tyres, building rubble), and location within the estuary.	+3	CMA 2016 Object 3(a).
K	Reach located within close proximity of a biodiversity priority action area (based on Council Biodiversity Strategies)	Interventions that support the existing biodiversity strategy for each LGA are scored more highly.	+3	CMA 2016 Object 3(a).
L	Reach adjacent to the oyster harvest zone or aquaculture lease	The Oyster Industry is an important commercial end user group that contributes to the local economy. The industry is highly dependent on good water quality and is often the first to be impacted from nutrient, sediment and ASS runoff.	+3	CMA 2016 Object 3(d).
M	Reach immediately adjacent to mapped estuarine vegetation – Seagrass	Determined from existing mapping, seagrass must be on the same side of the channel as the segment to receive the additional weighting.	+3	CMA 2016 Object 3(a). Georges River REP, 1999. Seagrass has been allocated a high rating due to its limited distribution in the estuary.
N	Reach contains mapped estuarine vegetation – Coastal Saltmarsh	Based on the PMHC EEC mapping dataset	+3	CMA 2016 Object 3(a). Georges River REP, 1999. Coastal saltmarsh has been allocated a high rating due to its susceptibility to sea level rise and the limited opportunities for landward expansion of the community.
O	Reach contains estuarine vegetation – Mangroves	Determined from existing mapping and aerial or other imagery	+2	CMA 2016 Object 3(a).

ID	Criteria	Description	Weighting	Notes
P	Site factors facilitate lower cost interventions	Some site factors such as severity of erosion, scale of required works, type of intervention, and materials requirements can significantly influence the costs of interventions. Lower cost interventions are scored more highly as cheaper interventions can free resources up for other interventions elsewhere.	+2	Cost of intervention is relative to the value of the asset or issue being addressed.
Q	Intervention likely to protect/enhance existing remediation works	Interventions that protect existing investments in estuary health or stability are considered to add additional value.	+2	Recognises the importance of maintaining existing assets which are contributing to estuary stability and health.
R	Reach located within a high use boating area	There is existing commercial boating use in the estuary (oyster growers, tourism, boat hire, etc.). Additionally, recreational boating is a very popular activity in many sections of the estuary. High use boating areas have been identified by the NSW Maritime BSO.	+2	CMA 2016 Object 3(b). CZMP 2013 Action ME2 Potential to increase the costs of remediation due to specific issues related to boat wave wash management but consistent with addressing multiple objectives protecting the social values of estuarine waterways.
S	Site complimentary to existing other NRM program	Interventions that support existing NRM programs in the estuary are scored more highly.	+1	CMA 2016 Object 3(h). e.g. Cultural heritage program, fish habitat program, etc.
T	Reach has a complicated approvals pathway due to proximity to coastal wetlands, littoral rainforest, or marine parks estate.	Reaches that are likely to involve significant costs and delays associated with approvals/permitting/licensing reasons are discounted slightly.	-3	Primarily related to the interaction of the *SEPP (Resilience and Hazards) 2021* with erosion issues within mapped coastal wetland or littoral rainforest areas.

Priority Reaches

The priority system outlined above has been applied to the 748 estuary reaches assessed during the NEAP field survey. Reaches were first reviewed against the objective criteria in *Table 15* and if the reach satisfied any of the criteria it was added to the "pool" of priority reaches. The criteria resulted in 32 reaches being added to the priority pool. Each of the reaches in the "priority pool" were then assessed against the ranking criteria in *Table 16*.

Overall Priority List

After accumulating adjacent reaches with similar processes and management issues into priority focus areas (for example reaches 290 and 292 at Voyagers Point Recreation Reserve; and reaches 923 and 925 at Bald Face Point Reserve on the Georges River), a ranked list of 30 priority reaches/focus areas remained. *Figure 21 s*hows the distribution of the priority reaches assessed in the study area.

Table 17 lists the top 11 ranked reaches/focus areas within the Georges River estuary study area. The main issues identified as affecting the reach and the objectives of management intervention are listed. These locations are considered higher priority for management interventions to improve flood resilience, protect public assets and infrastructure, improve water quality, improve estuary health, and protect or enhance important riparian vegetation communities. The location of the higher priority reaches and focal areas are indicated in **red** in *Figure 21.*

Tables 18–19 identify the top ranked locations for targeted programs that aim to protect public assets and infrastructure; or, protect or enhance riparian vegetation (specifically high conservation value vegetation types). These are subsets of the overall priorities and include some locations within and some location outside of the high priority list.

For the Georges River Estuary NEAP Assessment, reaches not listed in *Tables 17–19* should be pro-actively monitored for any change, for example after flood events. These reaches are listed in *Appendix B* and their locations are indicated by yellow in *Figure 21.*

