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Assessment of Selected Riparian Systems of the Ross and Black River Basins and Selected Other Drainage within the Townsville / Thuringowa Region Stage 2

Report prepared for Creek to Coral

January 2008

Signed on behalf of
C&R CONSULTING PTY LTD

Cecily Rasmussen *8 February 2008*

Director Date

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1 INTRODUCTION

1.1 SCOPE OF WORKS

C&R Consulting were commissioned by Creek to Coral (a joint venture of the Townsville and Thuringowa City Councils) to undertake a desktop review of riparian condition of selected river systems within the Ross and Black River Basins that were not analysed within Stage 1 of this project . After further negotiation with Creek to Coral the scope of works was extended to include nominated systems outside these basins, together with Alligator and Sandfly Creeks. This study uses the same methodology established in Stage 1. The study is based on a review of existing aerial photography, satellite imagery, vegetation maps, and soils maps, limited ground-truthing where necessary, and pre-existing knowledge of the study area.

1.2 RIPARIAN ZONE DEFINITION AND FUNCTION

The riparian zone is defined as the area of vegetated land adjacent to bodies of water such as streams, creeks, rivers or wetlands, and includes gullies and depressions where water only flows during wet periods. The width, characteristics and species composition of the natural riparian zone vary according to the geographical location of the water body, the location of the water body in the landscape, the climatic characteristics of the region, and the hydrogeomorphic features of the region (i.e. the ability of the adjacent landscape to capture and retain water/moisture).

Along river systems, the width, complexity, and species composition of the riparian zone is controlled by the geomorphology and underlying geology of the relevant section of the river. Riparian zones vary with stream flow characteristics and include over-bank flow channels and multiple stream flow heights within the channel.

Undisturbed landscapes associated with water courses are complex. Surficial swales and sand bars are built up and manipulated during flood events to create a landscape that traps and retains waters for subsequent slow seepage through the soil profile. Chemical dissolution within the soil profile creates a series of cemented layers that act as aquifers, providing moisture to deep rooted trees while slowing the movement of the water through the soil profile. In the semi arid tropics of North Queensland these cemented layers become interdigitated by the processes of formation and erosion. These interdigitated cemented layers retain waters percolating through the soil profile, but provide sufficient pathways for the subsequent slow release to the stream channel.

The hydrogeomorphic landscape created within the natural system establishes a series of interception zones, or multiple barriers, to trap, retain and slowly release runoff waters to the river channel or water body. In an undisturbed system, these features function to –

- Retain waters for subsequent release to the water body long after rainfall has ceased,
- Retain soil moisture for the maintenance of a multi-layered vegetation structure;
- Trap sediments and nutrients prior to entry to the water course, and
- Establish a complex hyporheic zone that supports the entire river system.

1.3 PHYSICAL BACKGROUND OF THE TOWNSVILLE/THURINGOWA REGION

Riparian diversity in the Townsville Region is dependent on a number of physical and chemical factors, including climate, hydrology/geomorphology (hydrogeomorphology), and soil structure.

1.3.1 Climate

The geographical location of Townsville and Thuringowa in the seasonally arid tropics indicates that it will be subjected to a rainfall pattern that is notoriously unreliable in its intensity, duration, and location, both temporally and spatially. Hot humid summers and mild dry winters are normal, while rainfall distribution, intensity and duration are highly variable.

Mean annual rainfall measured at Townsville is approximately 1140mm, although rainfall distribution is highly seasonal with around 70% of the annual rainfall occurring in the January to March period, and the sum of the average values for April to November well below the average figures for both January and/or February.

Annual average rainfall variation is also large, ranging from approximately 270mm minimum to 2370mm maximum. Around 60% of the years receive less than 75% of the average annual rainfall, with only a 40-50% probability of greater than average rainfall occurring in January or February. In addition, it is not uncommon to receive half the annual rainfall in a single rain event of 3 – 5 days.

The annual number of sunny days is estimated as 300 per year, and even during the wet season evaporation may, on most days, exceed rainfall. Hence, unless preceded by periods of gentle wetting of the soils, run-off is usually high due to the formation of surface crusts, and while it has been estimated that the amount of rainfall required to fully saturate the nearby Haughton River Catchment is around 60mm (Bureau of Meteorology, 2000), this saturation point can only be achieved if the catchment has been pre-wetted.

The combination of hot sunny days, long periods without rainfall, and highly irregular rainfall intensity and duration, creates a situation where evaporation exceeds precipitation for the majority of the year. Under these circumstances base-flow from fractured rocks and recharge zones at the base of the hills, gains considerable importance in the maintenance of riparian zones by providing moisture and/or water to the river system long after surface flow has disappeared (refer Section 1.3.2 *HydroGeomorphology)*..

Hence, across the narrow coastal plains of the Townsville / Thuringowa region, where rainfall is highly seasonal and evapotranspiration throughout the majority of the year is high, streams and rivers are usually ephemeral, transporting surface water through the channel for very short periods of each wet season. Under these conditions, riparian zones can be almost non-existent, particularly in the 1st and 2nd order streams of the drier catchments where stream flow is highly irregular and usually of very short duration.

Well developed riparian zones are generally restricted to river systems fed by a series of interdigitating, shallow aquifers, or from highly fractured rocks of the upper catchments. In areas where well developed riparian zones exist, the true width may be considerably limited relative to climates where rainfall distribution is more evenly distributed throughout the year. Thus, in the seasonally arid tropics, bank collapse and sediment transport during intense rainfall events is often high, even under normal circumstances. When an overlay of anthropogenic disturbance (e.g. industrialisation, land clearance, agricultural expansion, and/or urban expansion) is placed on top of the natural situation, the impact on surface and sub-surface flow, and subsequently, or consequently, the riparian zone, can be extreme.

Under these circumstances, a circle of compromise can be set in motion where bank stability and sediment buffering capacity are further compromised by the over-exposure of poorly vegetated, dry, erosive and dispersive soils.

1.3.2 HydroGeomorphology

The narrow coastal plains of the Townsville region are relatively flat and featureless. Small first and second order drainage features start in hills and mountains, flowing generally unimpeded to the flatter broader coastal plains where they converge to form 3rd and 4th order streams or rivers. Under the climatic conditions outlined in Section 1.3.1, the majority of these systems are ephemeral with above ground flows visible for a relatively short period after rain has fallen. However, below the surface, flows, cavity waters and pore waters contained within the hyporheic zone may retain water and provide subsurface environmental flows to riparian zones throughout the year. These factors, combined with modified systems where large unnatural bodies of water are held in the landscape for excessive periods of time, provide a diverse set of conditions for riparian zones to exist. Under such conditions, the natural development of riparian systems is generally governed by the river continuum concept. Representative river sections that relate to riparian variability are given in Table 1.

Table 1: Representative River Sections and Associated Vegetation Types

Representative River Section	Vegetation Type
Estuarine Zone (Saline / Brackish)	Mangrove development, often backed by wide expanses of highly saline inter-tidal areas favorable to the development of saltpans and salt marshes and accompanying saline tolerant saltwater couch and samphire vegetation units. In other near coastal areas, marine environments, sand dunes and associated fresh and saline swales are found.
Ephemeral Freshwater Zone	Extensive range of vegetation types can be found, including several types of *Melaleuca* and *Eucalypt* forest,
Zones of Permanent Freshwater	Predominantly areas of vine thickets and rain forest
Wetland and Billabong Systems	Several types of *Melaleuca* and *Eucalypt* forest dependent on water holding capacity of the soils, drainage, soil chemistry, and access to available waters

1.3.3 Soils

The dominant soils of the area are solodic, usually with a very thin (2-5cm) sandy or silty loam A1 horizon overlying a strongly bleached sandy loam A2 horizon. There is often an abrupt change to mottled grey or yellowish heavy alkaline clay in the B horizon. These clays are usually highly expansive and dispersive. Rainfall is intermittent, highly irregular, and strongly seasonal. Vegetation cover is sparse, leaving the highly dispersive, erodible, and frequently self-mulching soils relatively unprotected. Under natural conditions the impact on the landscape can be extreme, with large quantities of newly derived material transported to stream and river channels. Bank erosion, or bank collapse, is a physical response to river flow during high energy events, as well as a reaction to bank slumping caused by saturation during periods of extended rainfall. When both events coincide (i.e a long period of rainfall followed by a high energy rainfall event) the combined impact on bank stability can be significant.

For the above reasons it is considered advantageous to briefly describe the soils of the Townsville / Thuringowa region that will impact on either riparian development, or bank erosion and water quality if the riparian zone is removed. The most dominant soils of the Townsville / Thuringowa region are described below.

Soil Group	Description
Solodic	These soils tend to be very dense with low permeability and a high concentration of sodium ions leading to high dispersivity. The A Horizon of these soils is usually acidic with an underlying alkaline B Horizon. Loss of the A Horizon by surface flow and/or loss of the B Horizon by dispersive processes can have profound effects on vegetation types present. Vegetation developing on these soils is predominantly a combination of *Eucalyptus platyphylla, Corymbia tessellaris* and *C.dallach*iana with a mid stratum layer of *Melaleuca viridiflora* and *M.nervosa* an under story of *Themeda triandra* and *Heteropogon contortus* is observed.
Red Earths	This soil type is typically found in semi-arid to sub-humid climates. The surface soil is reasonably thick and the soils are best described as deep, freely drained mediums, with clear boundaries between the A and B horizons. Vegetation developing on these soils is predominantly deep rooted myrtaceous species forming a floristic assemblages of a open woodland or forest tree species observed in these environments include *Eucalyptus platyphylla, Corymbia clarksoniana, C.tessellaris* and *C.dallachiana*. In drier areas *Eucalyptus platyphylla* may be replaced by *E.crebra. A*n understory of *Themeda triandra, Heteropogon contortus, Mnesithea rottboellioides* and *Bothriochloa decipiens* may be observed.
Yellow Earths	These soils are similar to the red earths, but usually have a higher clay content. This may mean reduced infiltration but greater moisture retention properties. Vegetation developing on these soils is predominantly Melaleuca viridiflora, M.nervosa with infrequent Grevillea striata and Xantohria johnsoneii. The understory may include Themeda triandra, Panicum decompositum, Dichanthium sericeum and Sporobolus and aristida spp.
Siliceous Sands	Broad group varying in colour and characterised by their deep uniform sand to clayey sand texture and absence of any distinct horizons. The A1 Horizon may accumulate organic matter, giving it a dark appearance. However, if vegetation is not present, this horizon may be absent due to its weak structure. Vegetation developing on these soils is highly varied, ranging from open eucalypt woodland to Acacia shrub land. They differ from other vegetation assemblages in that species observed in these areas are more drought tolerant.
Red Podzolic	These soils are typical of warmer sub-humid environments. They exhibit a thin organic to organic-mineral layer (typically aluminium and/or iron), overlying a yellow/brown leached sandy loam. Vegetation developing on these soils are a c0mbination of *Eucalyptus crebra, Corymbia tessellaris* and *C.dallachiana.* In wetter areas a mid-stratum layer of *Melaleuca viridiflora* and *M.nervosa* may be observed. An understory of *Themeda triandra* and *Heteropogon contortus* will also be observed
Hydric soils	These soils accommodate a range of seasonally or permanently wet soils and thus there is some diversity within the order. The key criterion is saturation of the greater part of the profile for prolonged periods (at lest 2-3 months) in most years. The soils may or may not experience reducing conditions for all or part of the period of saturation, and thus manifestations of reduction and oxidation such as 'grey' colours and mottles may or may not be present. Saturation by a water table may not necessarily be caused by low soil permeability. Often site drainage will be the most important factor, while in other cases tidal influence is dominant. Quite often these soils are organic rich with a peaty/loam A horizon overlaying a C or R horizon. Vegetation developed on these soils is dominated by *Melaleuca/ Lophostemon* species. In tidal areas mangrove complexes dominate.

1.3.4 Vegetation Cover

Natural vegetation cover across the coastal alluvial plains of the semi-arid tropics is sparse, giving little protection to the extremely friable soils under normal conditions. Greater coverage is governed by proximity to accessible waters, either as surface flow, surface ponding, groundwater, or the ability of soils to hold water within their structure.

1.3.5 Riparian Development in the Townsville / Thuringowa Region

Riparian development in the Townsville / Thuringowa region is controlled by:

- Physical parameters (soils, geology, hydrogeomorphology).
- Climatic variables; and
- Location in the landscape

Proximity to water (either surface waters, groundwaters, or waters retained within the soil profile) is the single most dominant factor in the development of the riparian zone. While vegetation type and diversity is consequently also determined by the availability of a water source, the type, permanency, quantity, and quality of the water source will have a profound effect on species location. For example, water quality in the soil profile will alter significantly during the year with natural groundwater salinity varying by an order of magnitude between seasons.

In the semi-arid tropics where climatic conditions are extreme and rainfall is highly irregular, both in intensity and distribution (refer Section 1.2.1), the variety of water sources is possibly greater than in any other climatic region. Within a distance of less than 40km, access to water in the Townsville / Thuringowa region varies from saline in the lower estuaries to permanent freshwater in the upper catchments, with fresh and saline wetlands, permanent / semi-permanent lagoons, billabongs, and ephemeral wetlands in between.

Hence, in the Townsville / Thuringowa region riparian zones and associated habitats are spatially extensive and varied, consequently leading to relatively high ecosystem diversity. Further, the majority of the riparian zones have developed in concert with a specific suite of climatic and physical properties. Any interruption to these parameters can have significant impacts on the function of the riparian zones. This is of particular importance where the riparian zones act as buffers to ecologically sensitive waterways, or where those waterways drain into highly sensitive marine environments.

River basins of the Townsville / Thuringowa region drain into the Great Barrier Reef Marine Park, the Great Barrier Reef World Heritage Area, a State Marine Park, a State National Park, Dugong Protected areas, migratory bird habitats covered by RAMSAR, JAMBA, CAMBA and BONN Conventions, and declared Fish Habitat Areas. Any modification or alteration of riparian systems needs to accommodate the proximity of these highly valued areas to the catchments of the Townsville / Thuringowa region.

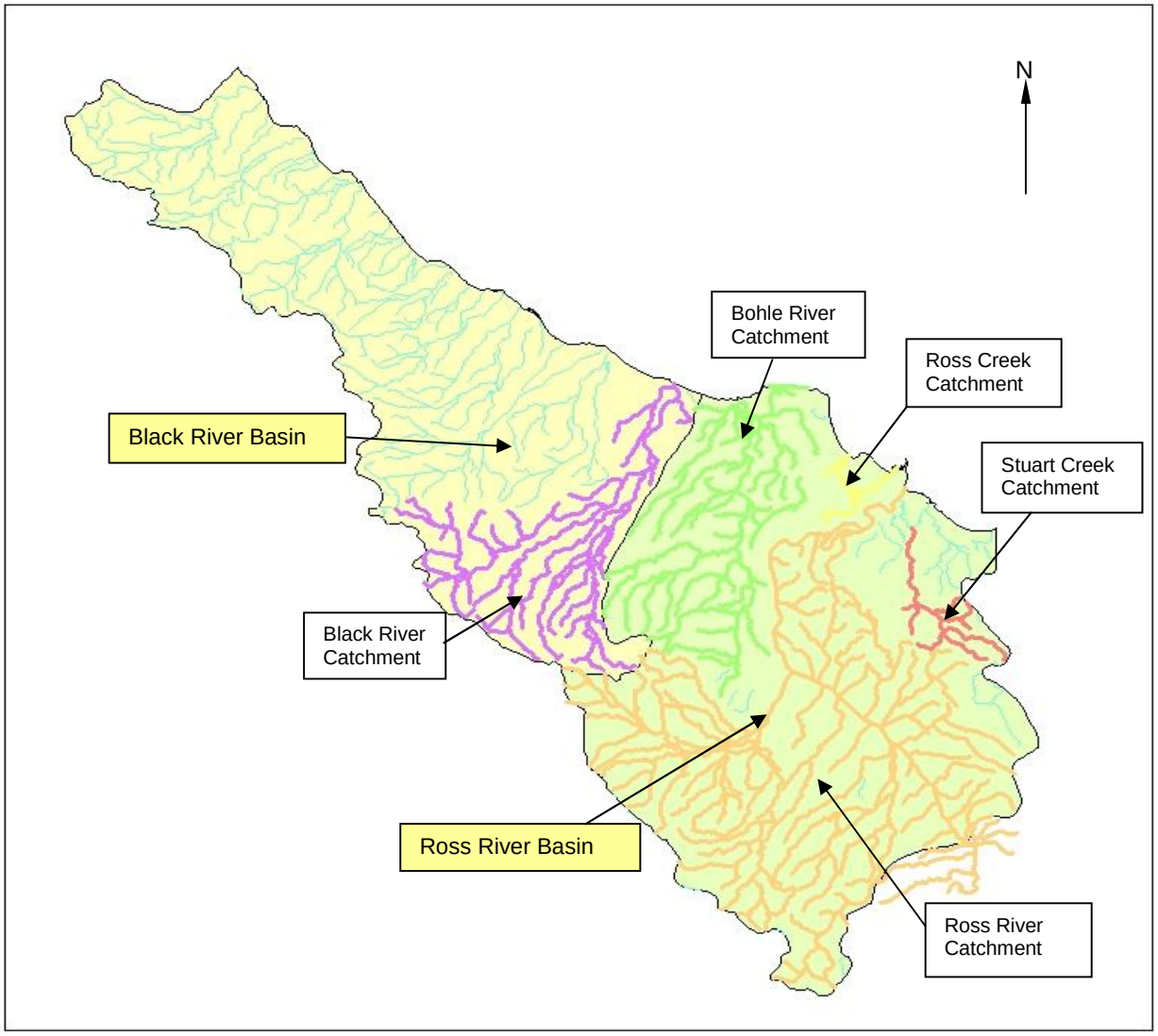
Additional management implications arise from the presence of rare, threatened and endangered flora and fauna covered by both the Environment Protection and Biodiversity Conservation Act 1999 (Commonwealth) and a variety of State Acts and Policies including the Nature Conservation Act (1992) and the Vegetation Management Act (1994).

1.4 STUDY AREA

The study area of the Ross and Black River Basins is shown in Figure 1. For ease of interpretation, the Ross and Black River basins are handled separately. Within this broader context, each basin is divided into catchments (e.g. the Ross River Basin includes the catchments of the Ross River, Ross Creek, Stuart Creek and Bohle River). Where appropriate, each catchment is subdivided into sections, predominantly according to topography (upper reaches), and/or geographic peculiarity (e.g. Lake Ross surrounds). The relevant basins, their catchments, and appropriate sections, are shown in Figure 1: *Study Area.* The full extent of non-remnant and cleared vegetation is also incorporated into the maps data base to assist data interpretation. A full list of the vegetation types that occur within the study area are given in **Appendix 1**

The following colour legends are used in all maps:

GREEN	Estuarine/ mangrove systems.
YELLOW	Sand dune wetlands and associated riparian zones.
ORANGE	Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on alluvial plains.
PINK	Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on granitic rock.
BLACK	Areas of non-remnant vegetation.
BLUE	The creek or river system under analysis.



Drainage of the Ross and Black River Basins showing focus and non-focus Catchments

Legend

- Stuart Creek
- Ross River
- Ross Creek
- Bohle River/ Town Common
- Black River
- Non focus study area drainage

STUDY AREA BASINS

- BLACK RIVER BASIN
- ROSS RIVER BASIN

Figure 1: Study Area: Drainage Basins, Catchments, and Relevant Catchment Sections of the Black and Ross River Basins

2 METHODOLOGY

Creeks and rivers within the study area have been evaluated using the minimal buffer width required by the current Vegetation Management Act (2004). However, the requirements of the Vegetation Management Act are, by necessity, generalised and predominantly based on climates considerably different to the tropical, seasonally arid, climate of the Townsville / Thuringowa region (refer Section 1.2 above).

