Eucalyptus camaldulensis (river red gum) Biogeochemistry: An Innovative Tool for Mineral Exploration in the Curnamona Province and Adjacent Regions

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CHAPTER 4

EUCALYPTUS CAMALDULENSIS BIOGEOCHEMICAL MAPS:

SPATIAL VARIATIONS THROUGH THE LANDSCAPE

4.1 RACECOURSE CREEK

4.1.1 Setting

Racecourse Creek (formerly known as Kimberly Creek; Lena Kelly, pers comm., 2003) is about 2 km east of Tibooburra, in far northwestern New South Wales, approximately 340 km north of Broken Hill (Figure 4.1). The study area is approximately 5 km by 10 km and is on the Milparinka 1:250 000 topographic mapsheet (SH54-07).

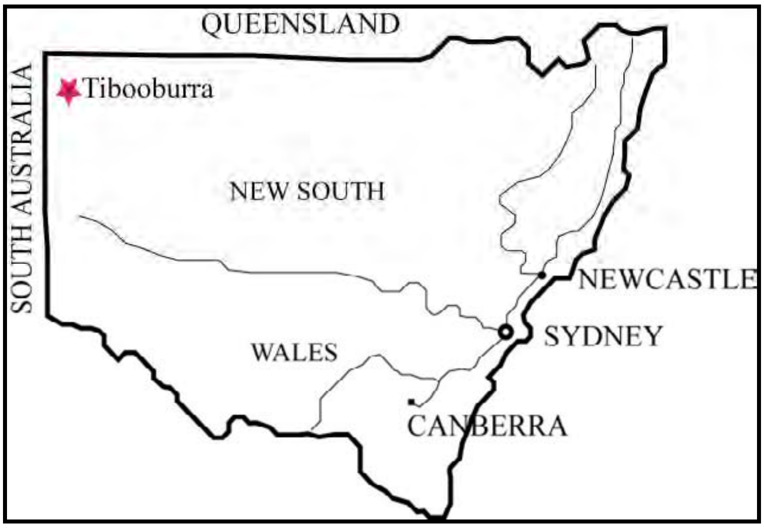


Figure 4.1: The location of Tibooburra in western New South Wales.

The area presently experiences a semi-arid to arid climate, with an average annual rainfall of 227 mm, predominantly falling in the summer. Temperatures range from an average summer maximum of 35.4°C to an average winter minimum of 6.2°C (Bureau of Meteorology, 2005e). The northern parts of the area are within the Tibooburra town common, whereas the southern parts are within 'Mt Stuart' station. The area has previously been host to minor Au-mining and prospecting, particularly during the 1880s when mines were active as a part of the Albert Au-fields. Most of the Au mined from the Tibooburra Inlier was hosted within transported regolith, either from Mesozoic sediments, or Cainozoic sediments associated with the reworking of the Mesozoic sediments.

4.1.2 Geology

The Tibooburra Inlier (Figure 4.2) includes an isolated cluster of bedrock inliers in the northwest of New South Wales. It is on the NW-SE trending Tibooburra Ridge (Cramsie & Hawke, 1984), a bedrock high largely covered by Eromanga Basin, Lake Eyre Basin and Bulloo-Bancannia Basin sediments (Hill, 2005).

The oldest exposed rocks in the Tibooburra town common are the Cambrian to Early Ordovician metasediments of the Easter Monday Beds (Thalhammer *et al*., 1998; (formerly known as the 'Wonominta beds'; Morton, 1982). They consist of pelitic and arenaceous phyllites, schist and sandstones with minor volcanics, including hornfels, phyllite and quartzite, which have been regionally metamorphosed to greenschist facies (Stevens & Etheridge, 1989; Thalhammer *et al.*, 1998).

The metasediments were intruded and contact metamorphosed by the Late Silurian – Early Devonian Tibooburra Granodiorite and associated tonalite bodies (Morton, 1982; Stevens & Etheridge, 1989). The Tibooburra Granodiorite was formerly referred to as the 'Tibooburra Granite' (Rose *et al*., 1967; Rose & Brunker, 1968 and Alexander, 1976). It is described as a coarse-grained, locally porphyritic, biotite-hornblende granodiorite (Stevens & Etheridge, 1989).