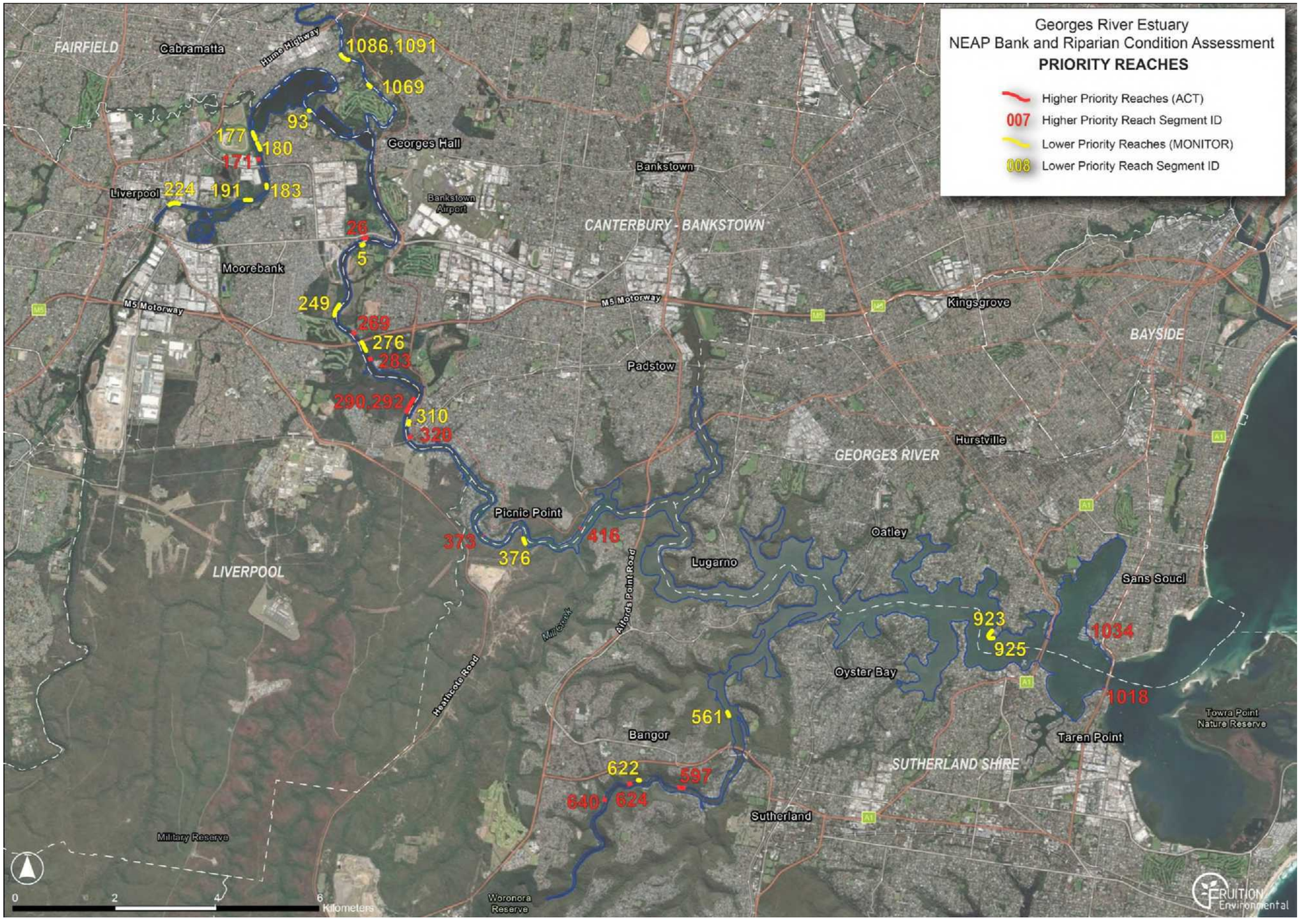

Figure 21 Locations and Reach reference IDs for priority reaches for management intervention in response to the Georges River Estuary NEAP Bank and Riparian Condition Assessment 2025.

Table 17 Ranked list of highest priority reaches for management interventions to improve overall bank and riparian condition in the Georges River estuary study area (Lower priority reaches which have been assessed as monitor only are included in Appendix B).

Rank	Reach	Location	Management Issues	Priority Score	Management Objectives
1	26	Georges River, mid estuary adjacent to Newbridge Rd	High severity erosion is impacting estuary access, amenity and bank protection infrastructure on Council-owned lands	41	Maintain public foreshore and access; improve flood resilience of built infrastructure; enhance recreational/aesthetic amenity
2	416	Georges River, Revesby Beach, Burrawang Reach Rd	Partial failure of rock protection works at Cattle Duffers Flat, with outflanking of the wall by erosion and collapse in area of public access	40	Preserve existing bank protection works; maintain public foreshore and access improve flood resilience of built infrastructure
3	463	Georges River, Old Ferry Road	Partial failure of rock protection works at Old Ferry Road, Georges River with moderate erosion adjacent to the road and powerline infrastructure.	35	Moderate severity erosion impacting exoisting bank protection works and potentially power line infrastructure on Council-managed Crown lands.
4	1018	Georges River, Old Taren Point Rd	Erosion has outflanked dilapidated bank protection infrastructure in close proximity to Old Taren Point Rd	33	Protect public infrastructure and assets; maintain public foreshore and access; preserve existing bank protection works; enhance recreational/aesthetic amenity
5	283	Georges River, Deepwater Park	Erosion is impacting candidate River Flat Eucalypt Forest EEC on Council-owned lands	32	Protect HCV vegetation and estuary habitat
6	320	Georges River, East Hills Park	Erosion is impacting bank protection infrastructure in area of public access at East Hills Park	32	Preserve existing bank protection works; maintain public foreshore and access; improve flood resilience of built infrastructure
7	373	Georges River, Picnic Point boat ramp	Partial failure of protection works at public access point at Alan Ashton Foreshore Reserve	30	Preserve existing bank protection works; maintain public foreshore and access improve flood resilience of built infrastructure
8	597	Woronora River, Gooyong Campsite	Moderate severity erosion having a medium impact on candidate Hinterland Riverflat Eucalypt Forest EEC and SEPP coastal wetland mapping	28	Protect HCV vegetation and estuary habitat