In recognition of these differences (refer Section 1.2.1 *Climate*), the riparian zone has been extended to encompass a buffer zone recommended by Geosciences Australia. This includes vegetation communities that would not traditionally be considered riparian communities, but which exist in all major drainage areas of the study area and whose value is equally important for bank stability and buffering capacity.

The required widths of the riparian zone as defined by the Vegetation Management Act (2004) are:

1st and 2nd order streams	50m from each high bank
3rd and 4th order streams	100m from each high bank

Where the high bank can not be clearly identified, the centre line of the major drainage channel has been used in accordance with the recommendations in the Geosciences Australia topographic data suite. A larger buffer width has been used in these cases to overcome the inability to assess the high bank. Widths suggested by Geosciences Australia are:

1st and 2nd order streams	75m from each high bank
3rd and 4th order streams	150m from each high bank

Additionally, the full extent of riparian vegetation has also been displayed. Riparian areas outside the 150m buffer zones are also displayed to demonstrate the full extent of relevant riparian regional ecosystems.

3 RIPARIAN EVALUATION / RESULTS

3.1 BLACK RIVER BASIN AND ALLIGATOR CREEK

Twenty five catchments are included in the Black River Basin excluding the Black River. Where a dedicated name is not listed, or reliance on a common name is not useful, the waterway is referred to as 'Creek 1', etc.

The Alligator Creek Catchment is not part of the designated Black and Ross River Basins but is included in this study because of its proximity to Townsville and its impact on Cleveland Bay.

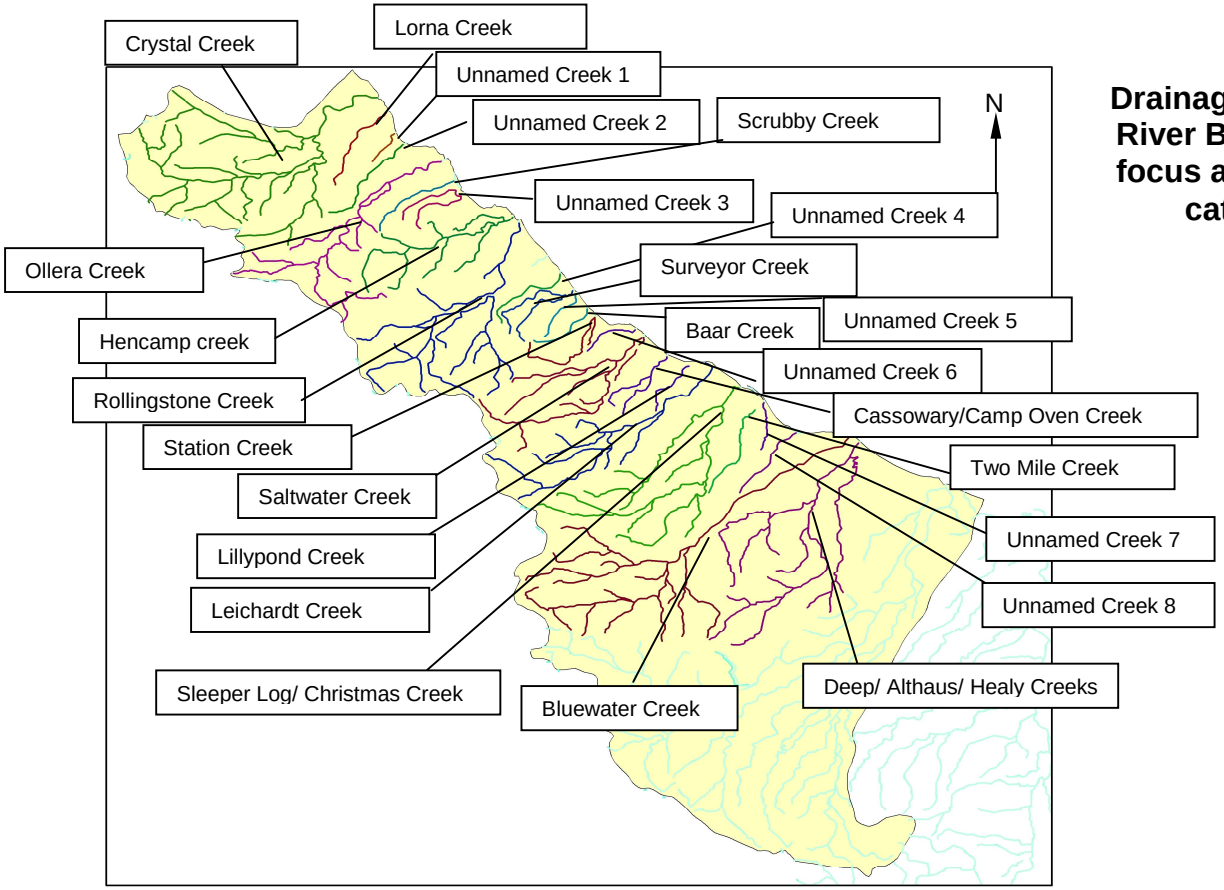
Black River Basin:

1. Crystal Creek
2. Lorna Creek
3. Creek 1 (name unknown)
4. Creek 2 (name unknown)
5. Ollera Creek
6. Scrubby Creek
7. Creek 3 (name unknown)
8. Hencamp Creek
9. Rollingstone Creek
10. Creek 4 (name unknown)
11. Surveyor Creek
12. Creek 5 (name unknown)
13. Baar Creek
14. Station Creek
15. Creek 6 (name unknown)
16. Saltwater Creek
17. Cassowary/campoven Creek
18. Lillypond Creek
19. Leichardt Creek
20. Sleeper Log / Christmas creek
21. Two Mile Creek
22. Creek 7(name unknown)
23. Creek 8(name unknown)
24. Bluewater Creek
25. Deep/Althaus/Healy Creek

Alligator Creek Catchment:
Alligator Creek

Each catchment will be reviewed individually. For ease of analysis, each catchment (excluding minor rivers and creeks) has been divided according to topography and other parameters. These sub-divisions and the appropriate catchments are shown on Figure 1: *Study Area, Ross and Black River basins,* and Figure 2: *Black River Basin.*

Figure 2: Black River Basin



Drainage of the Black River Basin showing focus and non-focus catchments

3.1.1 Crystal Creek Catchment

For convenience, the Crystal Creek Catchment is divided into two sections:

- Upper Reaches
- Lower Reaches

These divisions are shown in Figures 3 and 4.

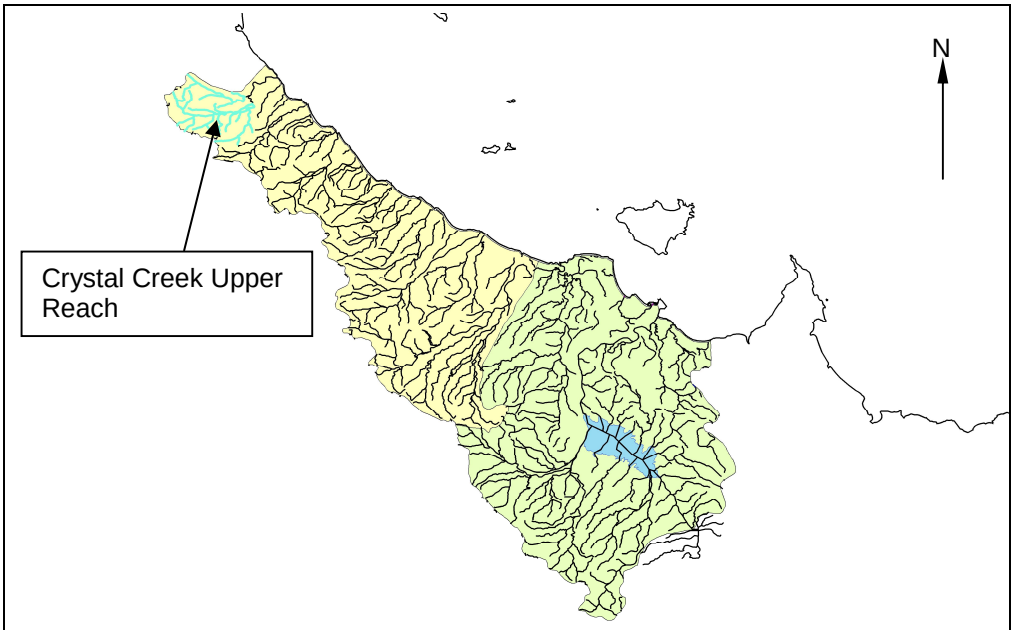


Figure 3: Crystal Creek Upper Reaches

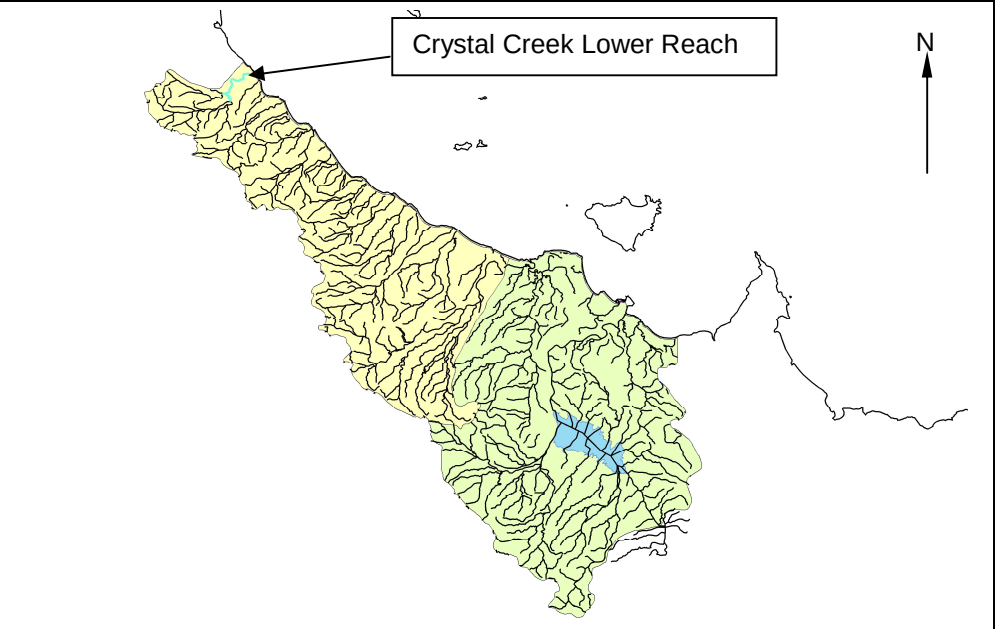
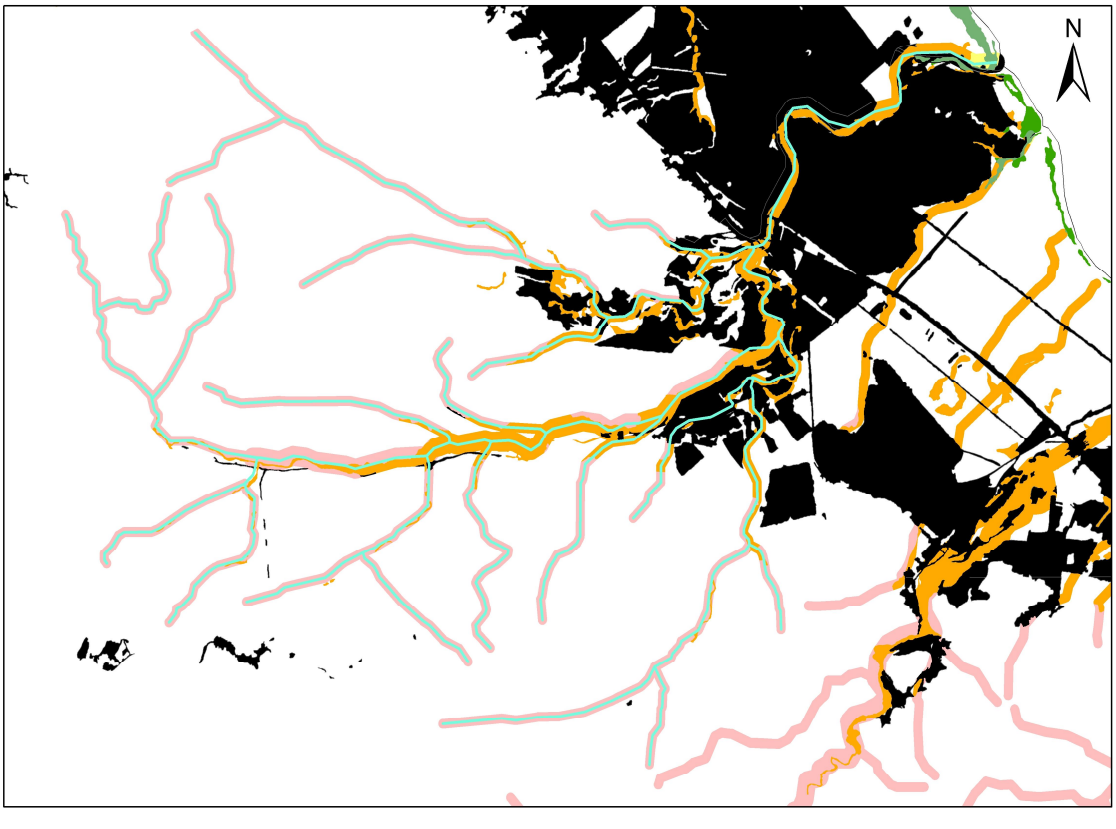


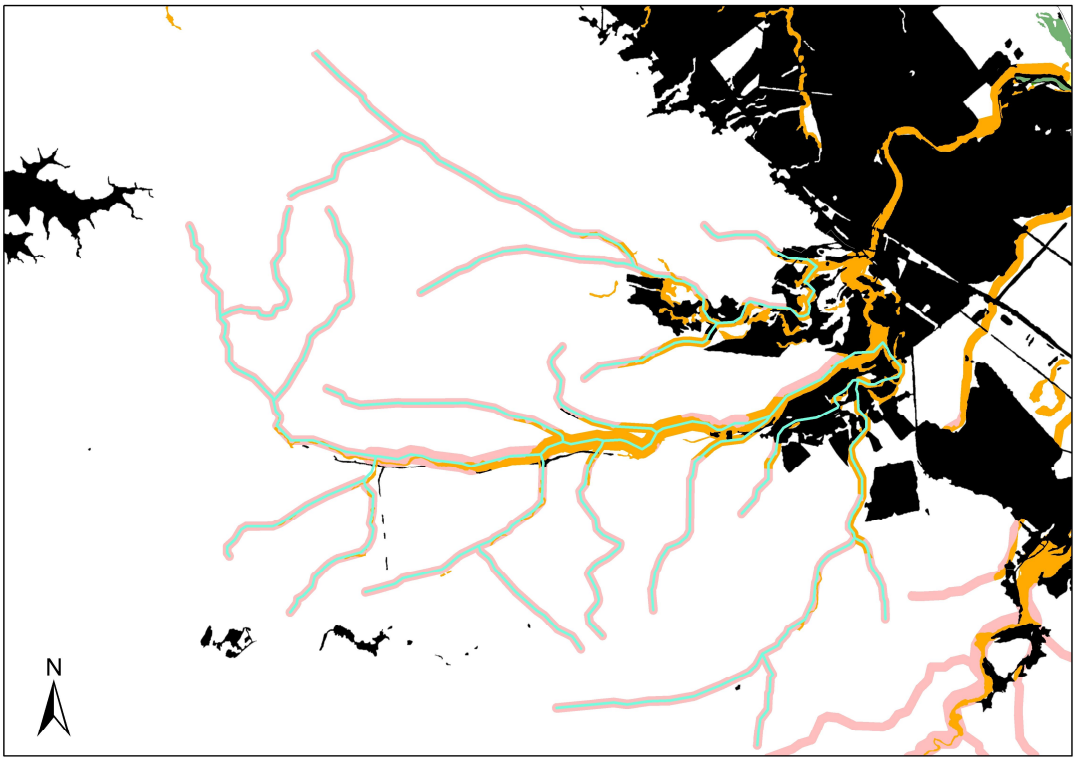
Figure 4: Crystal Creek Lower Reaches

Figure 5: Riparian Systems of the Total Crystal Creek Catchment.



GREEN	**Estuarine/ mangrove systems.**
YELLOW	**Sand dune wetlands and associated riparian zones.**
ORANGE	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on alluvial plains.**
PINK	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on granitic rock.**
BLACK	**Areas of non-remnant vegetation.**
BLUE	**The creek or river system under analysis.**

Figure 6: Riparian Systems of the Upper Reaches of the Crystal Creek Catchment.



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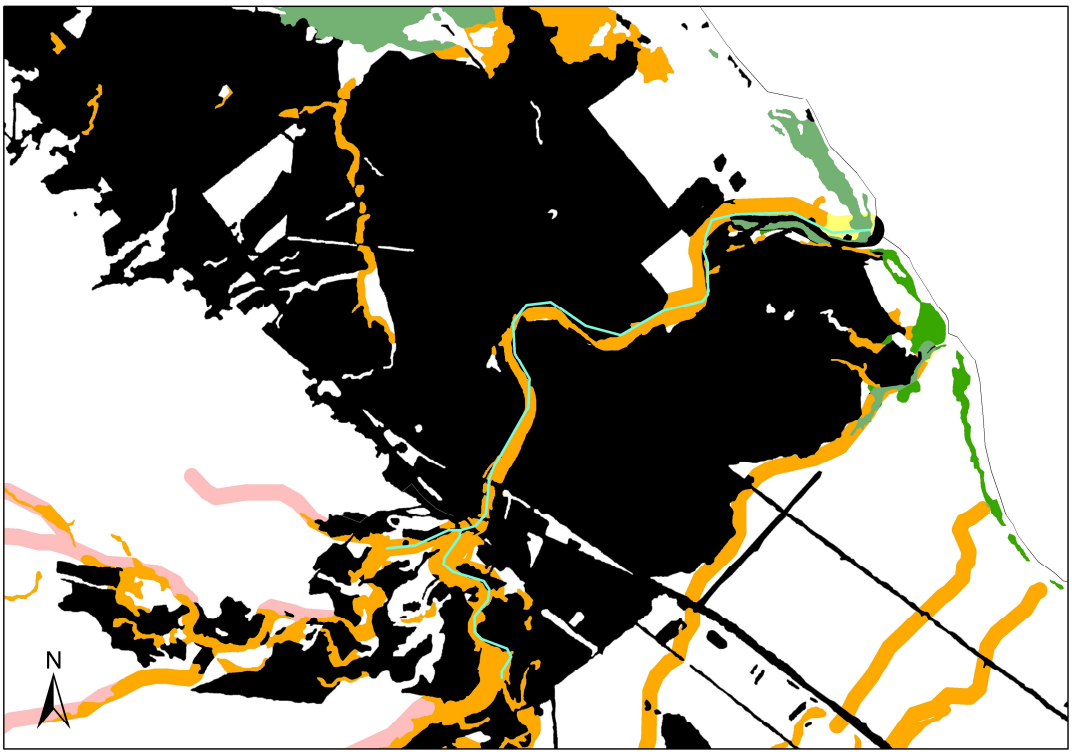
3.1.1.1 SECTION 1 – CRYSTAL CREEK, UPPER REACHES, RIPARIAN CONDITION

Thee upper reaches of Crystal Creek have a moderate to good riparian cover, primarily due to the rough terrain on relatively steep slopes and protection within the Mt Spec National Park.

Figure 7: Riparian Systems of the Lower Crystal Creek Catchment.