The intrusion of the granodiorite has created a contact metamorphic aureole, which produced a cordierite-K-feldspar-biotite-quartz assemblage extending up to approximately 600 m from the intrusive rocks and a cordierite-biotite-quartz assemblage extending up to 1 km from the intrusive rocks (Stevens & Etheridge, 1989; Thalhammer *et al*., 1998).

Mesozoic sediments of the Eromanga Basin extend across many of the low-lying parts of the catchment. These include quartzose gravels and sands with minor silts, which were locally defined as the 'Gum Vale Formation' by Morton (1982), and equivalent to the late Jurassic to Early Cretaceous Cadna-owie Formation. Overlying these, further away from the inlier, are fine sands, silts and clays of the Rolling Downs Group (locally including units such as the 'Wittabrinna Shale' of Morton, 1982). The deposition of the Mesozoic sediments is interpreted to have been within fluvial to marginal marine environments, followed by shallow marine conditions. Underlying these sediments is a regionally extensive unconformity and locally exhumed palaeosurface (Hill, 2000; 2005) associated with significant Au-dispersion and local Au concentration (Hill *et al.*, 2005).

Cainozoic sediments from the Lake Eyre Basin and the Bulloo-Bancannia Basin overlie parts of the Eromanga Basin sediments in the region. The deposition in the Lake Eyre Basin took place in three main phases (Callen *et al*., 1995; Alley, 1998);

- Late Paleocene to Middle Eocene, (Eyre Formation) alluvial sediments;
- Late Oligocene to Early Pliocene, (Namba Formation) lacustrine, and low energy alluvial deposition; and,
- an assortment of alluvial, aeolian, lacustrine and minor colluvial deposition through to the present day.

The Bulloo-Bancannia Basin (Hill, 2005) has received little attention, and includes the Cainozoic sediments deposited to the east of the Grey Range Divide. The sediments here appear to be equivalent to the Lake Eyre Basin sediments.