Rank	Reach	Location	Management Issues	Priority Score	Management Objectives
9	1034	Georges River, Plimsoll Street Reserve	Erosion has outflanked bank protection infrastructure causing potential hazard to public access at Plimsoll Street Reserve	28	Maintain public foreshore and access; enhance recreational/aesthetic amenity
10	171	Georges River, adjacent to Warwick Farm Racecourse	High severity erosion impacting candidate River Flat Eucalypt Forest EEC	27	Protect HCV vegetation and estuary habitat
11	269	Georges River, Riverlands Golf Course	Moderate severity erosion impacting candidate Swamp Oak Floodplain Forest EEC and SEPP coastal wetland at Riverlands Golf Course	27	Protect HCV vegetation and estuary habitat; replace inappropriate bank protection works; enhance recreational/aesthetic amenity

Priorities for Asset Protection and/or Maintenance

The ranked priority list presented in *Table 17* is a subset of reaches where the management objectives are related to infrastructure and public asset protection or maintenance and include reaches where:

- protecting public assets and infrastructure (e.g. roads) is the primary objective
- maintenance of existing bank protection works is the primary objective (i.e. existing investment protection), and/or
- protecting and maintaining safe public access is the primary objective

Table 18 Ranked list of priority reaches for management intervention to improve or maintain public assets, infrastructure and public access in the Georges River estuary study area.

Rank	Reach	Location	Management Issues	Priority Score	Management Objectives
1	26	Georges River, mid estuary adjacent to Newbridge Rd	High severity erosion is impacting estuary access, amenity and bank protection infrastructure on Council-owned lands	41	Maintain public foreshore and access; improve flood resilience of built infrastructure; enhance recreational/aesthetic amenity
2	416	Georges River, Revesby Beach, Burrawang Reach Rd	Partial failure of rock protection works at Cattle Duffers Flat, with outflanking of the wall by erosion and collapse in area of public access	40	Preserve existing bank protection works; maintain public foreshore and access; improve flood resilience of built infrastructure
3	463	Georges River, Old Ferry Road	Partial failure of rock protection works at Old Ferry Road, Georges River with moderate erosion adjacent to the road and powerline infrastructure.	35	Moderate severity erosion impacting exoisting bank protection works and potentially power line infrastructure on Council-managed Crown lands.
4	1018	Georges River, Old Taren Point Rd	Erosion has outflanked dilapidated bank protection infrastructure in close proximity to Old Taren Point Rd	33	Protect public infrastructure and assets; maintain public foreshore and access; preserve existing bank protection works; enhance recreational/aesthetic amenity
6	320	Georges River, East Hills Park	Erosion is impacting bank protection infrastructure in area of public access at East Hills Park	32	Preserve existing bank protection works; maintain public foreshore and access; improve flood resilience of built infrastructure
7	373	Georges River, Picnic Point boat ramp	Partial failure of protection works at public access point at Alan Ashton Foreshore Reserve	30	Preserve existing bank protection works; maintain public foreshore and access; improve flood resilience of built infrastructure
9	1034	Georges River, Plimsoll Street Reserve	Erosion has outflanked bank protection infrastructure causing potential hazard to public access at Plimsoll Street Reserve	28	Maintain public foreshore and access; enhance recreational/aesthetic amenity
13	640	Woronora River, upper estuary	Erosion has outflanked dilapidated bank protection infrastructure in close proximity to powerline infrastructure on Council-managed Crown lands	26	Protect public infrastructure and assets; replace existing bank protection works

Priorities for Riparian Vegetation Protection and Enhancement

Table 19 provides a ranked priority list of reaches where the management objectives are related to protecting or enhancing riparian vegetation, particularly High Conservation Value (HCV) vegetation communities (such as NSW Endangered Ecological Communities). Sites may also have additional objectives such as erosion protection, habitat protection or enhancement, and water quality improvement. Not all reaches contain riparian vegetation in Good or Very good condition and in some cases the actions required will include weed control, assisted natural regeneration, or active revegetation.

Table 19 Ranked list of priority reaches for management intervention to protect and/or enhance riparian vegetation in the Georges River Estuary study area.

Rank	Reach	Location	Management Issues	Priority Score	Management Objectives
5	283	Georges River, Deepwater Park	Erosion is impacting candidate River Flat Eucalypt Forest EEC on Council-owned lands	27	Protect HCV vegetation and estuary habitat
8	597	Woronora River, Gooyong Campsite	Moderate severity erosion having a medium impact on candidate Hinterland Riverflat Eucalypt Forest EEC and SEPP coastal wetland mapping	28	Protect HCV vegetation and estuary habitat
10	171	Georges River, adjacent to Warwick Farm Racecourse	High severity erosion impacting candidate River Flat Eucalypt Forest EEC	27	Protect HCV vegetation and estuary habitat
11	269	Georges River, Riverlands Golf Course	Moderate severity erosion impacting candidate Swamp Oak Floodplain Forest EEC and SEPP coastal wetland at Riverlands Golf Course	27	Protect HCV vegetation and estuary habitat; replace inappropriate bank protection works; enhance recreational/aesthetic amenity
12	624	Woronora River, upper estuary	Erosion is impacting candidate Swamp Sclerophyll Forest EEC and dilapidated bank protection infrastructure impacting the aesthetic amenity of the estuary on Council-managed Crown lands	26	Protect HCV vegetation and estuary habitat; replace existing bank protection works; enhance recreational/aesthetic amenity
15	290, 292	Georges River, Voyager Point Wetland Reserve	Moderate severity erosion impacting candidate River Flat Eucalypt Forest EEC and SEPP coastal wetland	23–28	Protect HCV vegetation and estuary habitat