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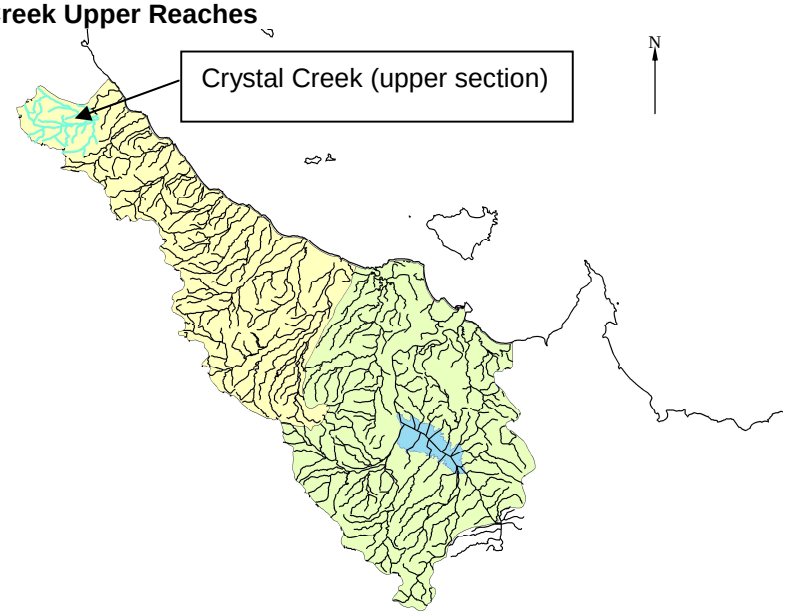
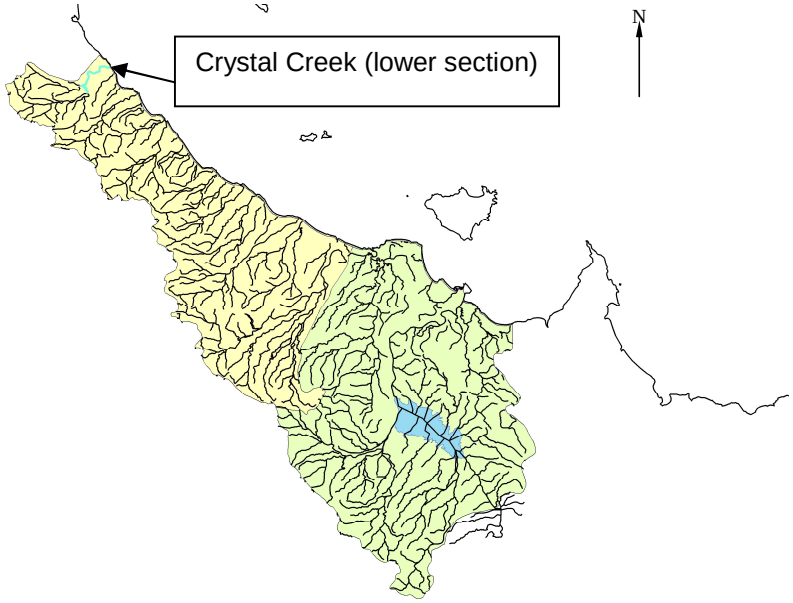
3.1.1.2 SECTION2 – CRYSTAL CREEK LOWER REACHES, RIPARIAN CONDITION

The lower reaches of Crystal Creek have a moderate riparian cover. These areas are currently used for agricultural purposes and historic clearing has caused significant incursion into the designated buffer width. This lack of riparian cover combined with the sodic/dispersive soils of the area may compromise water quality. Significant areas of non-remnant vegetation exist throughout the area on the lower reaches within the alluvial plains. The remnant habitat left is thought to be critical as it is the southern range of the essential habitat for the Mahogany Glider.

3.1.1.3 SUMMARY OF CONDITIONS WITHIN THE CRYSTAL CREEK CATCHMENT

Figure 8: Crystal Creek Catchment, Upper and Lower Sections

Crystal Creek Upper Reaches 	1st and 2nd order streams are generally in good condition. Threats to bank stability arise on alluvial sections, predominantly from a combination of: – Agricultural practices, and – Removal of remnant buffer zones.
Crystal Creek Lower Reaches 	Moderately modified remnant condition with significant clearing next to 3rd and 4th order streams. Major threats come from – Agricultural practices, – Removal of remnant buffer zones, and – The presence of sodic and erodible soils.

3.1.2 Lorna Creek

Lorna Creek has been assessed as one section.

Figure 9: Location of Lorna Creek

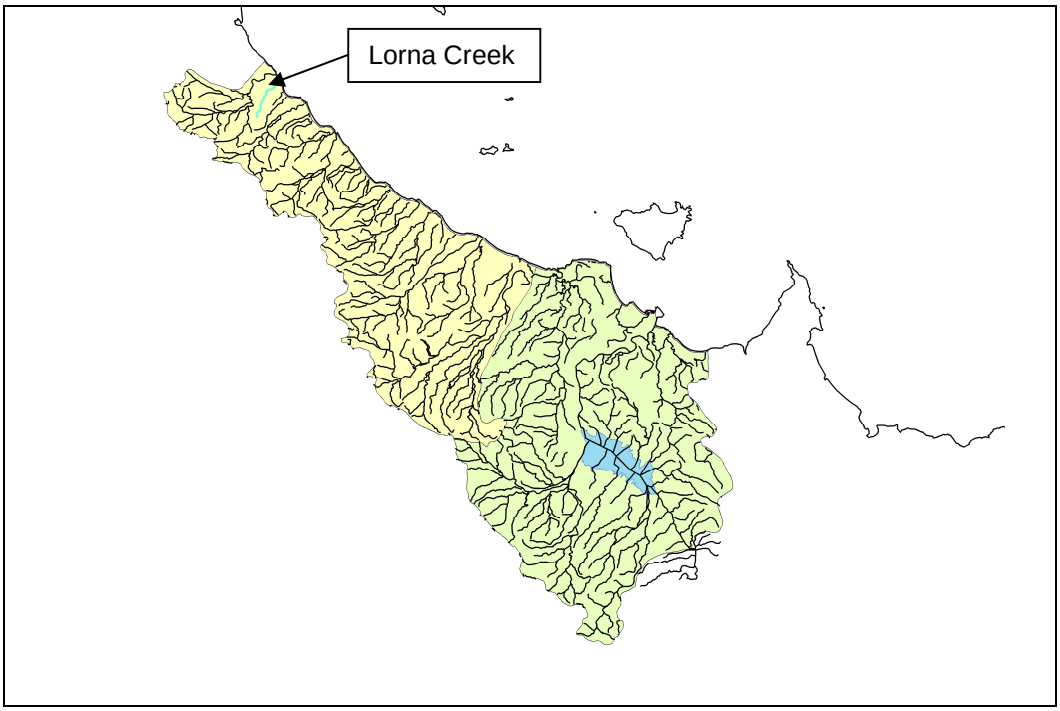
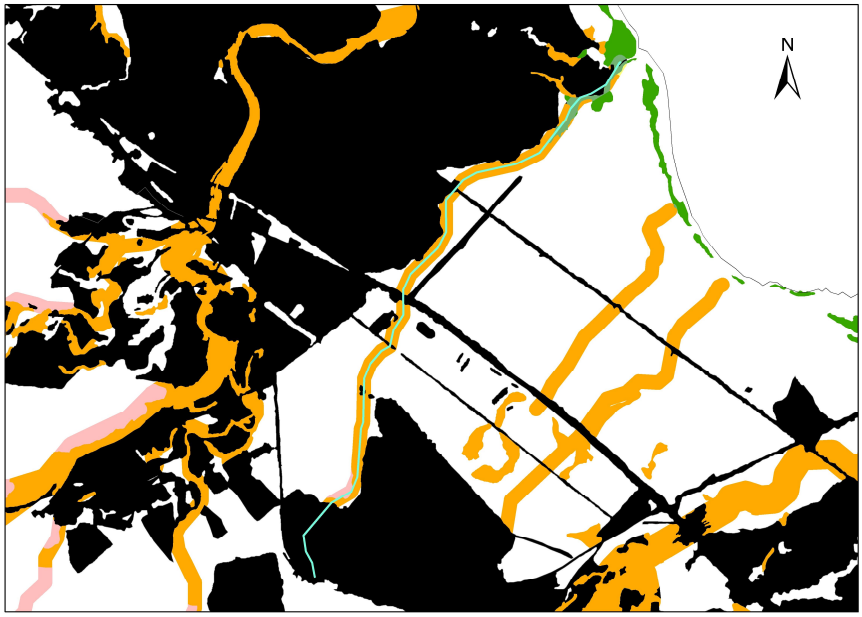


Figure 10: The Riparian Systems of Lorna Creek



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BLACK	**Areas of non-remnant vegetation.**
BLUE	**The creek or river system under analysis.**

3.1.2.1 LORNA CREEK RIPARIAN CONDITION

The riparian condition of Lorna Creek is in moderate to good condition. The upper section on granite has been cleared for agricultural purposes, as have areas within the designated buffer of the northern bank. 4WD tracks and motor bike tracks within the area may compromise bank stability in lower sections east of the Bruce Highway. There is minimal clearing into the designated riparian buffer zone.

3.1.3 Creek 1 (Name Unknown)

Figure 11: Location of Creek 1

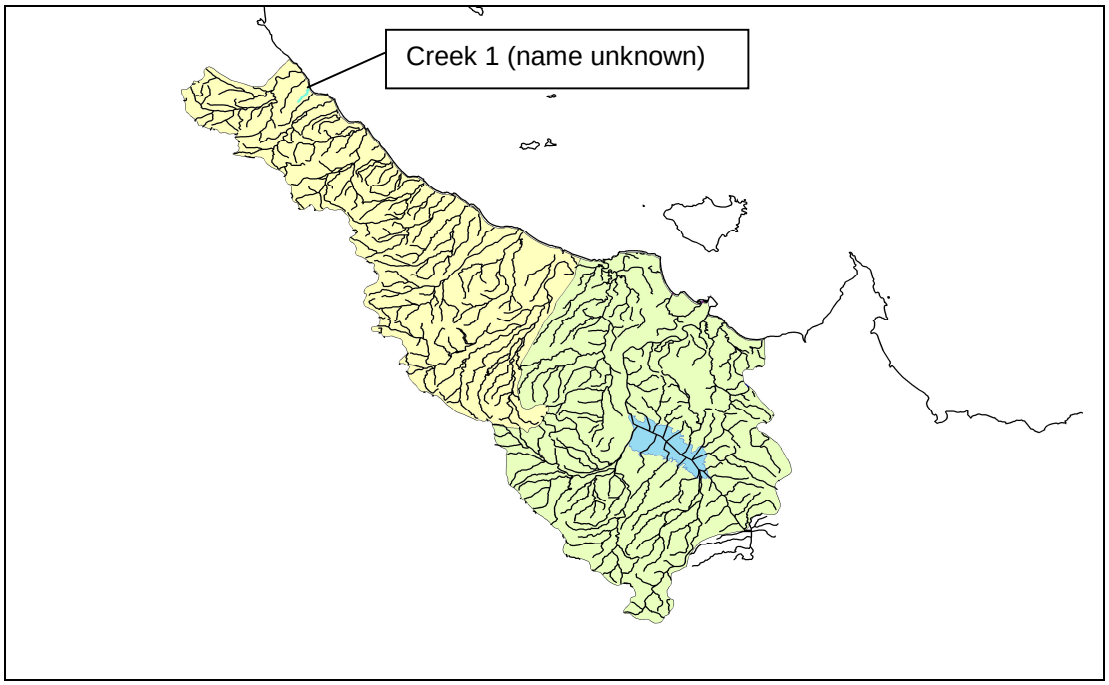
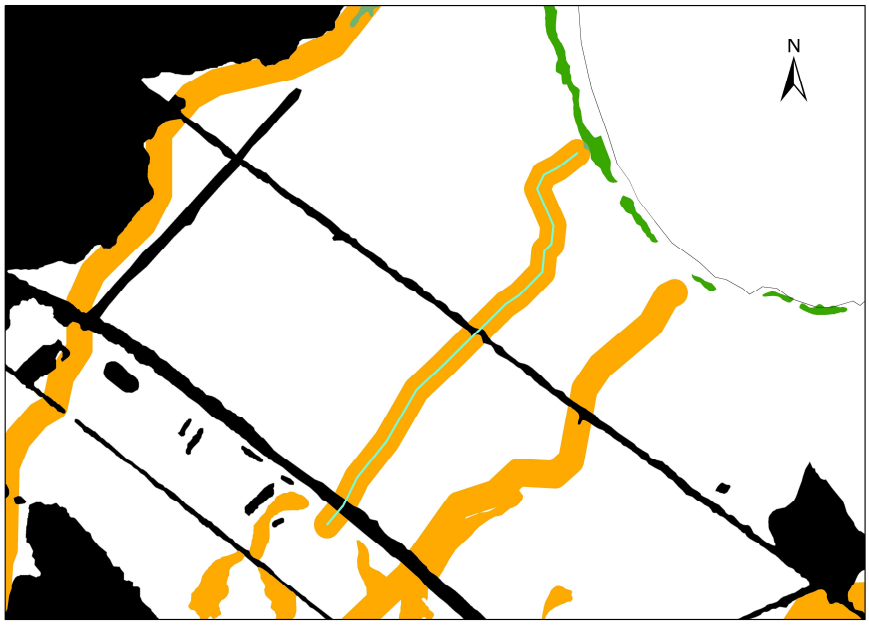


Figure 12: Riparian Systems of Creek 1



GREEN	**Estuarine/ mangrove systems.**
YELLOW	**Sand dune wetlands and associated riparian zones.**
ORANGE	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on alluvial plains.**
PINK	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on granitic rock.**
BLACK	**Areas of non-remnant vegetation.**
BLUE	**The creek or river system under analysis.**

3.1.3.1 CREEK 1 RIPARIAN CONDITION

The riparian condition of Creek 2 is good. Minimal clearing has occurred within this area with vegetation only cleared for the construction of major transport corridors (Bruce Highway and Queensland Rail).

3.1.4 Creek 2 (Name Unknown)

Figure 13: Location of Creek 2

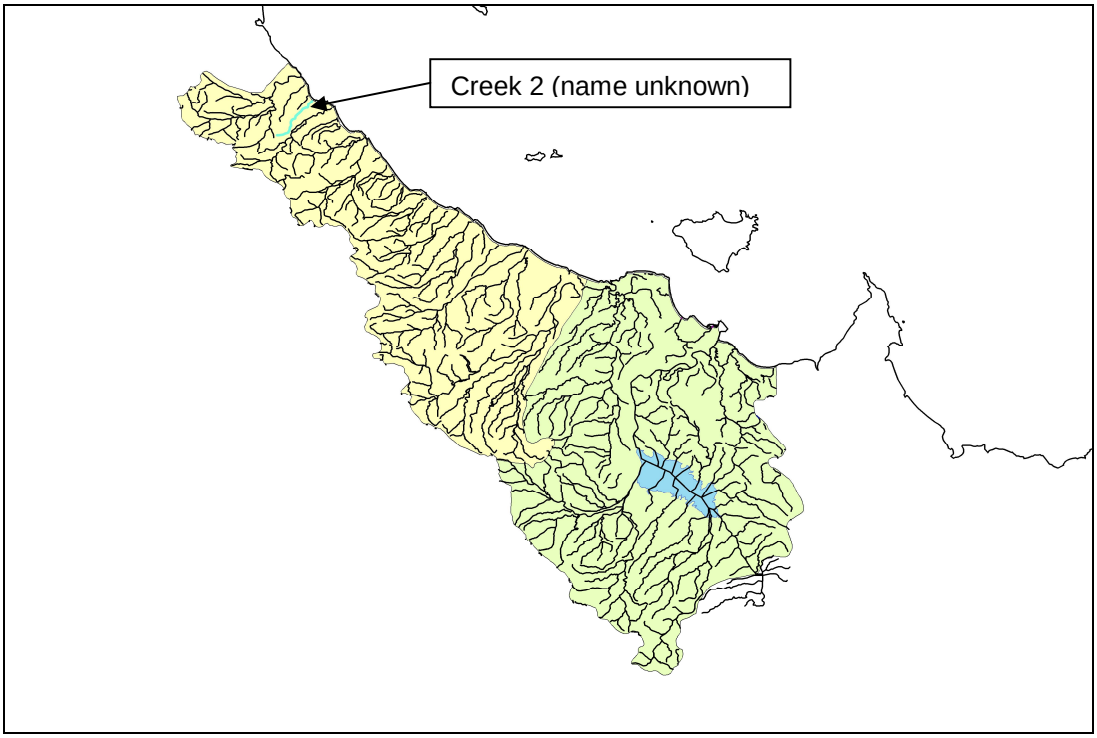
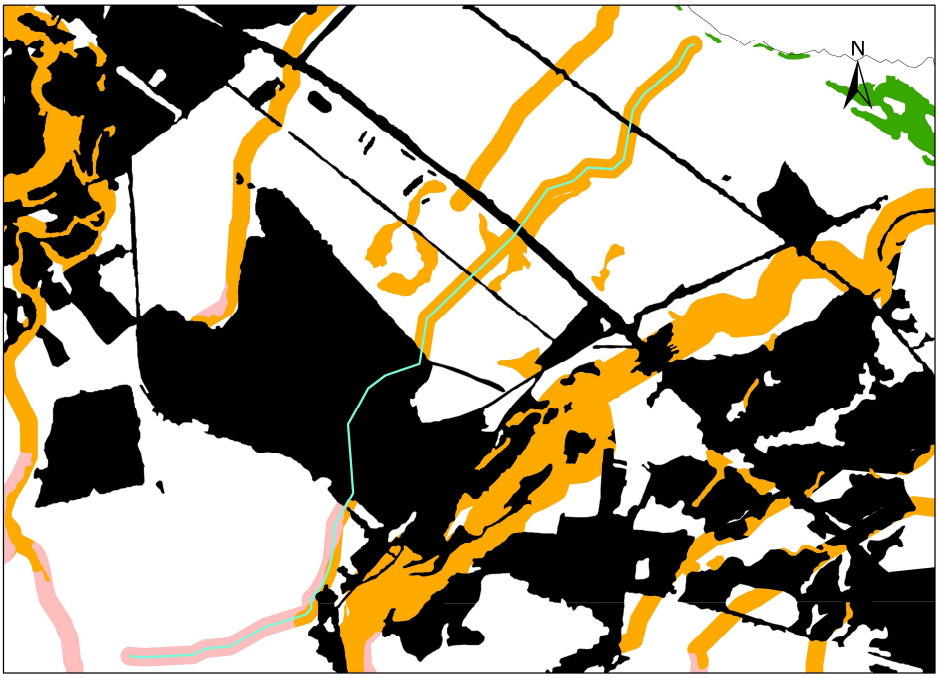


Figure 14: Riparian Systems of Creek 2



3.1.4.1 CREEK 2, RIPARIAN CONDITION

The riparian condition of Creek 2 is in moderate condition. The upper sections on granitic slopes are in good condition with minimal incursion into the designated buffer zone. At the base of the scarp the area has been cleared of all riparian vegetation for agricultural purposes. There is no incursion into the riparian zone from this point to the coast. Adjacent land users within this area have minimal clearing apart from the Railway and road corridors.