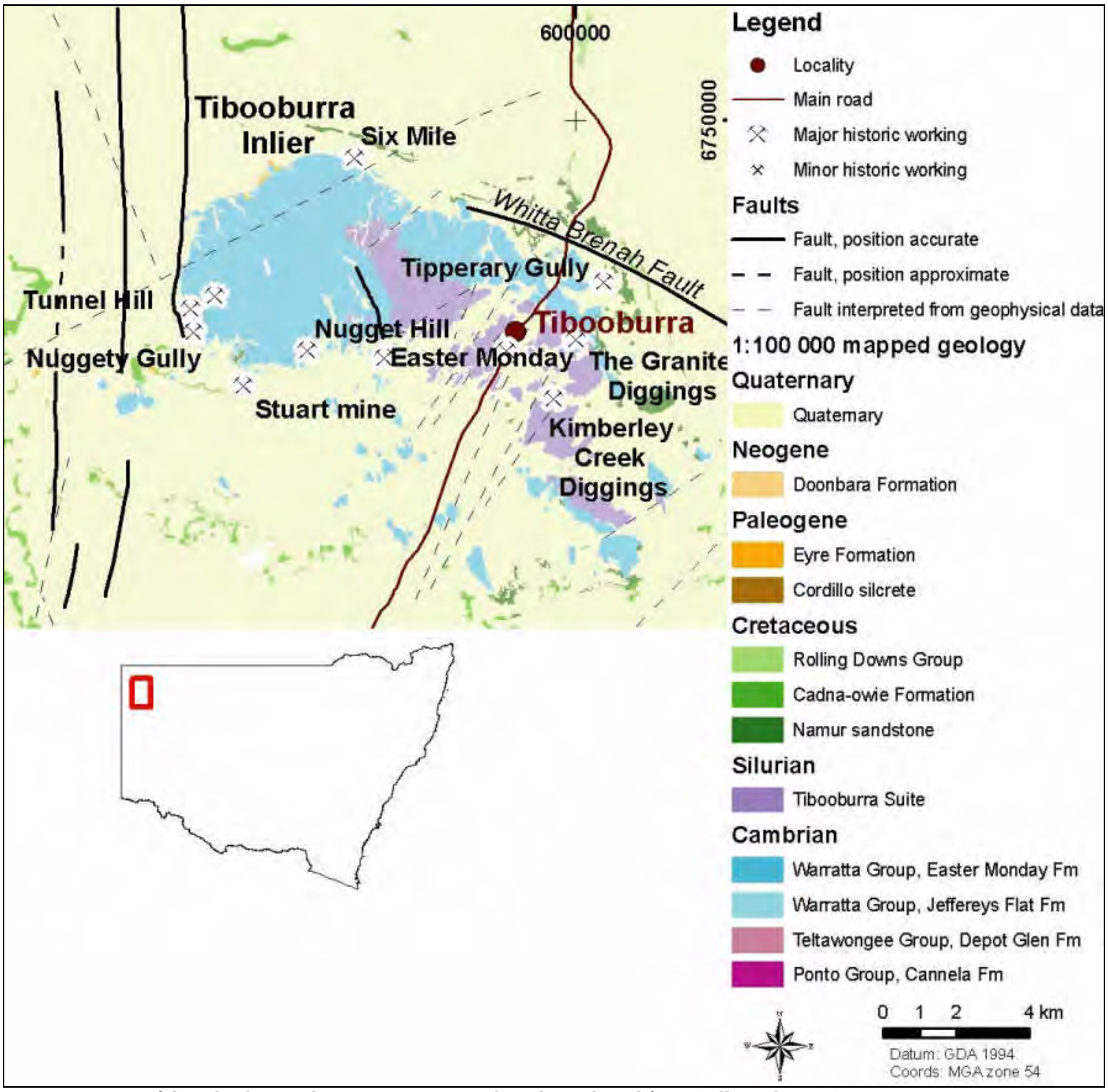


Figure 4.2: Location of the Tibooburra Inlier western New South Wales. Adapted from (Hill, *et al*., 2008).

4.1.3 Mineralisation

The Tibooburra goldfields (formerly known as the Albert goldfields) (Wilkinson, 1889; Gerritsen, 1981) include Au occurrences at Tibooburra, Mt Browne, New Bendigo and the Warratta Inlier. The goldfield has been described as a comparatively small field with yields between 25 000 to 32 000 oz from workings in the shallow alluvium, conglomerate and minor quartz veins. Gold was first discovered in the Milparinka area in 1867 and then near Tibooburra in 1881 and mined until the end of 1914. The demise of the Au-rush was due to its patchy distribution and low grade (Kenny, 1934).

Bedrock-hosted mineralisation is sparse and structurally controlled. It is restricted to vein systems (Au and/or Cu bearing) or possible stratiform (Cu, Zn, Pb/Ag or Au bearing) lodes, typically within the metasediment host rock such as in the Warratta Inlier (Barnes, 1974; Fleming, 1995). Throughout the Mt Browne – Tibooburra Goldfields three main types of Au deposits have been recognised (Barnes, 1974):

- quartz vein deposits within the Cambrian to Early Ordovician metasediments (e.g. Warratta Inlier);
- alluvial deposits in the Late Jurassic to Early Cretaceous 'Gum Vale Formation' basal conglomerates; and,
- contemporary alluvial systems derived from the reworking of the Late Jurassic to Early Cretaceous 'Gum Vale Formation' basal conglomerates and/or from the quartz veins from the Cambrian to Early Ordovician metasediments.

Primary Au, derived from quartz veins associated with the metasediments of the Warratta Inlier and its southern extensions (Thalhammer, 1991), occurs within quartz vein alteration zones characterised by small amounts of sulphide. The veins generally have low Au grade (Alexander, 1976), however the 'Pioneer Reef' yielded grades averaging less than 23 g/t with some assay values as high as 460 g/t (Kenny, 1934). To date, a total of 217 kg of Au has been extracted from quartz vein mining in the Milparinka – Tibooburra region since 1883 (Barnes, 1974).

The recovery of primary Au from the Tibooburra Inlier within quartz veins associated with the Cambrian to Early Ordovician metasediments and the Late Silurian – Early Devonian Tibooburra Granodiorite has been less successful. Alexander (1976) however, reports that thin quartz veins near Tibooburra are generally pyritic and occasionally carry low Au grades.