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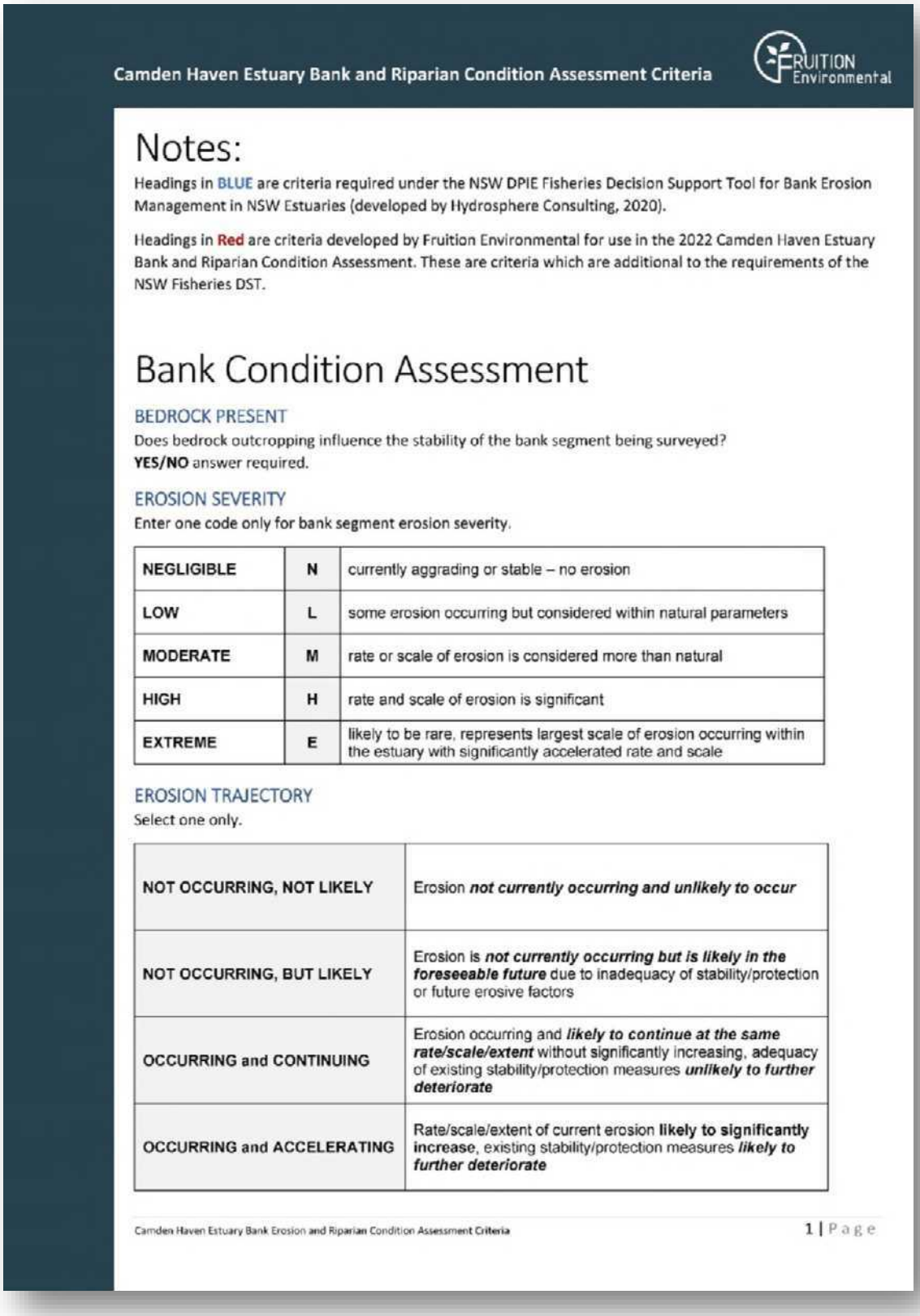
Appendix A – Bank and Riparian Condition Assessment Criteria



Camden Haven Estuary Bank and Riparian Condition Assessment Criteria

Notes:

Headings in BLUE are criteria required under the NSW DPIE Fisheries Decision Support Tool for Bank Erosion Management in NSW Estuaries (developed by Hydrosphere Consulting, 2020).

Headings in Red are criteria developed by Fruition Environmental for use in the 2022 Camden Haven Estuary Bank and Riparian Condition Assessment. These are criteria which are additional to the requirements of the NSW Fisheries DST.

Bank Condition Assessment

BEDROCK PRESENT

Does bedrock outcropping influence the stability of the bank segment being surveyed?
YES/NO answer required.

EROSION SEVERITY

Enter one code only for bank segment erosion severity.

NEGLIGIBLE	**N**	currently aggrading or stable – no erosion
LOW	**L**	some erosion occurring but considered within natural parameters
MODERATE	**M**	rate or scale of erosion is considered more than natural
HIGH	**H**	rate and scale of erosion is significant
EXTREME	**E**	likely to be rare, represents largest scale of erosion occurring within the estuary with significantly accelerated rate and scale

EROSION TRAJECTORY

Select one only.

NOT OCCURRING, NOT LIKELY	Erosion ***not currently occurring and unlikely to occur***
NOT OCCURRING, BUT LIKELY	Erosion is ***not currently occurring but is likely in the foreseeable future*** due to inadequacy of stability/protection or future erosive factors
OCCURRING and CONTINUING	Erosion occurring and ***likely to continue at the same rate/scale/extent*** without significantly increasing, adequacy of existing stability/protection measures ***unlikely to further deteriorate***
OCCURRING and ACCELERATING	Rate/scale/extent of current erosion **likely to significantly increase**, existing stability/protection measures ***likely to further deteriorate***

Camden Haven Estuary Bank Erosion and Riparian Condition Assessment Criteria 1 | Page

Camden Haven Estuary Bank and Riparian Condition Assessment Criteria

WATER DEPTH

Select one only

SHALLOW	***Less the 0.8m deep*** on average at estimated mean high water, measured 5m from the bank toe
MODERATE	***Between 0.8m and 1.5m deep*** on average at estimated mean high water, measured 5m from the bank toe
DEEP	***More than 1.5m deep*** on average at estimated mean high water, measured 5m from the bank toe

IMPACT RATINGS

Enter one code only for each of the three IMPACT CATEGORIES.