3.1.5 Ollera Creek

Figure 15: Location of Ollera Creek

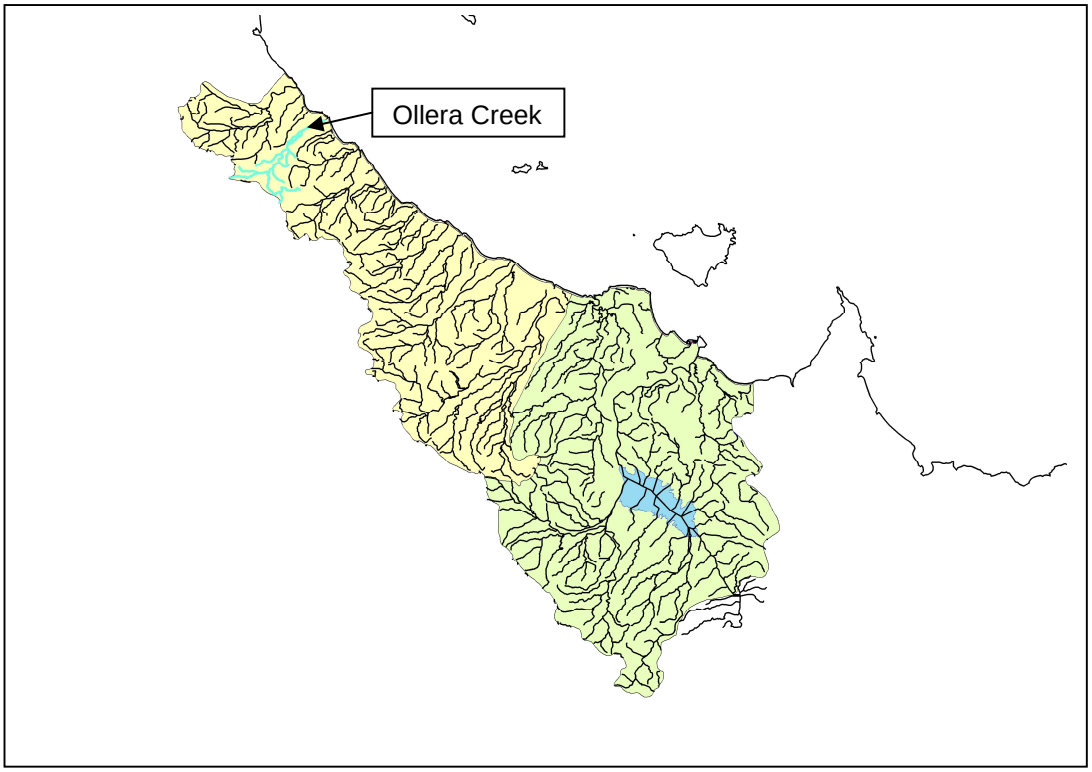


Figure 16: Riparian Systems of Ollera Creek

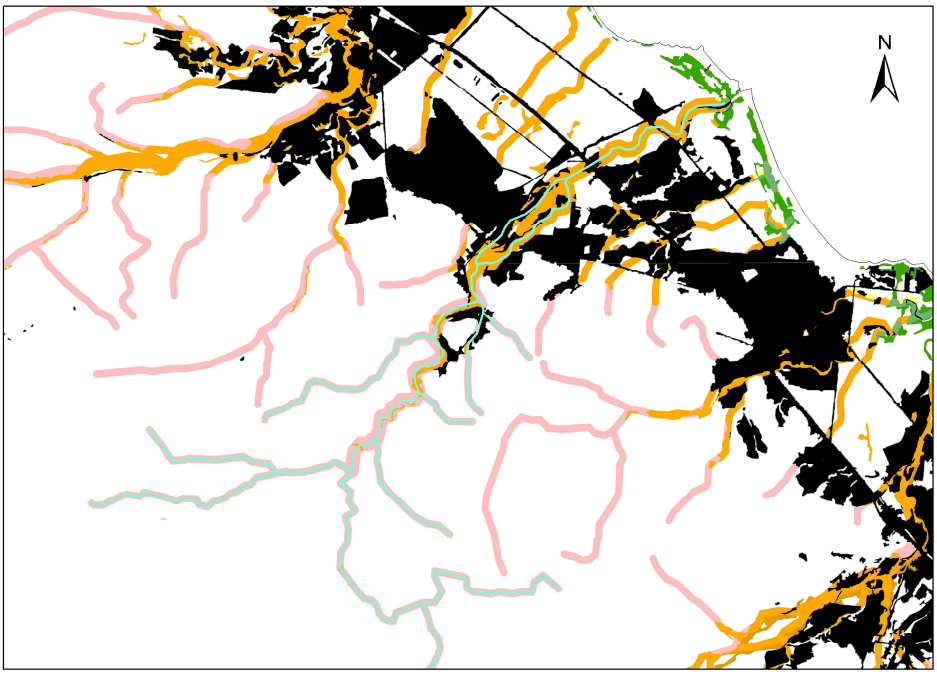
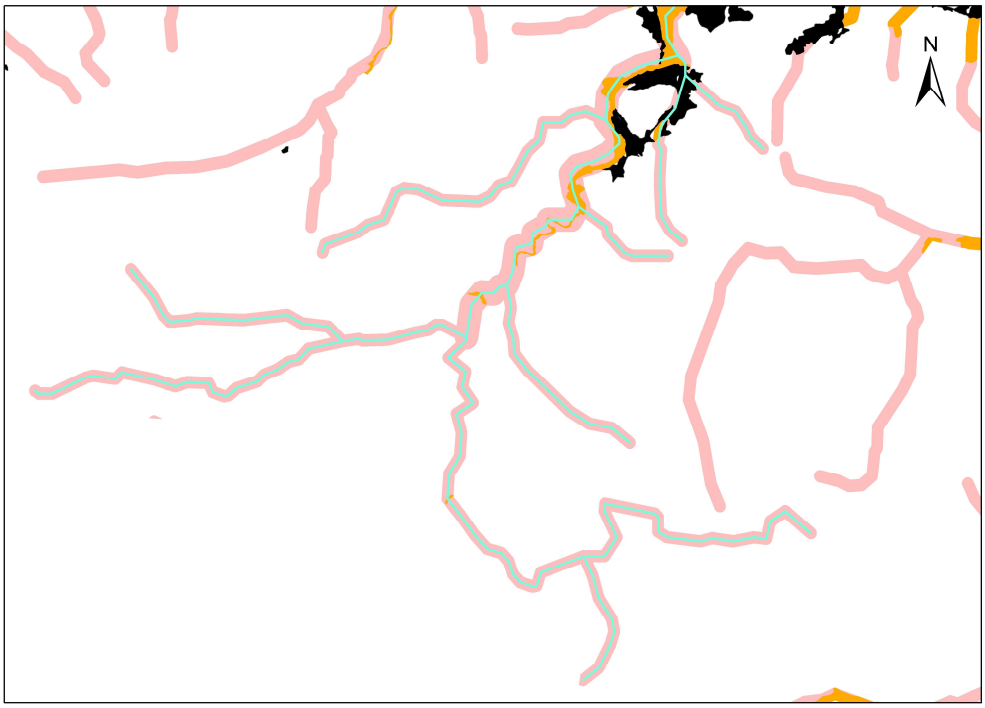


Figure 17: Riparian Systems of Ollera Creek Upper Reaches

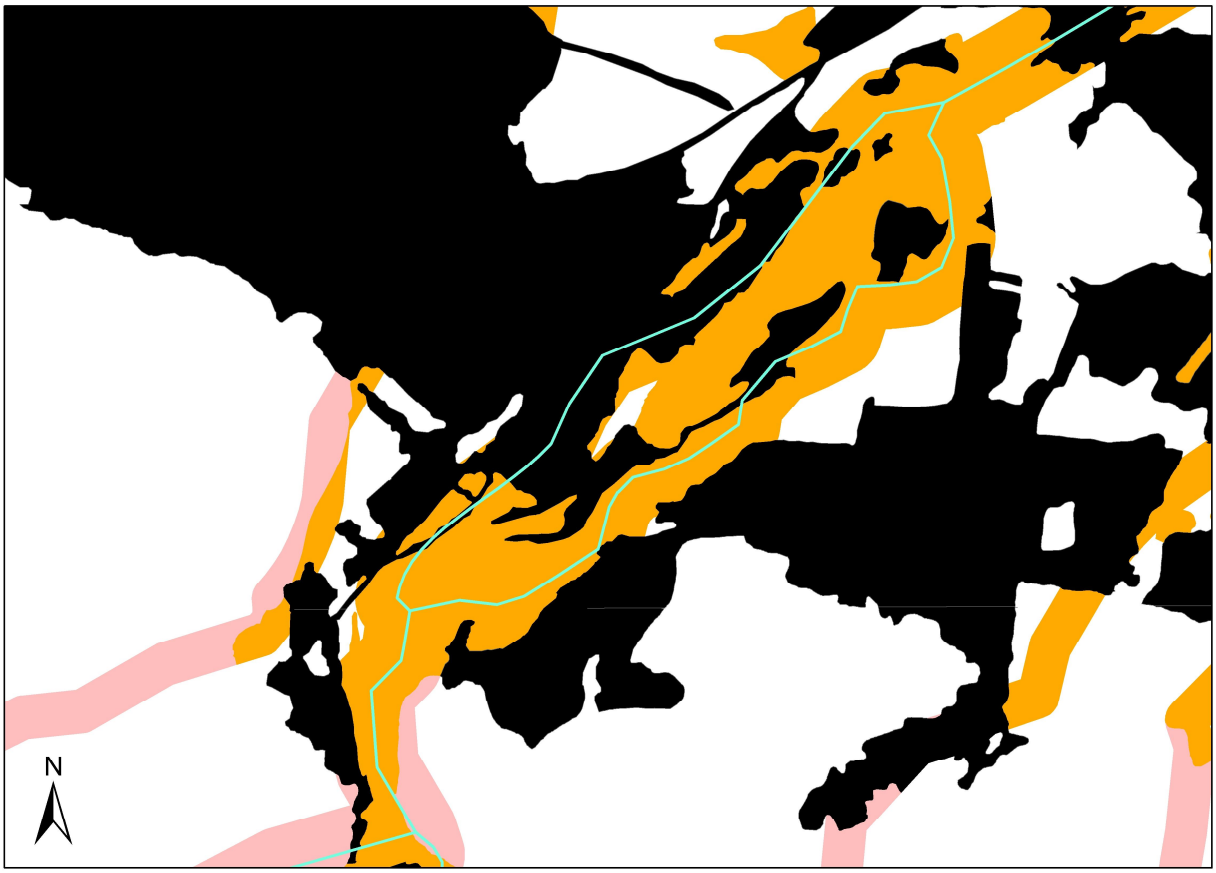


GREEN	**Estuarine/ mangrove systems.**
YELLOW	**Sand dune wetlands and associated riparian zones.**
ORANGE	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on alluvial plains.**
PINK	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on granitic rock.**
BLACK	**Areas of non-remnant vegetation.**
BLUE	**The creek or river system under analysis.**

3.1.5.1 OLLERA CREEK UPPER REACHES, RIPARIAN CONDITION

Thee upper reaches of Ollera Creek have good riparian cover, primarily due to the rough terrain on relatively steep granitic slopes and protection within the Mt Spec National Park. There is little to no clearing into the designated buffer width. With minimal clearing to the high bank on 1st and 2nd order streams

Figure 18: Riparian Systems of Ollera Creek Mid Reaches

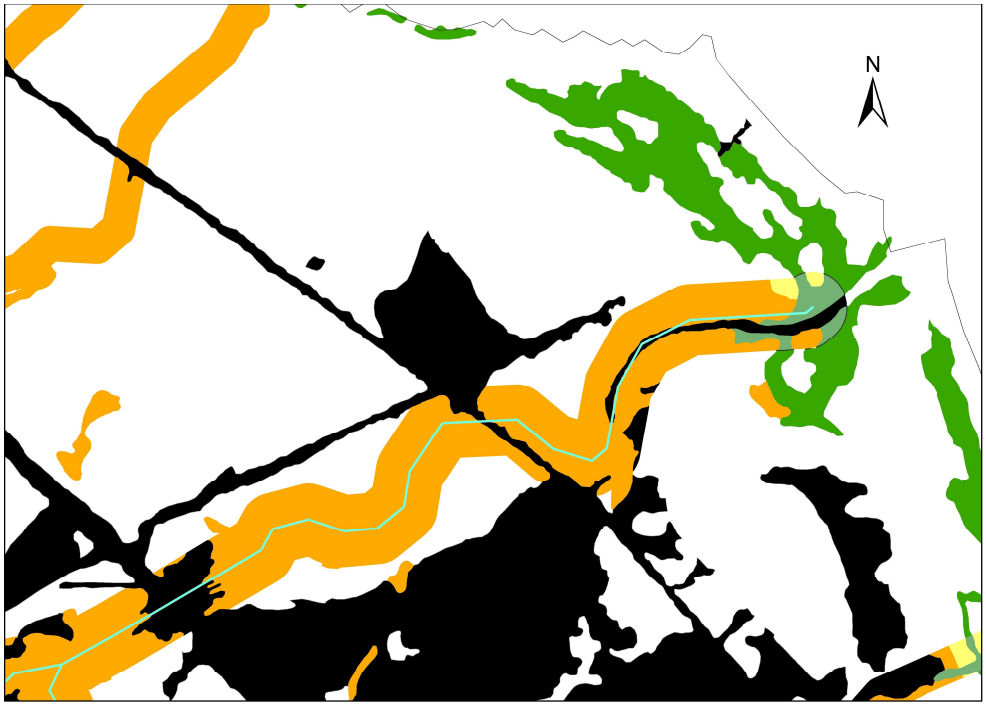


GREEN	**Estuarine/ mangrove systems.**
YELLOW	**Sand dune wetlands and associated riparian zones.**
ORANGE	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on alluvial plains.**
PINK	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on granitic rock.**
BLACK	**Areas of non-remnant vegetation.**
BLUE	**The creek or river system under analysis.**

3.1.5.2 OLLERA CREEK, MID REACHES, RIPARIAN CONDITION

The middle reaches of Ollera Creek are in moderate condition. The path of the creek path within this section is anastomosing with a significant break the creek again rejoins. The southern channel has a moderate to good riparian condition with minimal incursion into the designated buffer zone. The northern channel is in relatively poor condition with minimal riparian vegetation bordering on the high bank Adjacent landuses to this northern bank are predominantly agricultural uses which could compromise water quality via overland flows.

Figure 19: Riparian Systems of Ollera Creek Lower Reaches



GREEN	**Estuarine/ mangrove systems.**
YELLOW	**Sand dune wetlands and associated riparian zones.**
ORANGE	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on alluvial plains.**
PINK	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on granitic rock.**
BLACK	**Areas of non-remnant vegetation.**
BLUE	**The creek or river system under analysis.**

3.1.5.3 SECTION2 - OLLERA CREEK LOWER REACHES, RIPARIAN CONDITION

The lower reaches of Ollera Creek are in good condition. With minimal disturbance within the designated buffer zone. Zones of disturbance include areas around the railway and highway corridors. Scrubby Creek

Figure 20: Location of Scrubby Creek

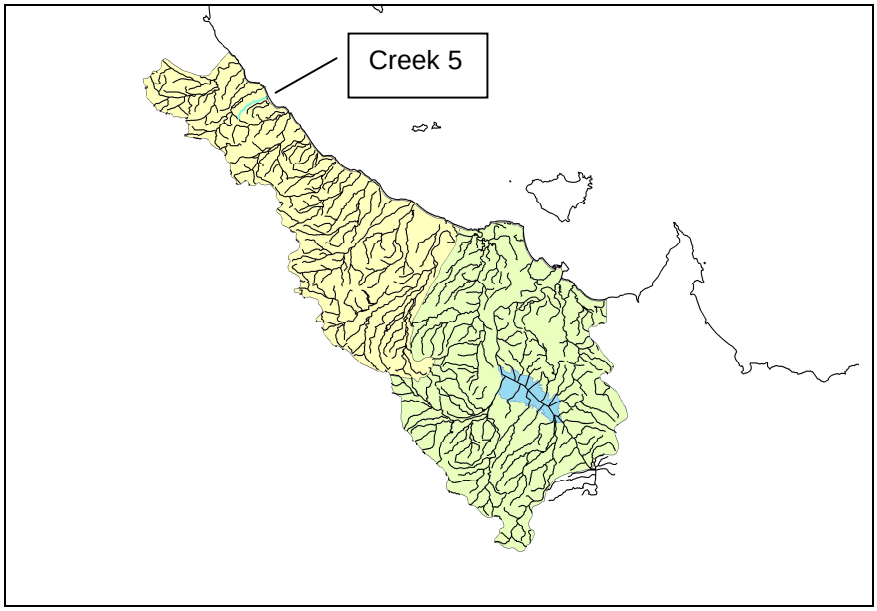
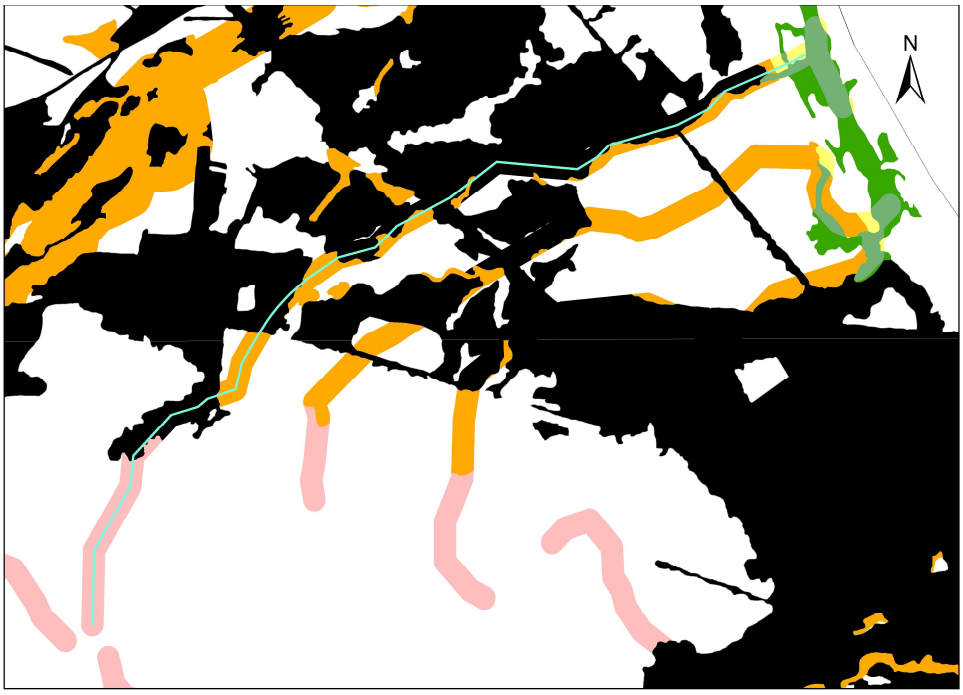


Figure 21: Riparian Systems of Scrubby Creek



GREEN	**Estuarine/ mangrove systems.**
YELLOW	**Sand dune wetlands and associated riparian zones.**
ORANGE	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on alluvial plains.**
PINK	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on granitic rock.**
BLACK	**Areas of non-remnant vegetation.**
BLUE	**The creek or river system under analysis.**

3.1.5.4 SCRUBBY CREEK, RIPARIAN CONDITION

The riparian condition of Scrubby Creek is moderate to poor. Little to no native vegetation exists within the designated buffer width of the creek. This area in the past has been extensively cleared and replaced by invasive weed species. These have some redeeming features in that they add some value to hold the dispersive and erosive soils together. However, this value is thought to be minimal