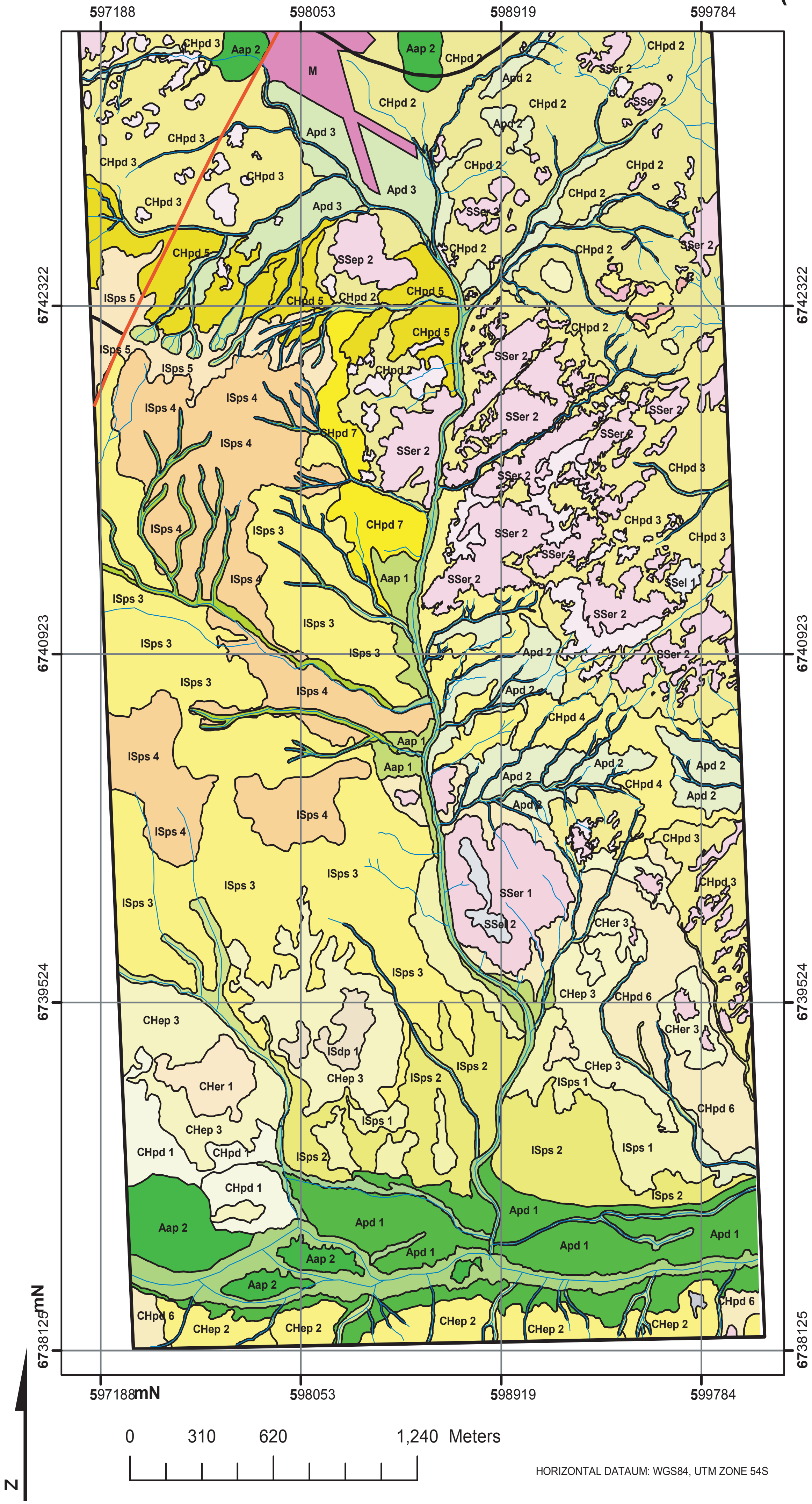
Early studies suggest that the source for the secondary Au was the quartz veins within the bedrock of the Tibooburra Inlier (Wilkinson, 1889). Approximately one quarter of the Au recovered across the Albert goldfields was gained from the Tibooburra Inlier (Alexander, 1976). The primary Au source for these sediments is most likely to be concealed by extensive regolith and basin sediments. Palaeocurrent indicators within these sediments are highly variable, but are consistent with a southern, presently regolith-dominated, source area (Chamberlain, 2001; Hill *et al*., 2005).