ENVIRONMENTAL IMPACTS

Select one category only for environmental impact.

NEGLIGIBLE	**N**	No features of biodiversity or conservation value threatened. Erosion at "natural rate". No impacts of erosion likely to effect downstream environments. Examples: • No erosion present (either naturally or because of erosion mitigation) • If Low Erosion Severity must be minimal water quality impacts and no vegetation being lost • If Moderate Erosion Severity then must be no water quality impacts and no biodiversity/conservation value impacts (eg. Sandy sediments)
LOW	**L**	No features of biodiversity or conservation value significantly threatened. Erosion rate/scale elevated above natural rate. Impacts of erosion likely to have local effects on water quality. Examples: • Localised water quality impacts (ie. localised turbidity within the bank segment) • Erosion threatening or small loss of "low value" vegetation
MEDIUM	**M**	Features of biodiversity or conservation value likely to be affected. Erosion rate/scale significantly greater than natural rate. Impacts of erosion likely to have water quality impacts beyond the segment surveyed. Examples: • Water quality impacts extending beyond the segment surveyed • Erosion threatening vegetation of biodiversity or conservation value
HIGH	**H**	Features of listed biodiversity or conservation value directly affected. Erosion rate/scale significantly greater than natural rate. Impacts of erosion having water quality impacts beyond the segment surveyed. Examples: • Erosion significantly impacting water quality beyond the segment surveyed (ongoing sedimentation, turbidity) • Erosion actively damaging vegetation of biodiversity or conservation value (eg. Moderate erosion affecting saltmarsh)

Camden Haven Estuary Bank and Riparian Condition Assessment Criteria

INFRASTRUCTURE/COMMERCIAL IMPACTS

Select one category only for infrastructure/commercial impact.

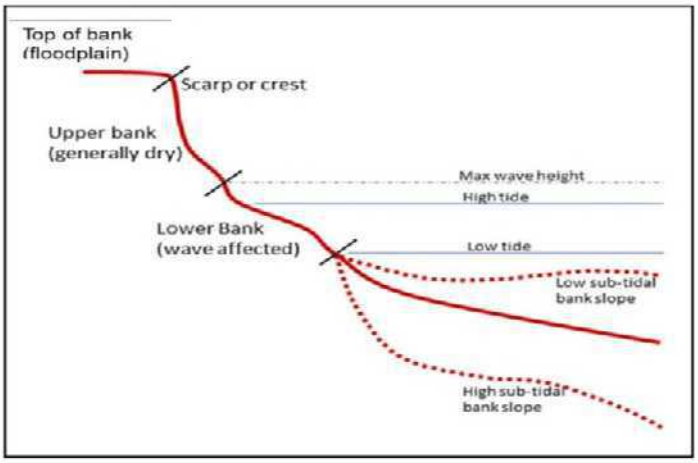
NEGLIGIBLE	**N**	No built or land assets under threat
LOW	**L**	Minor assets of low value under threat, AND Loss of land relatively minor and likely to be of low concern to landholder
MEDIUM	**M**	Assets of intermediate value threatened Examples: boat ramps, foot paths, park benches, access stairs.
HIGH	**H**	High value or important infrastructure under threat. Examples: power lines, water and sewerage infrastructure, houses, buildings, roads, carparks, etc.

AMENITY/SAFETY IMPACTS

Select one category only for amenity/safety impact.

NEGLIGIBLE	**N**	No impact on visual amenity, AND Very low risk of injury associated with erosion.
LOW	**L**	Minor impact on visual amenity to a small number of people, AND Low risk of injury associated with erosion.
MEDIUM	**M**	Significant visual impact, OR Public access to foreshore impeded, OR Greater risk of injury related to higher use area.
HIGH	**H**	Significant visual impact to high number of users, OR Foreshore access significantly impeded, OR Public safety risks associated with public areas.

LOCATION OF EROSION



NOTE:

Erosion on the top of the bank is rare.

Normally it will be Lower Bank or Upper Bank.

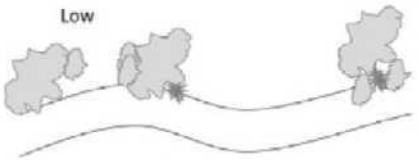
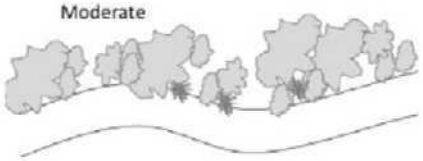
Enter YES/NO for each location in the survey

Camden Haven Estuary Bank Erosion and Riparian Condition Assessment Criteria 3 | Page

Riparian Condition Assessment

RIPARIAN VEGETATION CONTINUITY

The longitudinal continuity along the bank of riparian vegetation (recorded for the maximum vegetation structure likely at the site (ie. usually woody vegetation but may be only sedges/rushes in saltmarsh areas)

NEGLIGIBLE	No vegetation, OR Isolated individual trees and shrubs	None 
LOW	Woody vegetation discontinuous with significant gaps. Gaps more dominant than vegetation.	Low 
MODERATE	Woody vegetation almost continuous. Occasional small gaps but vegetation is dominant	Moderate 
HIGH	Woody vegetation continuious. No significant gaps.	High 

RIPARIAN VEGETATION AVERAGE WIDTH

Enter one code only for ***average*** riparian vegetation width for the segment. ***Measured from the low bank***.