3.1.6 Unnamed Creek 3

Figure 22: Location of Unnamed Creek 3

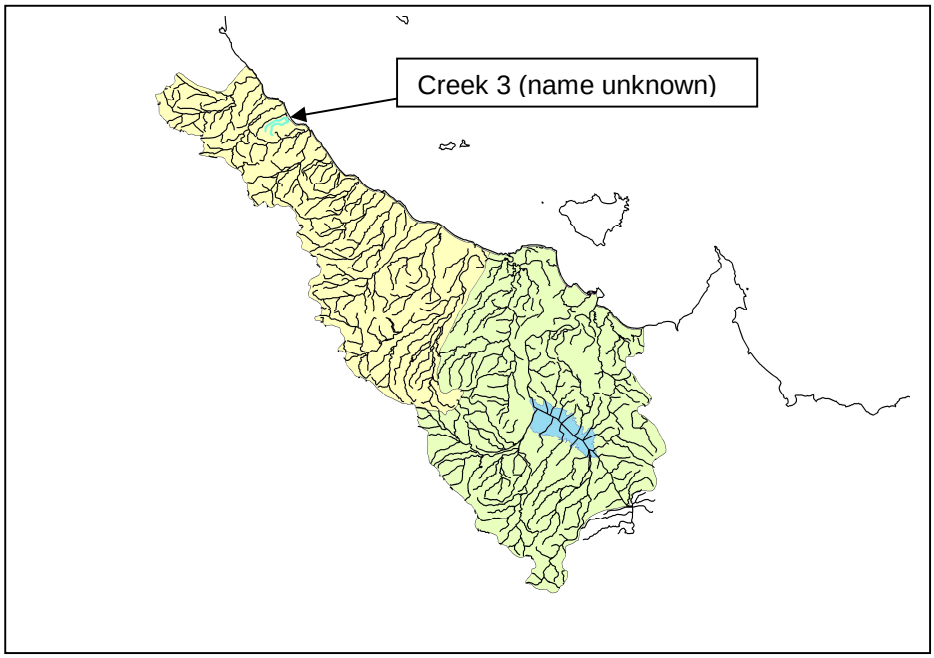
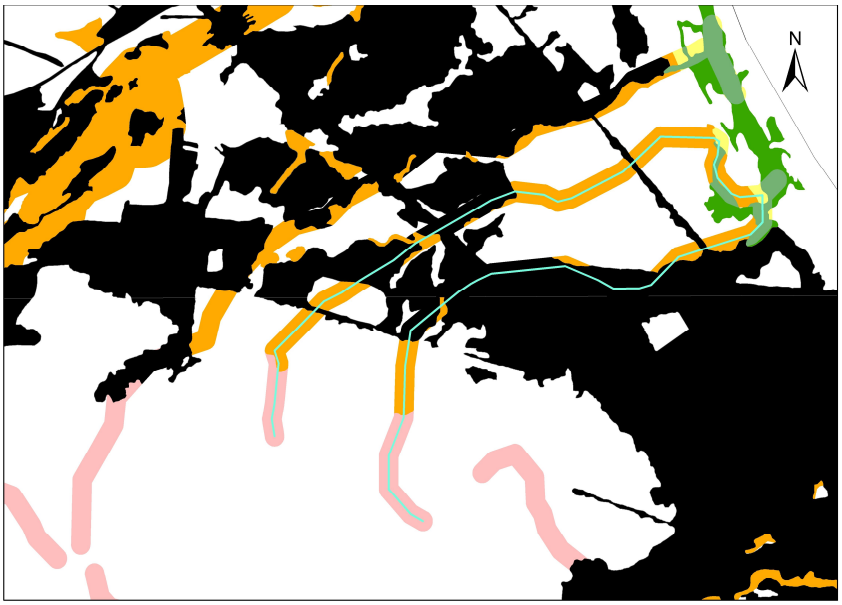


Figure 23: Riparian Systems of Creek 3



GREEN	**Estuarine/ mangrove systems.**
YELLOW	**Sand dune wetlands and associated riparian zones.**
ORANGE	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on alluvial plains.**
PINK	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on granitic rock.**
BLACK	**Areas of non-remnant vegetation.**
BLUE	**The creek or river system under analysis.**

3.1.6.1 *UNNAMED CREEK 3, RIPARIAN CONDITION*

The riparian condition of Creek 3 is moderate to poor. Condition of the two major channels is varied, ranging from full coverage within the designated buffer zone to no riparian coverage at the high bank. This area has been extensively cleared and the vegetation replaced by invasive weed species. These have some redeeming features in that they add some value by holding the dispersive and erosive soils together. However, this value is considered minimal.

3.1.7 Hencamp Creek

Figure 24: Location of Hencamp Creek

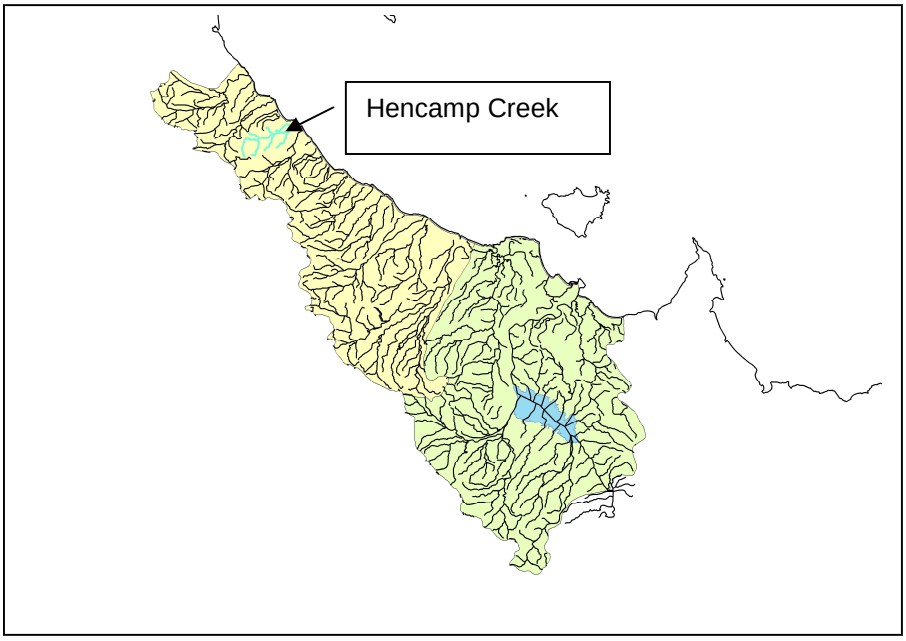
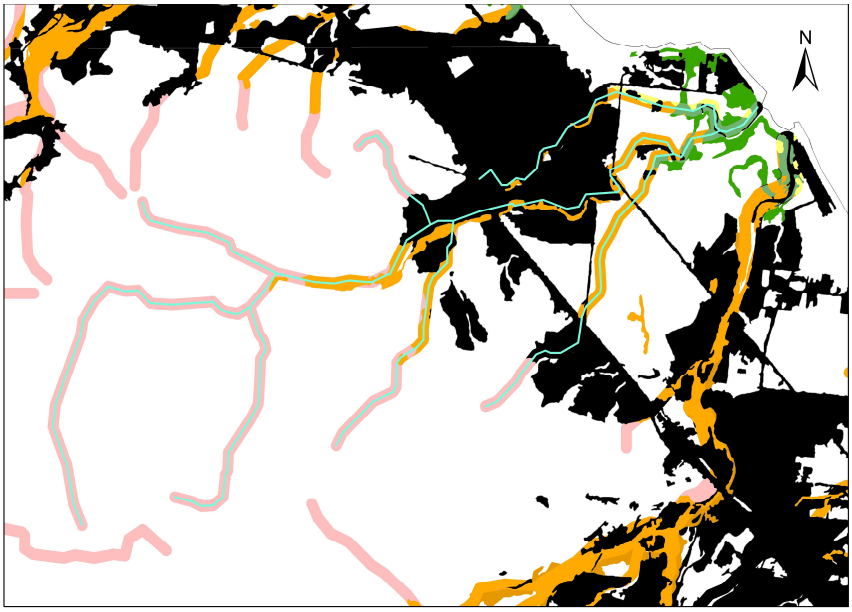
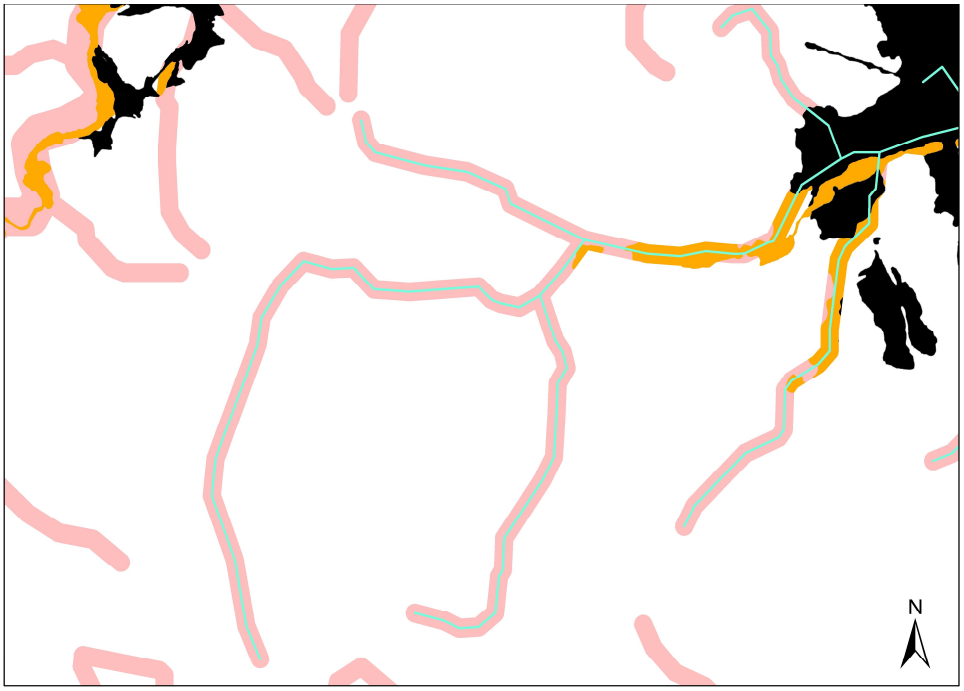


Figure 25: Riparian Systems of Hencamp Creek



GREEN	**Estuarine/ mangrove systems.**
YELLOW	**Sand dune wetlands and associated riparian zones.**
ORANGE	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on alluvial plains.**
PINK	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on granitic rock.**
BLACK	**Areas of non-remnant vegetation.**
BLUE	**The creek or river system under analysis.**

Figure 26: Riparian Systems of Hencamp Creek, Upper Reaches



GREEN	**Estuarine/ mangrove systems.**
YELLOW	**Sand dune wetlands and associated riparian zones.**
ORANGE	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on alluvial plains.**
PINK	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on granitic rock.**
BLACK	**Areas of non-remnant vegetation.**
BLUE	**The creek or river system under analysis.**

3.1.7.1 HENCAMP CREEK UPPER REACHES, RIPARIAN CONDITION

Thee upper reaches of Hencamp Creek have moderate to good riparian cover, primarily due to the rough terrain on relatively steep granitic slopes. There is little to no clearing into the designated buffer zone. There is minimal clearing to the high bank on 1st and 2nd order streams. However, these zones are located at the base of the scarp adjacent to agricultural land uses the lack of riparian vegetation within these zones could facilitate overland flows and compromise water quality.

Figure 27: Riparian Systems of Hencamp Creek, Lower Reaches

GREEN	**Estuarine/ mangrove systems.**
YELLOW	**Sand dune wetlands and associated riparian zones.**
ORANGE	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on alluvial plains.**
PINK	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on granitic rock.**
BLACK	**Areas of non-remnant vegetation.**
BLUE	**The creek or river system under analysis.**

3.1.7.2 HENCAMP CREEK LOWER REACHES, RIPARIAN CONDITION

The riparian condition of the lower reaches of Hencamp Creek is poor to moderate. Where riparian vegetation is absent it is cleared to the high bank with an adjacent land uses being agricultural. Where riparian zones are present they are generally in good condition with little to no incursion into the designated buffer. Areas with adjacent agricultural lands may have bank stability issues resulting in compromises in water quality.

3.1.8 Rollingstone Creek

Figure 28: Location of Rollingstone Creek

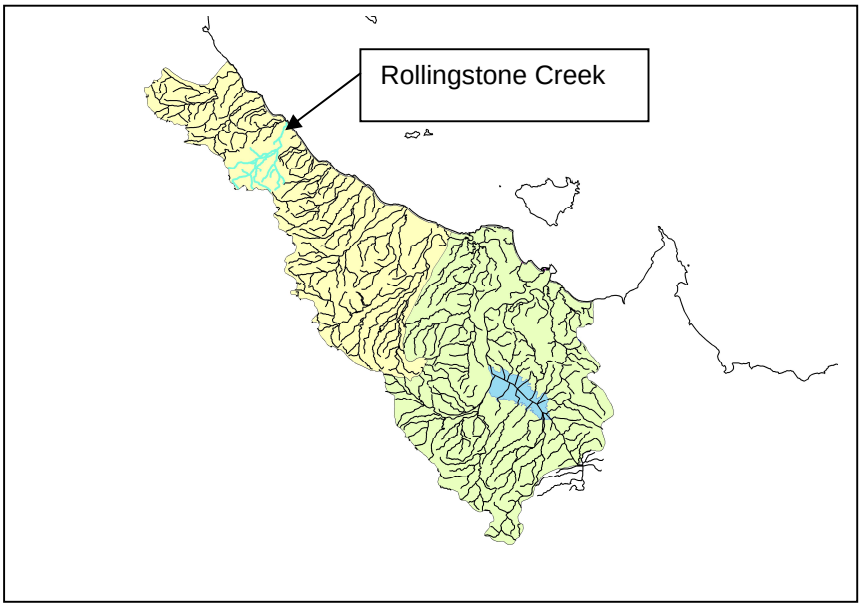
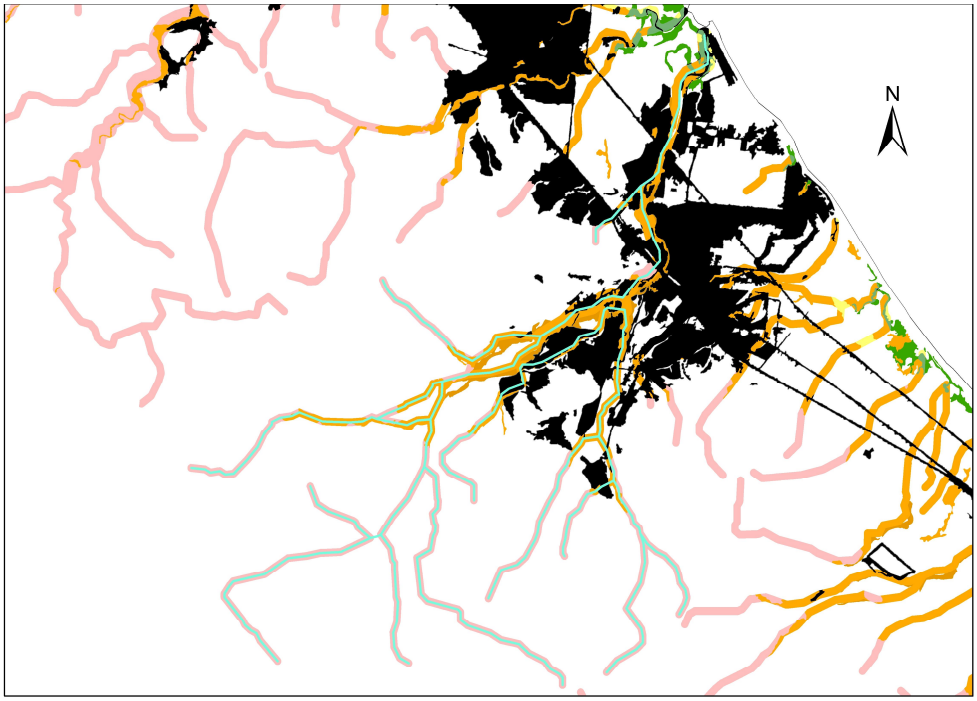
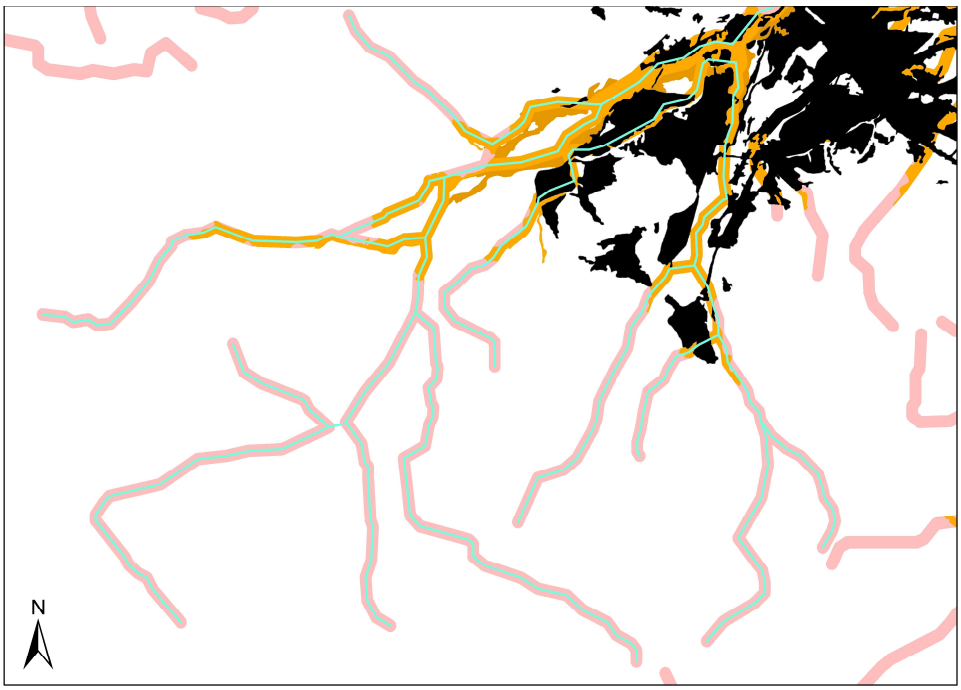


Figure 29: Riparian Systems of Rollingstone Creek, Total Catchment



GREEN	**Estuarine/ mangrove systems.**
YELLOW	**Sand dune wetlands and associated riparian zones.**
ORANGE	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on alluvial plains.**
PINK	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on granitic rock.**
BLACK	**Areas of non-remnant vegetation.**
BLUE	**The creek or river system under analysis.**

Figure 30: Riparian Systems of Rollingstone Creek, Upper Reaches

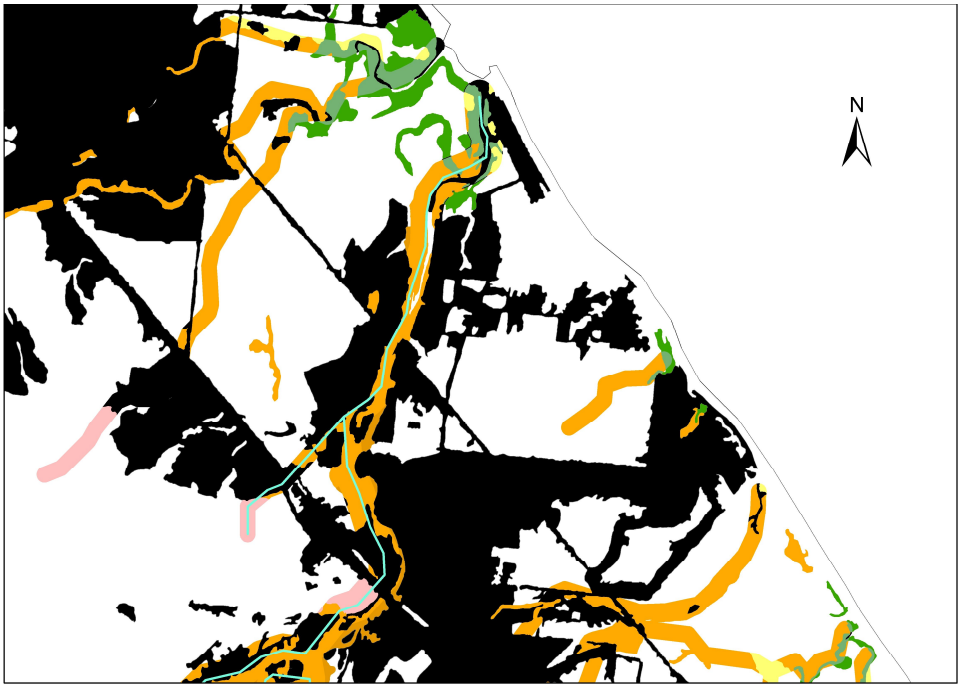


GREEN	**Estuarine/ mangrove systems.**
YELLOW	**Sand dune wetlands and associated riparian zones.**
ORANGE	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on alluvial plains.**
PINK	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on granitic rock.**
BLACK	**Areas of non-remnant vegetation.**
BLUE	**The creek or river system under analysis.**

3.1.8.1 ROLLINGSTONE CREEK UPPER REACHES, RIPARIAN CONDITION

The riparian zone of the upper reaches of Rollingstone Creek is in moderate-good condition. The upper granitic slopes are in pristine condition with little to know incursion into the designated buffer zone. The alluvial flats are in relatively good condition. However, there is some incursion into the designated buffer zone, where the area has been cleared predominantly for agricultural purposes, but with some smaller areas cleared for grazing and hobby farms. These areas, although small, may facilitate overland flows and compromise water quality

Figure 31: Riparian Systems of Rollingstone Creek, Lower Reaches



GREEN	**Estuarine/ mangrove systems.**
YELLOW	**Sand dune wetlands and associated riparian zones.**
ORANGE	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on alluvial plains.**
PINK	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on granitic rock.**
BLACK	**Areas of non-remnant vegetation.**
BLUE	**The creek or river system under analysis.**

3.1.8.2 ROLLINGSTONE CREEK LOWER REACHES, RIPARIAN CONDITION

The riparian condition of the lower reaches of Rollingstone Creek is moderate, with minimal incursion into the designated buffer width adjacent to 3rd and 4th order streams. Clearing has occurred on the high bank. Adjacent land use within this area is historically and currently agricultural with some areas showing moderate to severe signs of degradation. Sediment laden overland flow into drainage pathways within these areas is possible.