4.2 REGOLITH-LANDFORM UNITS

Prior to this study, regolith research conducted in the Tibooburra area comprises work by Hill (2000) and Chamberlain & Hill (2002), which included the compilation of a 1:25 000 scale regolith-landform map. More detailed mapping (1:10 000) of the Dee Dee catchment headwaters has been conducted by (Hill, 2004; Hill, 2005; Hill, *et al.*, 2005).

To provide a landscape context for the *E. camaldulensis* biogeochemistry within the Racecourse Creek catchment, 1: 10 000 regolith-landform mapping was undertaken (Chapter 2, section 2.1 mapping methods). The catchment is mostly characterised by weathered bedrock, forming erosional hills, rises and plains. Transported regolith includes alluvial, colluvial and aeolian sediments. These sediments are mostly in low-lying landscape settings; however, they may occur on the flanks of rises and hills. A total of 253 field characterisation points were recorded from forty regolith-landform units within the 1:10 000 map area. The accompanying regolith map (Figure 4.3) and the following section provides a description of the attributes of each regolith-landform unit.

TIBOOBURRA (RACECOURSE CREEK) REGOLITH-LANDFORM MAP (1:10 000)



TRANSPORTED REGOLITH

ALLUVIAL SEDIMENTS — *ALLUVIAL SEDIMENTS*

Aap 1	Red-brown to grey-brown quartzose, slightly micaceous silts and sands. Very minor sub-angular to rounded milky quartz with minor lithic clasts (10-30 mm) and minor fragments of ferruginous regolith, on a very low relief landsurface. Minor-major gullying into Racecourse Creek. Vegetation dominated by chenopod shrubs *Maireana pyramidata*, also stands of *Eucalyptus camaldulensis* with scattered *Acacia victoriae*, *Acacia clivicola* and *Acacia tetragonaphylla*.
Aap 2	Light brown to red-brown quartzose, slightly micaceous silts and sands. Minor sub-angular to rounded milky quartz with minor lithic clasts (10-30 mm) and minor fragments of ferruginous regolith, on a very low relief landsurface. Gullying into Thompson Creek. Vegetation dominated *Acacia victoriae*, with minor chenopod shrubs *Atriplex vesicaria*, *Maireana pyramidata*, also small stands of *Eucalyptus camaldulensis* and scattered *Myoporum montanum*.
Aed 1	Red-brown quartzose silts and sands, with minor sub-angular to rounded milky quartz with minor lithic clasts (<5 mm),along elongated drainage depressions including narrow incised channel and lower valley margins. Gullying from surrounding Aed units with minor melon-holes. Vegetation dominated by *Eucalyptus camaldulensis* with minor chenopod shrubs *Atriplex vesicaria*, *Maireana pyramidata*, with small stands of *Eucalyptus microtheca* and scattered *Acacia victoriae* and *Acetosa vesicaria*.
Aed 2	Red-brown quartzose silts and sands, with minor sub-angular to rounded milky quartz with minor lithic clasts (<5 mm) along elongated drainage depressions including narrow incised channels and lower valley margins. Gullying from surrounding Aed units with minor melon-holes. Vegetation dominated by *Acacia victoriae* and *Sida petrophila* with minor chenopod shrubs *Atriplex vesicaria*, *Maireana pyramidata*, and scattered *Cassia artemisiodes*, *Acetosa vesicaria* and *Solanum ellipticum*.
Aed 3	Red-brown quartzose silts and sands, with minor sub-angular to rounded milky quartz with minor lithic clasts (<5 mm) along elongated drainage depressions including narrow incised channel and lower valley margins. Gullying from surrounding Aed units with minor melon-holes. Vegetation dominated by *Eucalyptus terminalis*, flanked by minor chenopod shrubs *Maireana pyramidata*, *Maireana sedifolia* and scattered *Acacia victoriae*, *Casuarina cristata. ssp pauper*, *Solanum ellipticum*, *Sida petrophila* and *Acetosa vesicaria*.
Apd 1	Light brown to red-brown quartzose, slightly micaceous silts and sands, with minor sub-angular to rounded milky quartz and minor lithic clasts (<10 mm) and minor fragments of ferruginous regolith. Minor-major gullying/rilling into Racecourse Creek. Vegetation dominated by chenopod shrubs *Maireana pyramidata*, minor *Eucalyptus microtheca* and juvenile *Eucalyptus camaldulensis* and *Craspedia uniflora*.
Apd 2	Light brown to red-brown quartzose, slightly micaceous silts and red, rounded quartzose sands, with abundant sub-angular to sub-rounded milky quartz and minor lithic clasts (<10 mm) and minor fragments of ferruginous regolith. Minor gullying into local Aed units. Vegetation dominated by chenopod shrubs *Maireana pyramidata*, and *Atriplex vesicaria*, with minor *Bassia ssp*.
Apd 3	Light brown to red-brown quartzose, slightly micaceous silts and red, rounded quartzose sands, with minor sub-angular to rounded milky quartz and minor lithic clasts (<10 mm) and minor fragments of ferruginous regolith. Minor gullying into local Aed units and relic gold diggings. Vegetation dominated by chenopod shrubs *Atriplex vesicaria*, *Maireana pyramidata*, and minor *Acacia victoriae* and, *Bassia ssp*.