<2m	Less than 2m average width of riparian vegetation
<5m	Less than 5m average width of riparian vegetation
<10m	Less than 10m average width of riparian vegetation
<20m	Less than 20m average width of riparian vegetation
>20m	Greater than 20m average width of riparian vegetation

Camden Haven Estuary Bank and Riparian Condition Assessment Criteria

RIPARIAN VEGETATION STRUCTURE

Riparian Vegetation Structure refers to the existence or otherwise of expected vegetation sub-strata (eg. canopy, shrub layer, ground layer, etc). ***This is a relative measure of structure based on what vegetation community would be expected to naturally occur at that location given the estuary location and context.***

Enter one code only for riparian vegetation structure for the segment.

VERY POOR	No riparian vegetation present in the segment OR only grass present
POOR	Riparian vegetation is mostly grass with sporadic canopy trees/shrubs
MEDIUM	Riparian vegetation is missing one or more sub-strata through entire segment (ie. no shrubs present but groundcover and canopy present through whole segment)
GOOD	Riparian vegetation structure has all of the expected elements for that location but has some areas of patchiness within the segment
VERY GOOD	Riparian vegetation structure has all expected elements for that location for the whole segment (eg. Intact riparian forest or intact saltmarsh or mangrove forest)

RIPARIAN VEGETATION DIVERSITY

Riparian Vegetation Diversity refers to what would be expected in a natural situation at that location, focussing on native riparian vegetation species. ***It is a relative measure of diversity based on what vegetation community would be expected to naturally occur at that location given the estuary location and context.***

Enter one code only for riparian vegetation diversity for the segment.

VERY POOR	No riparian vegetation present in the segment OR only grass present
POOR	Sporadic native shrubs and/or trees (unless mapped as saltmarsh) with a uniform grass understorey (often grazed, parklands or private foreshore areas)
MEDIUM	Moderately diverse native vegetation species but impacted by land use or clearing. May be regenerating but lower diversity of shrubs and groundcovers than would otherwise occur without disturbance.
GOOD	Disturbed remnant vegetation BUT with diverse ground cover species (ie. some grazing or clearing impacts)
VERY GOOD	Remnant riparian vegetation (eg. intact riparian forest, mangrove forest or Saltmarsh)

WEED PRESENCE

Enter one code only for ***presence of woody weeds and exotic vines***. Measured as **Estimated Foliage Projective Cover** (FPC) for weed species observed.

NIL OBSERVED	No woody or vine weed species observed
LOW	Less than 10% FPC for woody and vine weeds observed
MODERATE	10%-25% FPC for woody and vine weeds observed
HIGH	25%-50% FPC for woody and vine weeds observed
VERY HIGH	Greater than 50% FPC for woody and vine weeds observed

WEED SPECIES

Do any of the listed priority weed species occur in the segment? **YES/NO** answer required for each possibility.

Existing Controls and Erosion Works

EXISTING CONTROLS PRESENT

Do any of the existing controls occur in the segment? **YES/NO** answer required for each possibility.

PERCENTAGE OF SEGMENT WITH EXISTING CONTROLS

Tick one only.

<10%	Less than **1/10**th of the bank segment has existing works
10-25%	About **1/10**th to **½** of the bank segment has existing erosion works
25-50%	About **¼** to **½** of the bank segment has existing erosion works
50-75%	About **½ to ¾** of the bank segment has existing erosion works
75-100%	More than **¾** of the bank segment has existing erosion works

EFFECTIVENESS OF EXISTING CONTROLS

Tick one only.

COMPLETELY	Existing acceptable controls that are completely effective
PARTIALLY (CONDITION)	Existing acceptable controls that are only partially effective due to deterioration, maintenance may ameliorate.
PARTIALLY (DESIGN)	Existing acceptable controls that are only partially effectiveness due to a design flaw (ie.work doesn't address processes, etc)
INEFFECTIVE	Existing control not effective and maintenance would not improve
REDUNDANT	Existing control unacceptable form or not contributing to bank stability
UNDER CONSTRUCTION	Bank protection controls are currently under construction

Appendix B – Lower Priority Reaches for Ongoing Monitoring

The table presented in this Appendix lists the reaches and focus areas from the priority pool which fall outside the highest 10 priorities after applying the ranking criteria. In general, these reaches should be monitored for any change that may affect the priority scores, for example after flooding.

Rank	Reach	Location	Management Issues	Priority Score	Management Objectives
14	1086	Prospect Creek, adjacent to Knight St	Erosion is impacting candidate River Flat Eucalypt Forest EEC and dilapidated bank protection infrastructure on Council-owned and private lands	26	Replace existing bank protection works; enhance recreational/aesthetic amenity
16	561	Woronora River, opposite Bonnet Bay boat ramp	Erosion is impacting candidate Swamp Oak floodplain forest EEC and coastal saltmarsh EEC	26	Protect HCV vegetation and estuary habitat
17	93	Georges River, Floyd Bay	Slumping and wave erosion is impacting good condition candidate Swamp Oak Floodplain Forest EEC on Crown land	25	Protect HCV vegetation and estuary habitat
18	276	Georges River, mid estuary downstream of M5 Motorway	Erosion is impacting candidate River Flat Eucalypt Forest EEC and bank protection infrastructure on Council-owned lands	24	Protect HCV vegetation and estuary habitat; preserve existing bank protection works on public lands; improve flood resilience of built infrastructure
19	5	Georges River, Vale of Ah Reserve	Public access to foreshore is impacted by erosion due to public access	23	Maintain public foreshore and access; enhance recreational/aesthetic amenity
20	177	Georges River, South Park	Slumping and wave erosion is impacting good condition candidate River Flat Eucalypt Forest / Swamp Oak floodplain forest EEC on Crown land	23	Protect HCV vegetation and estuary habitat
21	183	Georges River, upper estuary at Chipping Norton	High severity erosion is impacting candidate River Flat Eucalypt Forest EEC	22	Protect HCV vegetation and estuary habitat
22	224	Georges River, upper estuary at Liverpool Hospital	Extreme severity erosion in close proximity to commercial infrastructure	22	Protect public infrastructure and assets; improve flood resilience of built infrastructure; enhance recreational/aesthetic amenity