3.1.9 Creek 4 (Name Unknown)

Figure 32: Location of Creek 4

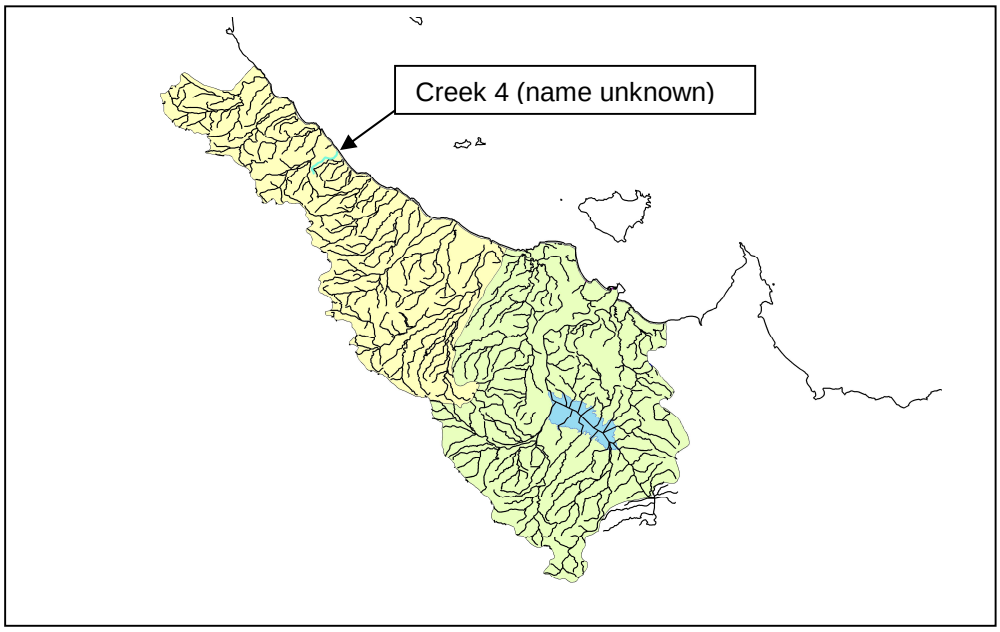
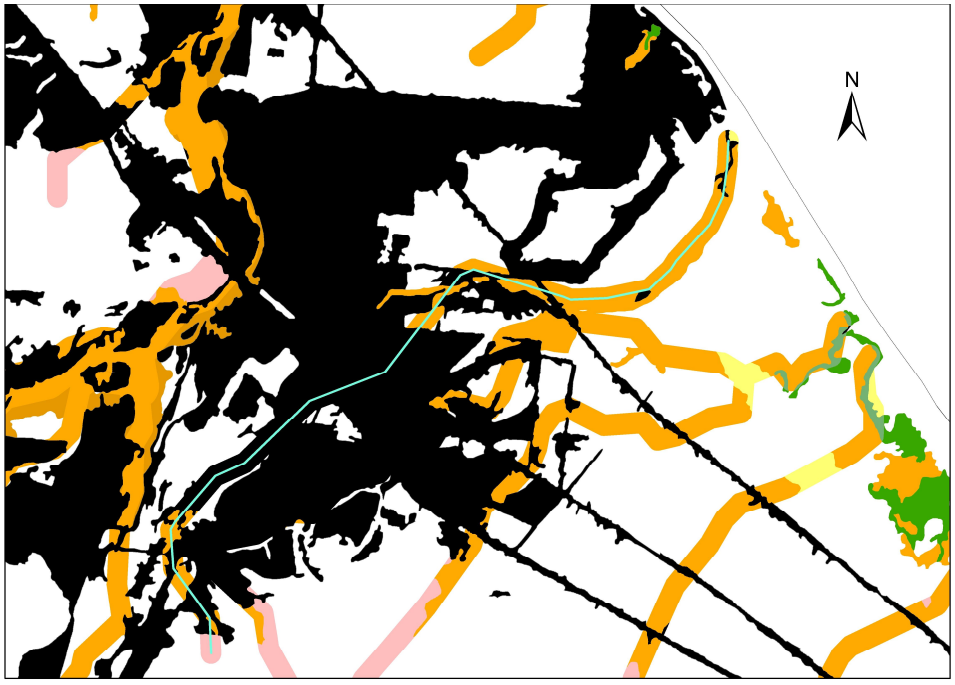


Figure 33: Riparian Systems of Creek 4



GREEN	**Estuarine/ mangrove systems.**
YELLOW	**Sand dune wetlands and associated riparian zones.**
ORANGE	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on alluvial plains.**
PINK	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on granitic rock.**
BLACK	**Areas of non-remnant vegetation.**
BLUE	**The creek or river system under analysis.**

3.1.9.1 CREEK 4, RIPARIAN CONDITION

Creek 4 is in poor condition over half of the creek has been cleared to the high bank with adjacent land uses being current agricultural or previous agricultural pastoral lands riparian vegetation is seen in the lower parts of the catchment. However, the majority of these areas have been cleared.

3.1.10 Surveyor Creek

Figure 34: Location of Surveyor Creek

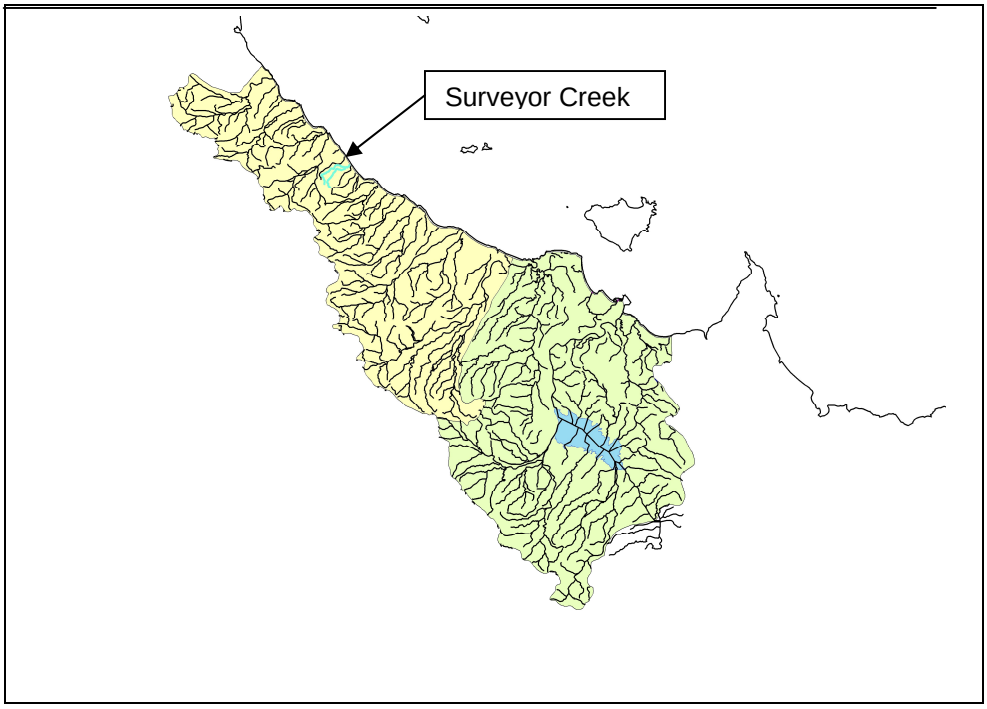
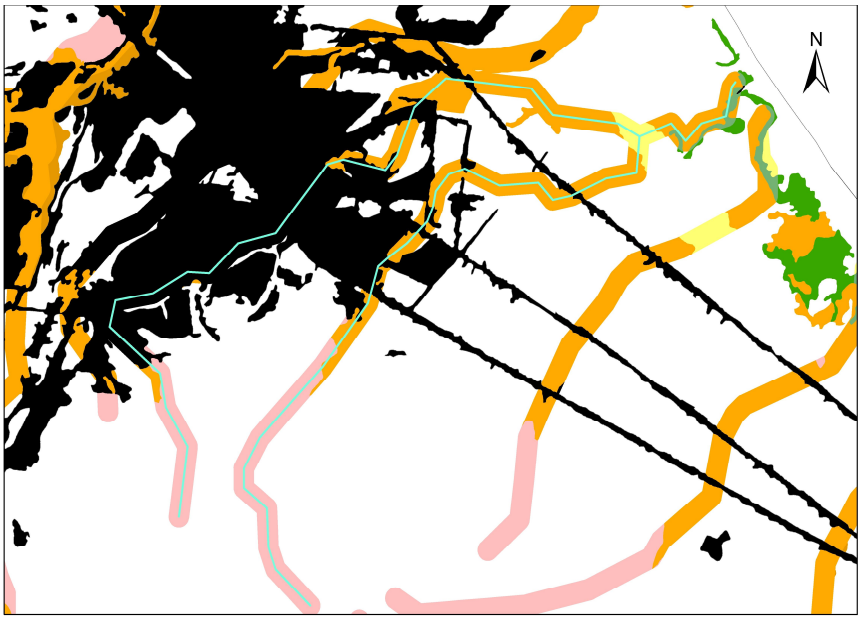


Figure 35: Riparian Systems of Surveyor Creek



GREEN	**Estuarine/ mangrove systems.**
YELLOW	**Sand dune wetlands and associated riparian zones.**
ORANGE	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on alluvial plains.**
PINK	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on granitic rock.**
BLACK	**Areas of non-remnant vegetation.**
BLUE	**The creek or river system under analysis.**

3.1.10.1 SURVEYOR CREEK, RIPARIAN CONDITION

Surveyor Creek Has a poor to moderate riparian condition there are 2 main channels within this catchment. The northern channel has a poor condition with over half of the reach cleared to the high bank. The Southern channel is in moderate to good condition with little incursion into the designated buffer width. After the streams converge there is good sand dune and estuarine riparian coverage. Adjacent land use within the cleared zones in the upper reaches are degraded pasture and agricultural lands.

3.1.11 Creek 5 (Name Unknown)

Figure 36: Location of Creek 5

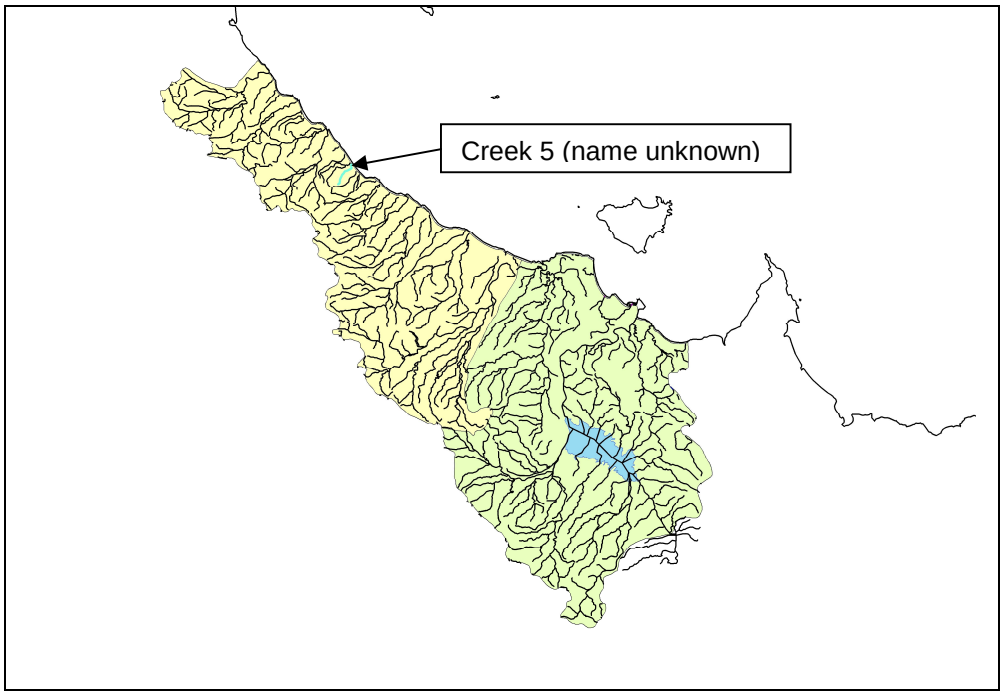
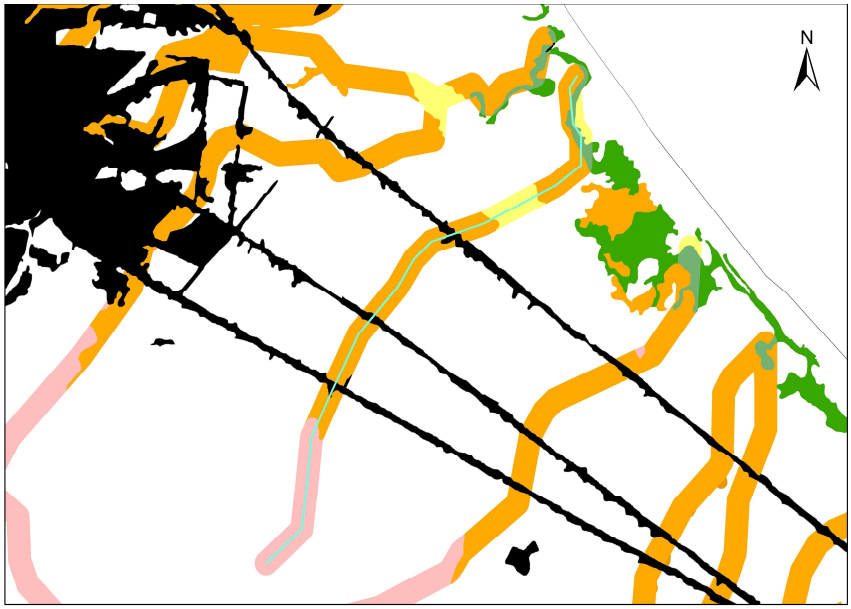


Figure 37: Riparian Systems of Creek 5



GREEN	**Estuarine/ mangrove systems.**
YELLOW	**Sand dune wetlands and associated riparian zones.**
ORANGE	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on alluvial plains.**
PINK	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on granitic rock.**
BLACK	**Areas of non-remnant vegetation.**
BLUE	**The creek or river system under analysis.**

3.1.11.1 CREEK 5, RIPARIAN CONDITION

Creek 5 is in good condition with minimal incursion into the designated buffer zone. The only breach of the designated buffer zone is for road and rail corridors. Apart from these minor incursions there is no compromise of the designated buffer zone.

3.1.12 Baar Creek

Figure 38: Location of Baar Creek

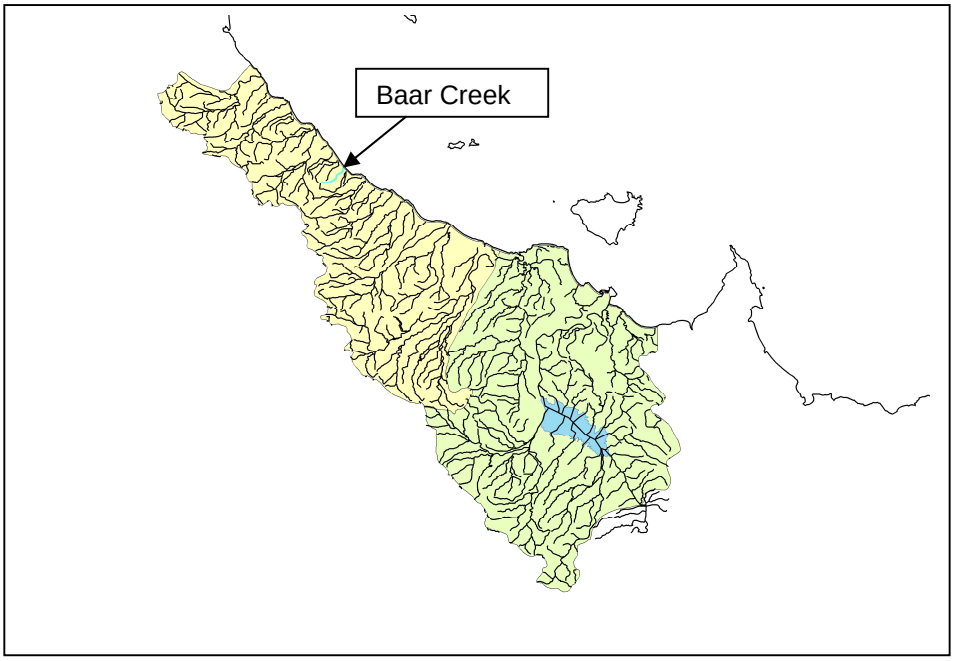
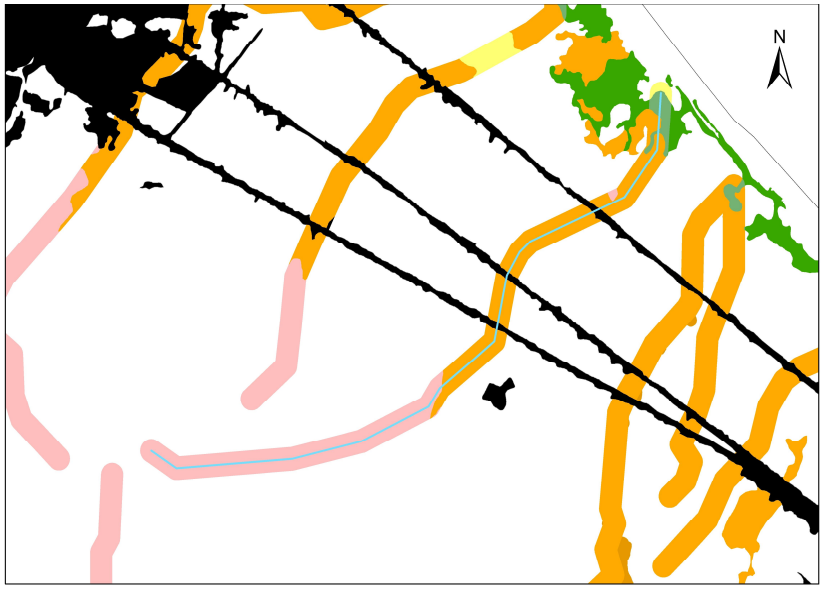