CHANNEL DEPOSITS

ACar 1	Major ephemeral meandering channel approximately 40-80 m wide, consisting of a single thread reflecting a surrounding substrate control. Grey-brown to red-brown quartzose, silts and sands, with angular to sub-angular lithic clasts and sub-angular to sub-rounded milky quartz (50-100 mm). Braided channels, with vegetated sand bars approximately 30-90 m long. Vegetation dominated by *Eucalyptus camaldulensis* with minor *Eucalyptus terminalis* and *Eucalyptus microtheca*.
ACar 2	Minor ephemeral meandering channel approximately 20-50 m wide. Grey-brown to red-brown quartzose, silts and sands, with angular to sub-angular lithic clasts and sub-angular to sub-rounded milky quartz (50-100 mm). Vegetation dominated by *Eucalyptus camaldulensis* with minor *Eucalyptus terminalis* and scattered chenopods shrubs *Maireana pyramidata* and *Maireana sedifolia*.

AEOLIAN SEDIMENTS — *AEOLIAN SANDS*

ISps 1	Red, well-rounded quartzose sands, with slightly micaceous silts, with minor sub-angular to rounded milky quartz with minor lithic clasts (<5 mm) and minor fragments of ferruginous regolith, on a low relief landsurface. Minor-major gullying into Racecourse Creek and surrounding Aed units. Vegetation dominated by *Maireana sedifolia*, with minor mulga and *Rhodanthe floribunda*.
ISps 2	Red, well-rounded quartzose sands, minor angular milky quartz (5-30 mm), on a low relief landsurface. Minor gullying with local bedrock exposure. Vegetation dominated by *Acacia aneura*, *Maireana prymidata*, with minor *Acacia victoriae*.
ISps 3	Red, well-rounded quartzose sands, with abundant iron-oxide stained sub-angular to rounded milky quartz (5-30 mm), on a low relief landsurface. Minor gullying with local bedrock exposure. Vegetation dominated by sparse *Acacia aneura*, with minor chenopod shrubs *Maireana prymidata*, *Acacia tetragonaphylla*, and scattered *Ptilotus. ssp*. and mitchell grasses.
ISps 4	Red, well-rounded quartzose sands, with abundant iron-oxide stained sub-angular to rounded milky quartz (5-30 mm), on a low relief landsurface. Minor gullying with local bedrock exposure. Vegetation dominated by abundant *Acacia aneura*, with minor *chenopod shrubs Maireana prymidata*, *Acacia tetragonophylla*, and scattered *Ptilotus. ssp*. and mitchell grasses.
ISps 5	Red, well-rounded quartzose sands, with abundant iron-oxide stained sub-angular to rounded milky quartz (5-30 mm), on a low relief landsurface. Minor gullying with local bedrock exposure. Vegetation dominated by *Eremophila duttonii*, with minor minor *Acacia aneura*, *Bassia. ssp*.
ISpd 1	Red, well-rounded quartzose sands on a scalded land surface. Minor angular milky quartz (5-50 mm) and minor fragments of ferruginous regolith, on a low relief scalded landsurface. Vegetation dominated by *Maireana sedifolia*, *Acacia clivicola* and *Maireana pyramidata*, with minor *Rhodanthe floribunda*.