Rank	Reach	Location	Management Issues	Priority Score	Management Objectives
23	191	Georges River, upper estuary at Chipping Norton	High severity erosion is impacting candidate River Flat Eucalypt Forest EEC	21	Protect HCV vegetation and estuary habitat
24	249	Georges River, Wurrungwuri Reserve	Moderate severity erosion impacting candidate River Flat Eucalypt Forest EEC	21	Protect HCV vegetation and estuary habitat
25	180	Georges River, South Park	High severity erosion impacting disturbed HCV vegetation on Crown land	19	Protect HCV vegetation and estuary habitat
26	310	Georges River, East Hills Footbridge	Erosion is impacting bank protection infrastructure on Council-owned lands	18	Preserve and replace existing bank protection works on public lands; improve flood resilience of built infrastructure
27	376	Georges River, mid estuary opposite Cattle Duffers Flat	Erosion is impacting mangrove forest SEPP coastal wetland in close proximity to coastal saltmarsh EEC	18	Protect HCV vegetation and estuary habitat
28	622	Woronora River, upper estuary	Erosion has outflanked dilapidated bank protection infrastructure on Council-managed Crown lands and in close proximity to private powerline infrastructure	18	Replace existing bank protection works; enhance recreational/aesthetic amenity
29	1091	Prospect Creek, adjacent to Knight St	Erosion is impacting dilapidated bank protection infrastructure on Council-owned and private lands	18	Replace existing bank protection works; enhance recreational/aesthetic amenity
30	923, 925	Georges River, Bald Face Point Reserve	Wave wash and slumping at Bald Face Point is impacting the environmental and aesthetic values of Coastal Enriched Sandstone Dry Forest HCV and Grey-headed flying fox habitat on Council-managed Crown lands	15	Protect HCV vegetation and estuary habitat; enhance recreational/aesthetic amenity

Appendix C – Council Biodiversity Strategy Summaries

Canterbury-Bankstown Urban Bushland and Biodiversity Strategic Plan

The Urban Bushland and Biodiversity Strategic Plan (the Plan) details Council's 2024–2034 approach to protecting and enhancing biodiversity, supporting priorities identified in the Community Strategic Plan, particularly around protecting and improving natural resources, bushland biodiversity and waterways. The Plan highlights further broad priorities and outlines strategic actions for the protection, management and enhancement of local biodiversity, including:

- Embed aquatic and terrestrial ecosystem management principles in all open spaces.
- Embed Aboriginal cultural heritage within the Green Web.
- Develop a three-river parkland system: Cooks, Georges and Duck rivers.
- Expand the City's indigenous plant and animal ecologies.
- Increase native vegetation and tree canopy across the City.
- Reframe water infrastructure from grey to green.
- Protect, preserve and promote the biodiversity of living spaces and the natural environment.

As per the objectives, actions are broad and focused on planning activities, from which more specific programs can be developed. Few of the actions have direct relevance to this study, although tacitly indicate the importance of specific issues within the Plan and community. Further, the Council is developing a Catchment and Waterways Strategic Plan to complement the Plan in protecting and improving rivers and catchments, which will likely bare greater relevance. Nonetheless, actions within the Plan target improving ecological restoration and are relevant to this study:

- **BP2 –** Ensure planning within riparian corridors accounts for vegetation rehabilitation and biodiversity enhancement as a primary focus.
- **BP4 –** Update environmental overlays mapping, including terrestrial biodiversity and riparian lands and watercourses mapping in all relevant locations.
- **BP8 –** indirectly highlights the value and importance of protecting intertidal ecosystems ecosystems such as riparian vegetation, wetlands, saltmarsh and mangroves.
- **BK&D2 –** Identify priority locations to invest resources for biodiversity restoration
- **ER1 –** Investigate the feasibility of establishing new Biodiversity Stewardship sites to protect our most significant patches of remnant bushland.
- **ER5 –** Implement programs targeted at improving the water quality rating of watercourses for aquatic flora and fauna habitats
- Ongoing conservation management and bushcare activities in Council Reserves

Fairfield City Biodiversity Strategy, 2022

The Strategy establishes the strategic approach and action plan to manage biodiversity and natural assets (flora and fauna) over the next decade. It identifies the values, threats and existing management approaches to establish an action plan that prioritises activities for Fairfield City Council to complete or commence over a 10 year period to best enhance and protect biodiversity in Fairfield City.

Framed around strategy themes and objectives, the actions relevant to estuary management include:

Objective: Habitat is restored for a diverse range of species

- **Action 2.6:** Prioritise planting along creek banks, recognising the multiple benefits including bank stabilisation, improved water quality, and enhanced connectivity for wildlife movement, with 30% of both sides of creek banks rehabilitated to natural condition over the medium term
- **Action 2.7:** Maintenance programs are maintained and increased to improve native vegetation cover and condition in natural areas.