Figure 39: Riparian Systems of Baar Creek



GREEN	**Estuarine/ mangrove systems.**
YELLOW	**Sand dune wetlands and associated riparian zones.**
ORANGE	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on alluvial plains.**
PINK	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on granitic rock.**
BLACK	**Areas of non-remnant vegetation.**
BLUE	**The creek or river system under analysis.**

3.1.12.1 BAAR CREEK, RIPARIAN CONDITION

Baar Creek is in good condition with minimal incursion into the designated buffer zone. The only breach of the designated buffer zone is for road and rail corridors. Apart from these minor incursion there is no compromise of the designated buffer zone

3.1.13 Station Creek

Figure 40 Location of Station Creek

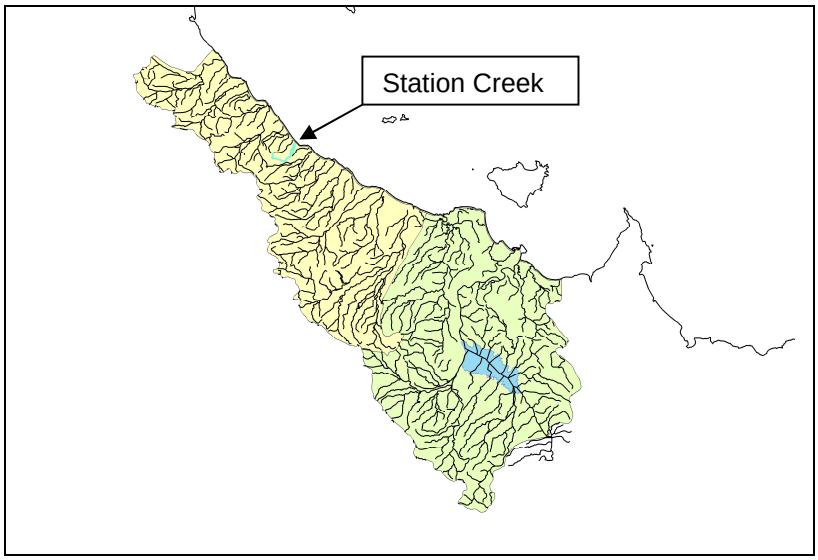
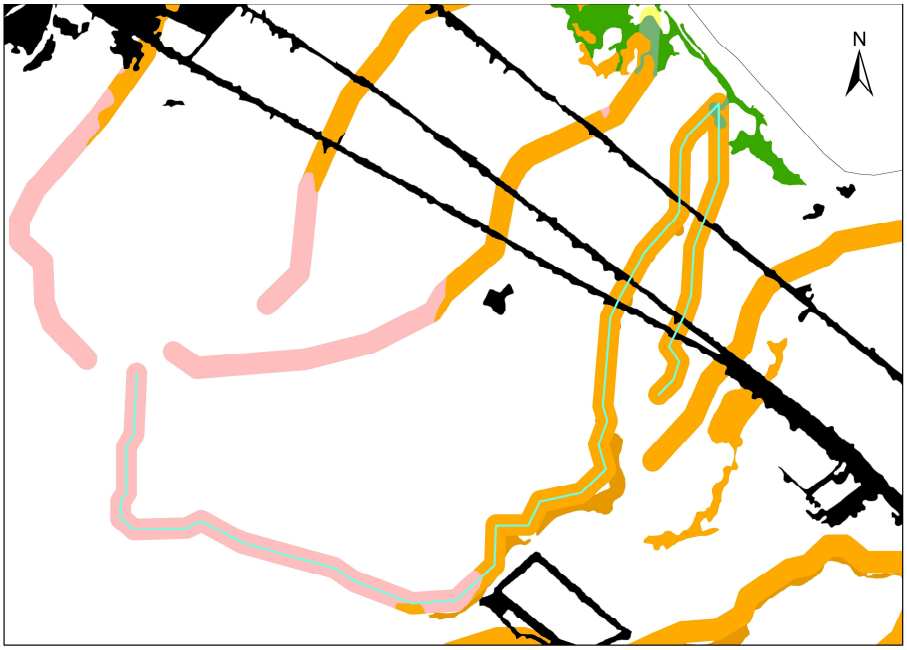


Figure 41: Riparian Systems of Station Creek



GREEN	**Estuarine/ mangrove systems.**
YELLOW	**Sand dune wetlands and associated riparian zones.**
ORANGE	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on alluvial plains.**
PINK	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on granitic rock.**
BLACK	**Areas of non-remnant vegetation.**
BLUE	**The creek or river system under analysis.**

3.1.13.1 STATION CREEK, RIPARIAN CONDITION

Station Creek is in good condition with minimal incursion into the designated buffer zone. The only breach of the designated buffer zone is for road and rail corridors. Apart from these minor incursions there is no compromise of the designated buffer zone.

3.1.14 Creek 6 (Name Unknown)

Figure 42: Location of Creek 6

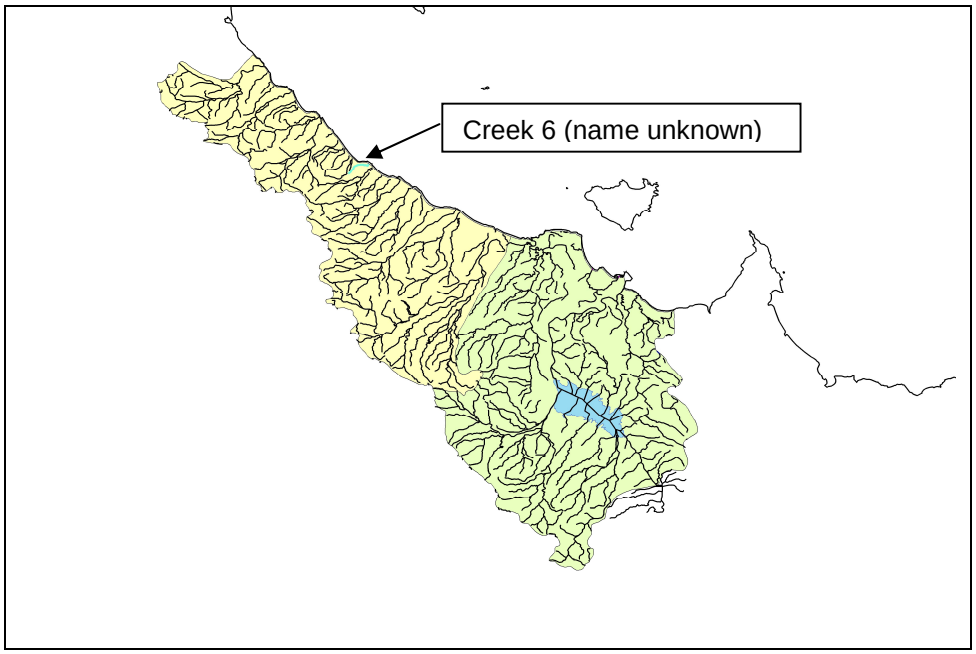
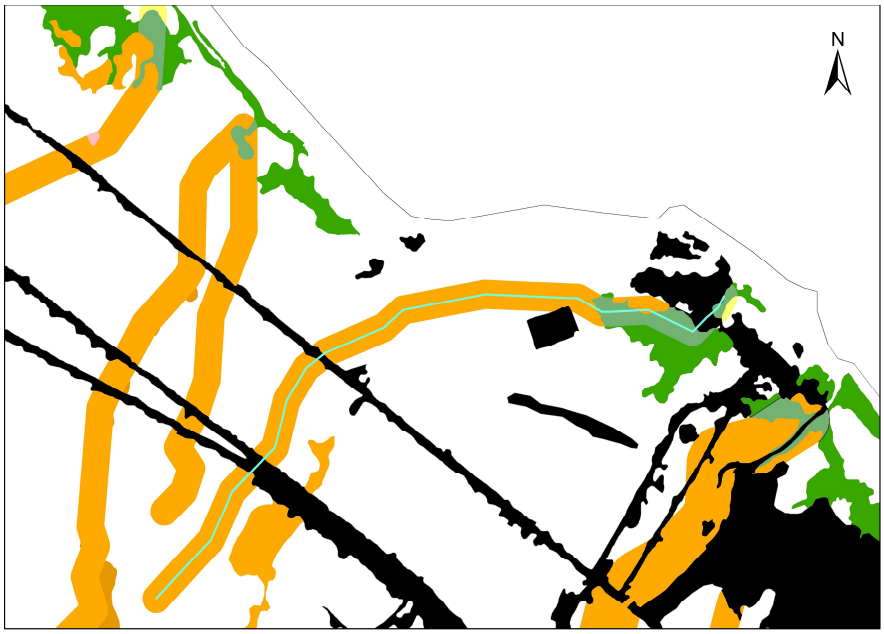


Figure 43: Riparian Systems of Creek 6



GREEN	**Estuarine/ mangrove systems.**
YELLOW	**Sand dune wetlands and associated riparian zones.**
ORANGE	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on alluvial plains.**
PINK	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on granitic rock.**
BLACK	**Areas of non-remnant vegetation.**
BLUE	**The creek or river system under analysis.**

3.1.14.1 CREEK 6, RIPARIAN CONDITION

Creek 6 is in good condition with minimal incursion into the designated buffer zone. The only breach of the designated buffer zone is for road and rail corridors and some minor clearing for unknown purposes in the estuarine sand dune zone. Apart from these minor incursion there is no compromise of the designated buffer zone.

3.1.15 Saltwater Creek

Figure 44: Location of Saltwater Creek

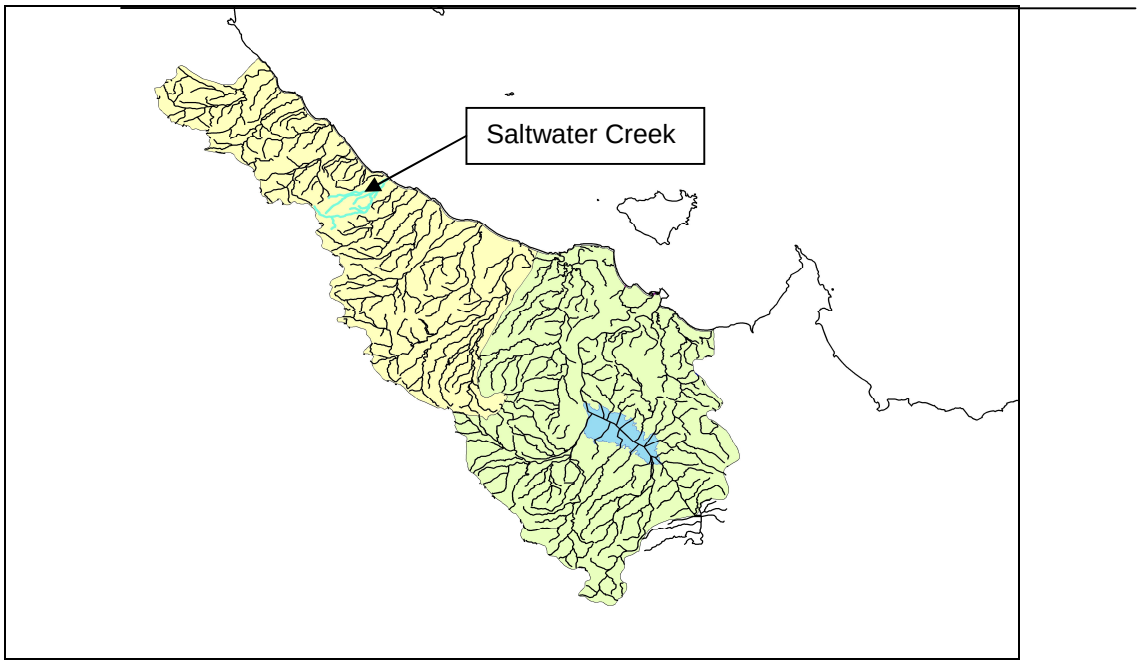
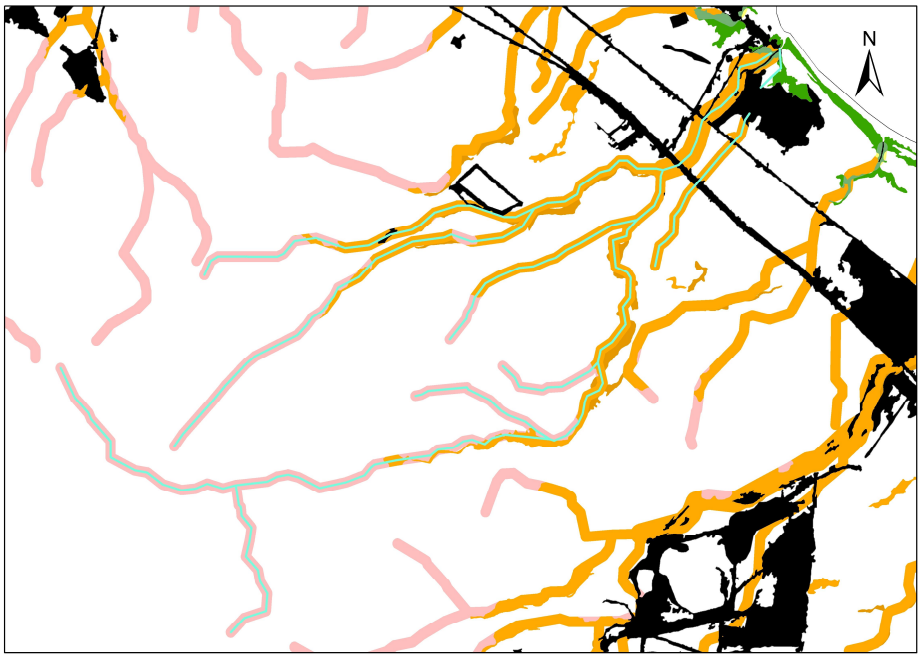
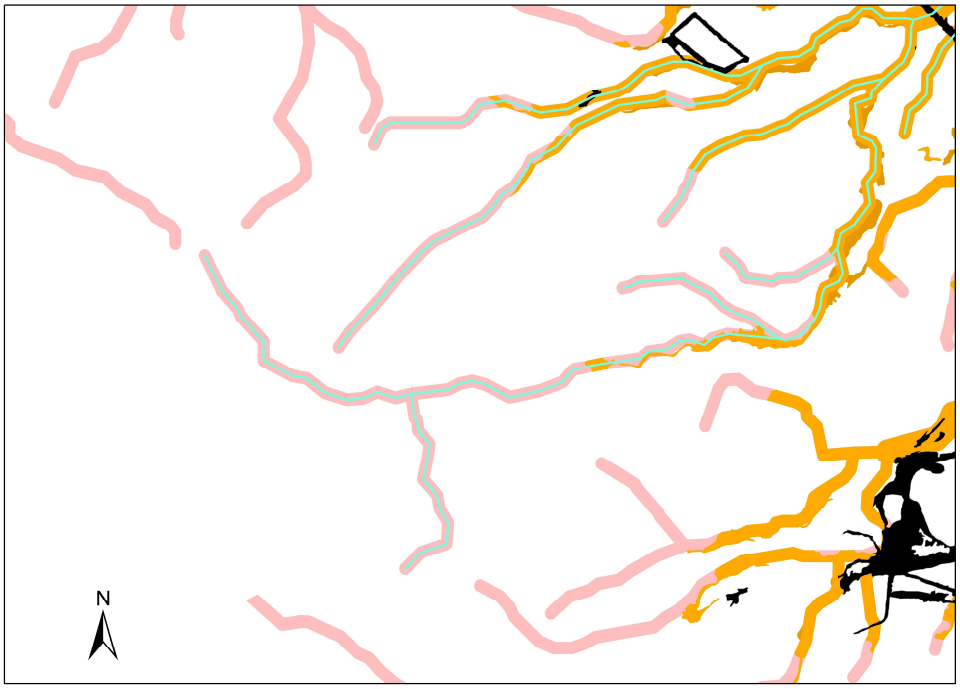


Figure 45: Riparian Systems of Saltwater Creek



GREEN	**Estuarine/ mangrove systems.**
YELLOW	**Sand dune wetlands and associated riparian zones.**
ORANGE	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on alluvial plains.**
PINK	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on granitic rock.**
BLACK	**Areas of non-remnant vegetation.**
BLUE	**The creek or river system under analysis.**

Figure 46: Riparian Systems of Saltwater Creek, Upper Reaches

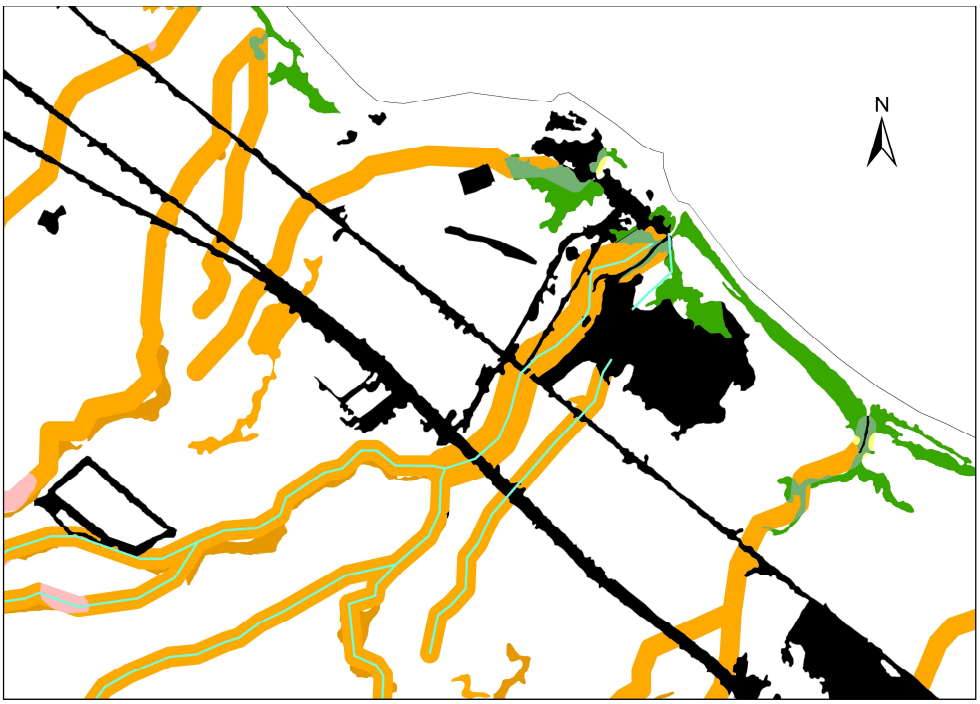


GREEN	**Estuarine/ mangrove systems.**
YELLOW	**Sand dune wetlands and associated riparian zones.**
ORANGE	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on alluvial plains.**
PINK	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on granitic rock.**
BLACK	**Areas of non-remnant vegetation.**
BLUE	**The creek or river system under analysis.**

3.1.15.1 SALTWATER CREEK UPPER REACHES, RIPARIAN CONDITION

The riparian condition within the upper reaches of Saltwater Creek is pristine. Minimal clearing has taken place with only two minor breaches into the designated buffer zone. All other areas have extensive riparian cover.

Figure 47: Riparian Systems of Saltwater Creek Lower Reaches



GREEN	**Estuarine/ mangrove systems.**
YELLOW	**Sand dune wetlands and associated riparian zones.**
ORANGE	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on alluvial plains.**
PINK	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on granitic rock.**
BLACK	**Areas of non-remnant vegetation.**
BLUE	**The creek or river system under analysis.**

3.1.15.2 SALTWATER CREEK, LOWER REACHES, RIPARIAN CONDITION

Saltwater Creek lower reaches are in moderate to good condition with minimal incursion into the designated buffer zone. Breaches of the designated buffer zone include road and rail corridors and some minor clearing for unknown purposes and aquaculture. Creeks that traverse these areas have no riparian coverage, with water travelling over non-vegetated surfaces. Apart from the noted minor incursion, there is no compromise of the designated buffer zone

3.1.16 Cassowary/ Camp Oven Creeks

Figure 48: Location of Cassowary/ Camp Oven Creeks

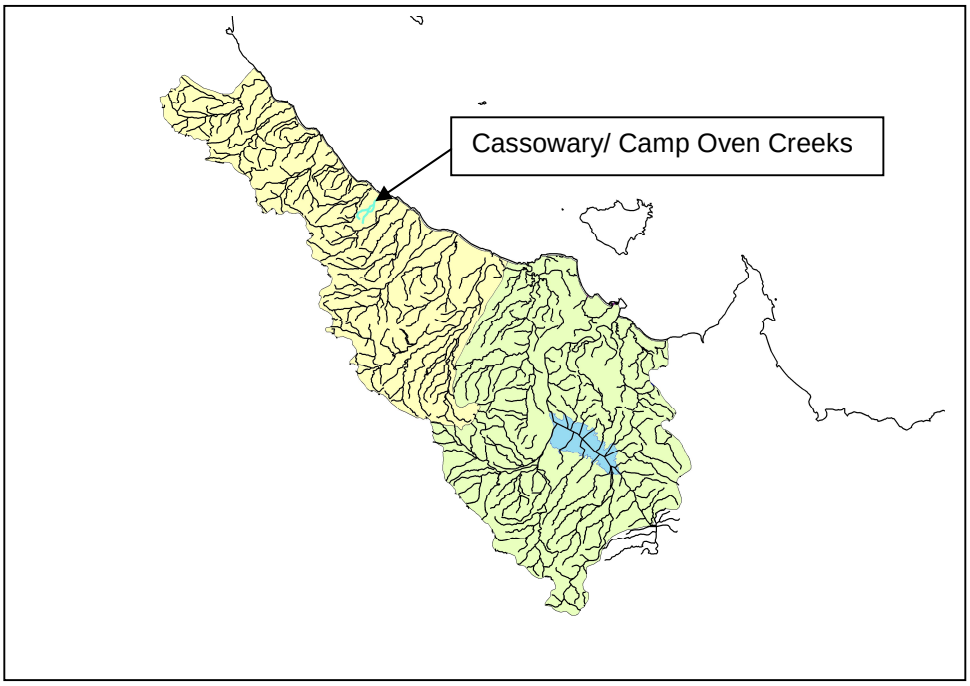
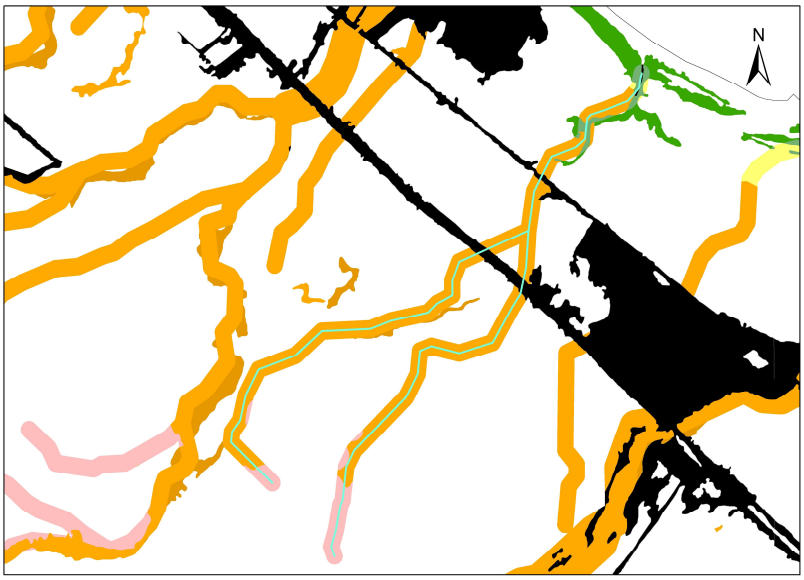


Figure 49: Riparian Systems of Cassowary/Camp Oven Creeks



GREEN	**Estuarine/ mangrove systems.**
YELLOW	**Sand dune wetlands and associated riparian zones.**
ORANGE	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on alluvial plains.**
PINK	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on granitic rock.**
BLACK	**Areas of non-remnant vegetation.**
BLUE	**The creek or river system under analysis.**

3.1.16.1 CASSOWARY CREEK/CAMP OVEN CREEKS, RIPARIAN CONDITION

The riparian zones of Cassowary/Camp Oven Creeks are in good condition with minimal incursion into the designated buffer zone by road and rail corridors. Apart from these minor incursions, there is no compromise of the designated buffer zone.

3.1.17 Lillypond Creek

Figure 50: Location of Lillypond Creek

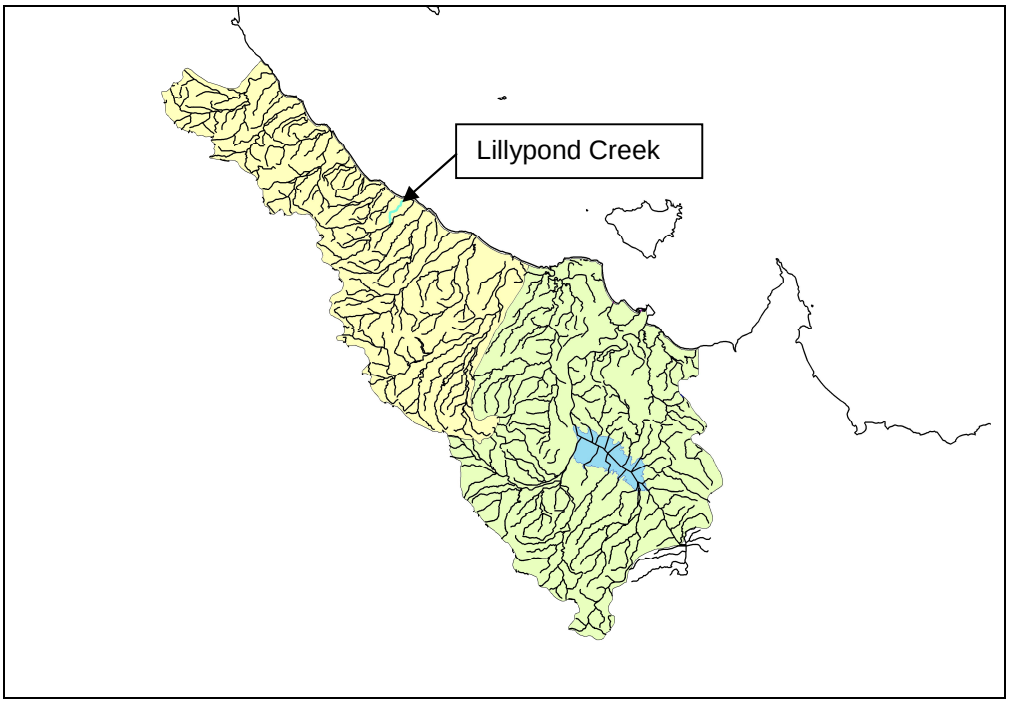
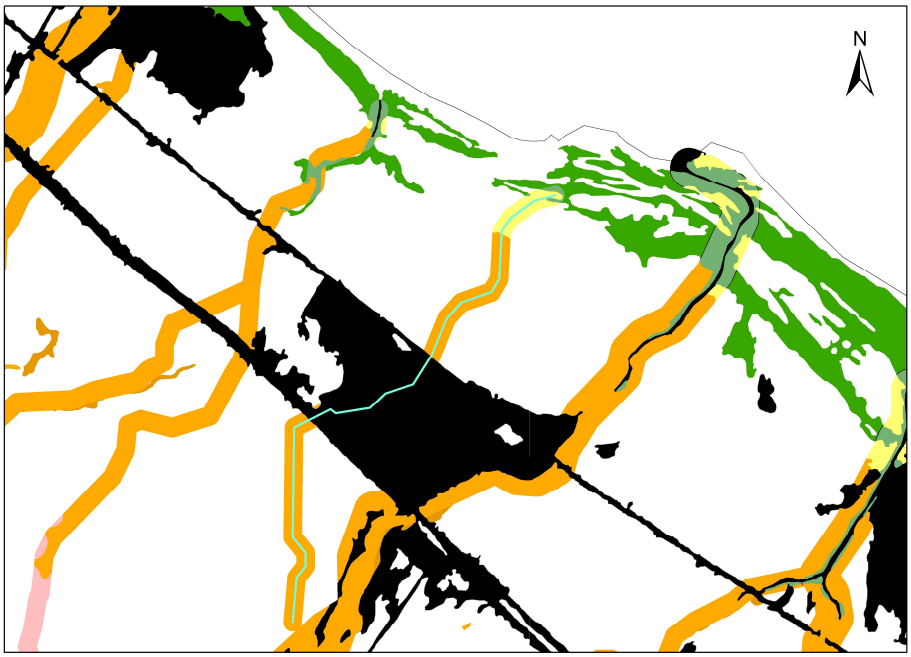


Figure 51: Riparian Systems of Lillypond Creek



GREEN	**Estuarine/ mangrove systems.**
YELLOW	**Sand dune wetlands and associated riparian zones.**
ORANGE	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on alluvial plains.**
PINK	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on granitic rock.**
BLACK	**Areas of non-remnant vegetation.**
BLUE	**The creek or river system under analysis.**

3.1.17.1 LILLYPOND CREEK, RIPARIAN CONDITION

Lillypond Creek has a moderate riparian condition. A large section of non-remnant vegetation exists between the rail and road corridor. This area is degraded agricultural/pastoral land which is showing signs of regrowth with a mixture of native and invasive species. These hold some riparian value in that they slow the velocity of overland flows within these areas. All other areas outside of this non-remnant zone have good riparian condition.

3.1.18 Leichhardt Creek

Figure 52: Location of Leichhardt Creek

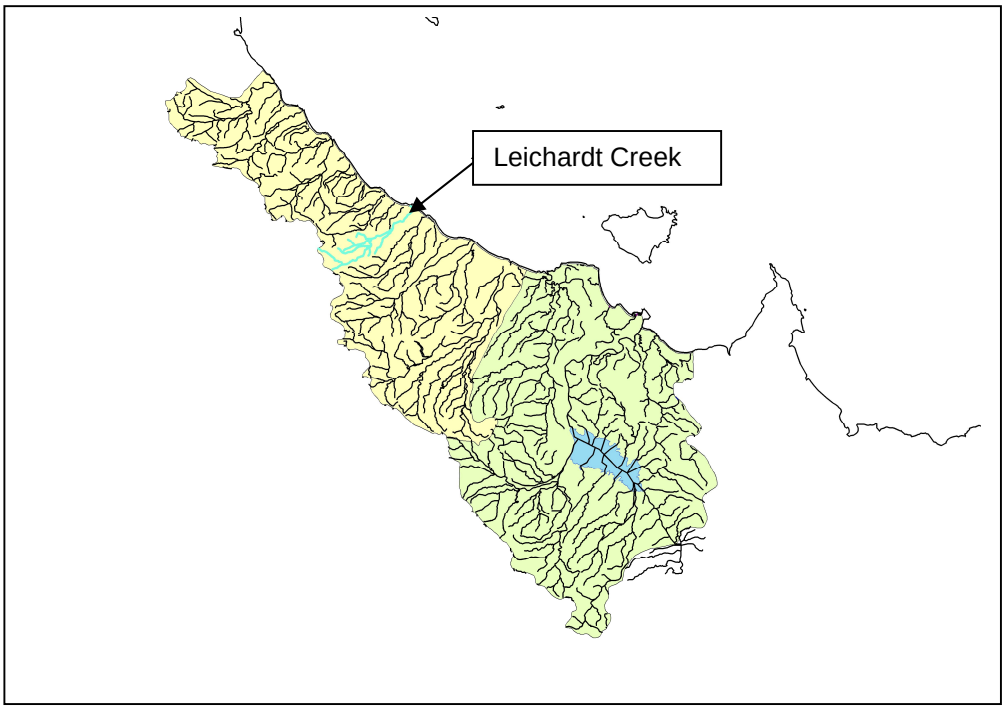
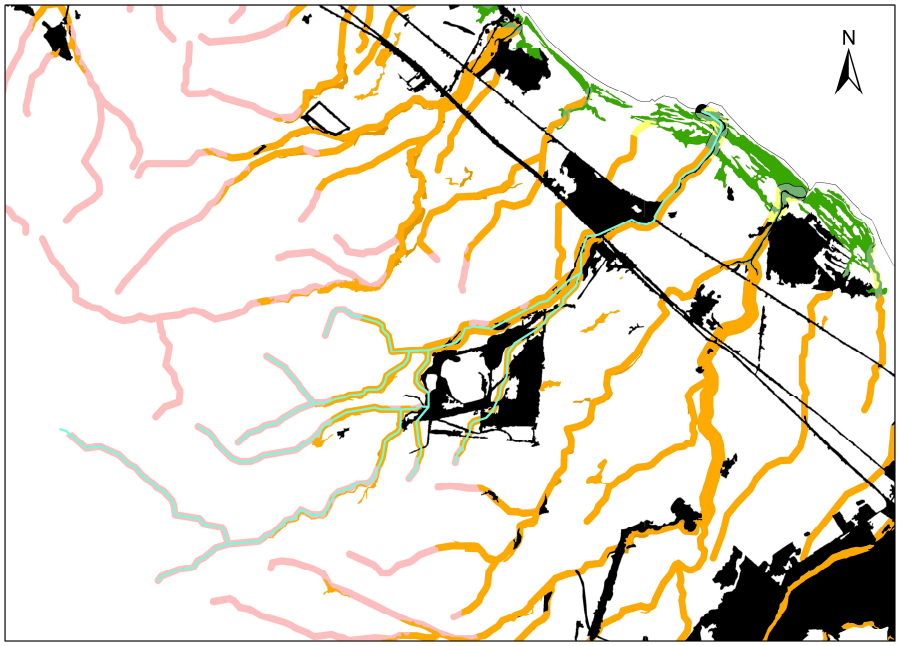
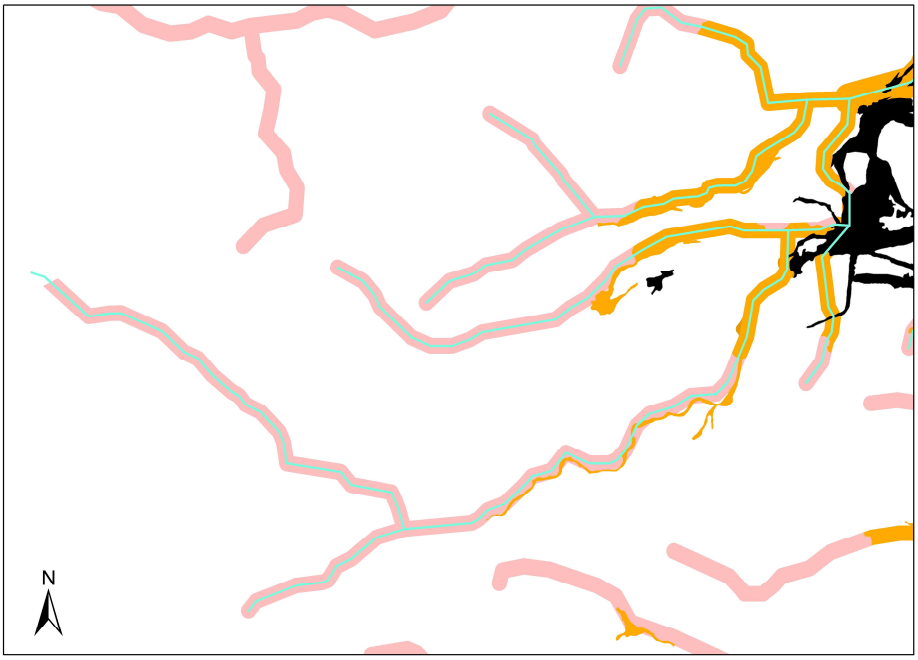


Figure 53: Riparian Systems of Leichhardt Creek



GREEN	**Estuarine/ mangrove systems.**
YELLOW	**Sand dune wetlands and associated riparian zones.**
ORANGE	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on alluvial plains.**
PINK	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on granitic rock.**
BLACK	**Areas of non-remnant vegetation.**
BLUE	**The creek or river system under analysis.**

Figure 54: Riparian Systems of Leichhardt Creek Upper Reaches

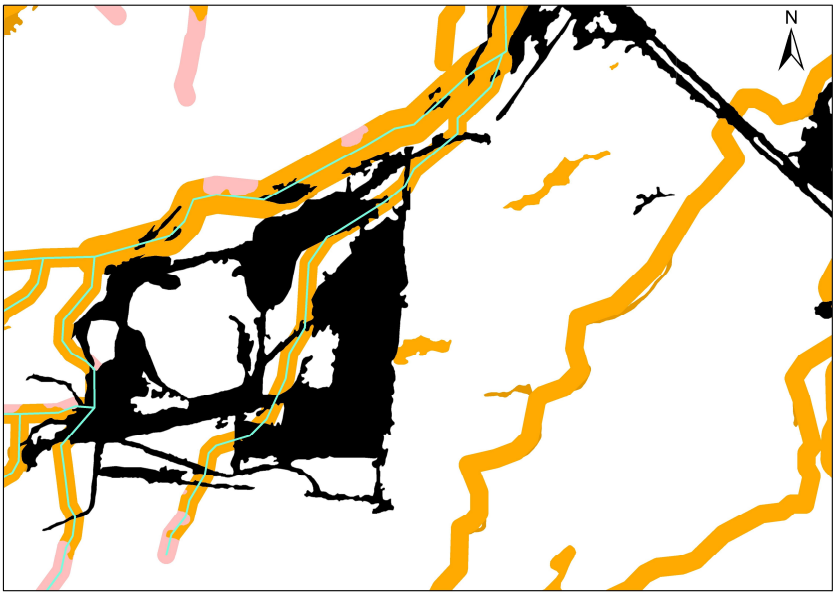


GREEN	**Estuarine/ mangrove systems.**
YELLOW	**Sand dune wetlands and associated riparian zones.**
ORANGE	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on alluvial plains.**
PINK	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on granitic rock.**
BLACK	**Areas of non-remnant vegetation.**
BLUE	**The creek or river system under analysis.**

3.1.18.1 LEICHHARDT CREEK UPPER REACHES, RIPARIAN CONDITIONS

The riparian zones of the upper reaches of Leichhardt Creek are in good condition. Minimal clearing has occurred with only one breach into the designated buffer zone for property access on the alluvial plains. All other areas have extensive riparian cover on both the granitic slopes and alluvial plains

Figure 55: Riparian Systems of Leichhardt Creek Middle Reaches



GREEN	**Estuarine/ mangrove systems.**
YELLOW	**Sand dune wetlands and associated riparian zones.**
ORANGE	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on alluvial plains.**
PINK	**Vegetation associated with creek lines/river systems, wetlands, and associated riparian vegetation on granitic rock.**
BLACK	**Areas of non-remnant vegetation.**
BLUE	**The creek or river system under analysis.**

3.1.18.2 LEICHHARDT CREEK MID REACHES, RIPARIAN CONDITION

The riparian condition of Leichhardt Creek's middle reaches is moderate. Disturbances in the upper part of this reach appear to be related to an old quarrying operation. Although disruptive to the vegetation there has not been extensive clearing or modification within the designated buffer zone. All other areas have extensive coverage with only minor disturbances within the designated buffer zone.