Objective: Wildlife movement is facilitated and enhanced across a variety of zones and tenures

- **Action 3.1:** Identify bushland in good condition, areas for revegetation, wildlife corridors, opportunities for urban greening and potential biodiversity stewardship sites
- **Action 3.3:** Preferentially locate biodiversity enhancement and restoration programs within identified wildlife corridors and 'green grid' connections

Liverpool City Council Biodiversity Strategy, 2003

The Biodiversity Strategy aims overall to enable better management of the native plants and animals and their environment (biodiversity) in the Liverpool local government area. Specifically, the aims are to:

1. Provide for the conservation of native plants, animals, habitat and ecological processes.
2. Provide priorities and guidance for Council in making relevant management decisions.
3. Provide guidance for the use, conservation and enhancement of natural resources.
4. Provide a greater level of certainty for the community via a pre-defined, transparent and accountable process.

The overall Biodiversity Strategy includes a number of Land and Water Management strategies that each include related management actions. The actions within the Strategy have been established in order to protect Endangered Ecological Communities, threatened species of flora and fauna, as well as endangered populations. Strategies that directly or indirectly relate to riparian vegetation management priorities within this project include:

- ***LM1*** *Acquire and manage land to proactively protect and restore native vegetation communities and species habitat*
- ***LM5*** *Improve water quality and habitat for aquatic biodiversity*
- ***LM8*** *Evaluate, develop and implement operational practices that protect and enhance biodiversity values on Council lands*

Further, part of the strategy has included vegetation mapping and classification of conservation significance in Liverpool LGA. A set of management objectives have been developed to ensure areas are management for their biodiversity value. The following management objectives link clearly to riparian vegetation management priorities within the estuary:

3.2.3 Core – Urban Remnants Management

- To protect and retain small isolated remnants of Critical EECs within an urban setting,
- No net loss of 'Core – Urban Remnants',
- To protect the contribution 'Core – Urban Remnants' have to regional connectivity areas and riparian corridors.

3.2.5 Riparian Corridors Management

- To protect and manage existing good condition vegetation remnants in 'Riparian Corridors',
- To restore degraded vegetation in 'Riparian Corridors',
- To regenerate vegetation in cleared areas along 'Riparian Corridors'
- To protect and restore buffer areas to vegetation in the 'Riparian Corridors',
- To identify, protect and manage the aquatic ecological values, and
- To protect the linkages provided by 'Riparian Corridors'.

3.2.6 Regional Connectivity Areas Management

- To protect and manage existing good condition vegetation remnants in 'Regional Connectivity Areas',
- To protect the linkages provided by 'Regional Connectivity Areas',
- To restore degraded vegetation, and
- To regenerate vegetation in cleared areas.

Sutherland Biodiversity Strategy, 2000

The Biodiversity Strategy establishes the Sutherland Shire Council as a manager of land under its care, control and management. It sets out a policy to preserve and maintain biodiversity, both within and outside the Sutherland Shire, consistent with the principles of ecologically sustainable development. The Strategy outlines several objectives and actions related to the conservation of vegetation. The Strategy places a strong emphasis on integrated engagement and catchment management, with cooperation between council, community groups and private landholders. Key objectives that related to the conservation of riparian vegetation include:

2.1 Habitat Protection objectives

- Retain bushland in parcels of a size and configuration which will enable the existing plant and animal communities to survive in the long term.
- Protect the habitats of native flora and fauna, including threatened species.
- Protect wildlife corridors and vegetation links with other bushland.
- Protect bushland as a natural stabiliser of the soil surface, and protect existing landforms such as natural drainage lines, water courses and foreshores.
- Protect bushland of scenic value and retain the unique visual character of the landscape.
- Protect the recreational and educational value of bushland.

3.1 Habitat Corridors objectives

- Protect existing wildlife corridors and vegetation links with other bushland.
- Establish a viable network of corridors linking areas of bushland.
- Increase the effective population size of bushland reserves through a network of linking corridors.

4.1 Threatened Species objectives

- Prevent the extinction and promote the recovery of threatened species and communities.
- Protect the critical habitat of threatened species and communities.
- Eliminate or manage processes that threaten the survival and development of threatened species and communities.
- Ensure that the impacts of any action affecting threatened species and communities is properly assessed.

Focused on achieving these objectives, Actions establish how the Strategy will be implemented, including detailed tasks under each action that further specify practical, ground-level efforts for protecting and restoring vegetation.

Actions and tasks relevant to the management priorities within this study include:

Habitat protection

Action 1: Inventory of habitat types

- Map and regularly update data on habitat types, condition, and species.
- Identify and record areas of conservation significance, including riparian zones.

Action 2: Identify threatening processes

- Analyse trends in habitat loss and key threats (e.g. urbanisation, stormwater).
- Prioritise threats for action based on impact and feasibility.

Action 3: Develop management policies

- Promote the conservation of a range of habitat types, and ameliorate or eliminate processes that threaten these habitats
- Strengthen development controls and stormwater guidelines to protect sensitive vegetation.
- Support native plant propagation, weed management, and planning tools like DCPs and the Urban Tree Policy.

Action 4: Encourage community participation

- Support Bushcare and similar programs with resources and training.
- Educate the public on riparian values, native planting, and weed control.

Habitat corridors

Action 1: Inventory of habitat corridors

- Map and assess condition, vegetation type, and species usage in existing corridors.
- Update data annually alongside State of the Environment reporting.

Action 2: Establish new corridors

- Identify isolated bushland and linkages to improve connectivity for wildlife.
- Determine and address barriers to effective corridor function.

Action 3: Corridor management policies

- Incorporate corridor protection into zoning and planning instruments.
- Encourage native street tree planting and private landholder cooperation.