COLLUVIAL SEDIMENTS — *SHEET FLOW DEPOSITS*

CHer 1	Light brown to red-brown quartzose silts and sands, with minor sub-angular to rounded milky quartz (50-100 mm) with minor lithic clasts (<50 mm) and minor fragments of ferruginous regolith. Scattered rabbit warrens and minor drainage depressions. Vegetation dominated by chenopod shrubs *Maireana pyramidata*, with minor *Atriplex vesicaria*, *Acacia aneura* and *Bassia. ssp*.
CHer 2	Pale yelow-orange slightly micaceous well sorted quartzose silts and sands, with minor fragments of sandstone and sub-angular to rounded milky quartz (50-100 mm) with minor fragments of ferruginous regolith. Vegetation dominated by chenopod shrubs *Maireana sedfolia*, with minor *Acacia aneura, Bassia. ssp. and Acetosa vesicaria.*
CHer 3	Light brown to red-brown quartzose silts and sands, with sub-angular to rounded milky quartz (50-100 mm) with minor lithic clasts (10-150 mm) and minor bedrock exposures. Minor gullying into local depressions. Vegetation dominated by *Bassia. ssp*, with some chenopod shrubs *Maireana sedifolia*, *Maireana pyramidata*, and minor *Acacia victoriae*.
CHep 1	Light brown to red-brown quartzose silts and sands, with abundant sub-angular to rounded milky quartz with minor lithic clasts and ferruginous gravels (<70 mm). Vegetation dominated by chenopod shrubs *Maireana pyramidata*, and *Atriplex vesicaria*, and minor *Bassia. ssp*.
CHep 2	Light brown to red-brown quartzose slightly micaceous silts and sands with abundant sub-angular lithic clasts and ferruginous gravels with minor sub-angular to rounded milky quartz (<70 mm). Highly weathered bedrock exposures. Gullying into Thompson Creek and scattered rabbit warrens. Vegetation dominated by chenopod shrubs *Maireana pyramidata*, with minor *Bassia. ssp*, and *Acacia canna*.
CHep 3	Light brown to red-brown silts and red, very well-rounded quartzose sands, with minor sub-angular rounded milky quartz (10-50 mm) with minor lithic clasts (<10 mm) and minor fragments of ferruginous regolith. Surfical contour banding of lithic gravels are well developed in some sites. Minor drainage depressions and scattered rabbit warrens. Vegetation dominated by chenopod shrubs *Maireana pyramidata*, with minor *Atriplex vesicaria*, *Acacia aneura* and *Bassia. ssp*.

Figure 4.3: Tibooburra (Racecourse Creek) Regolith-landform 1: 10 000 map and legend.

TRANSPORTED REGOLITH

COLLUVIAL SEDIMENTS — *SHEET FLOW DEPOSITS*

CHpd 1	Light brown to red-brown quartzose, and slightly micaceous silts and sands, with sub-angular to rounded milky quartz with minor lithic clasts (<30 mm), and minor fragments of ferruginous regolith on a low topographical relief. Minor-major gullying into local depressions. Vegetation dominated by chenopod shrubs *Maireana pyramidata*, *Atriplex vesicaria* with minor *Craspedia uniflora*.
CHpd 2	Light brown to red-brown quartzose, silts and sands, with sub-angular to rounded milky quartz with minor lithic clasts (50-100 mm), and exposed well rounded granodiorite boulders on a low topographical relief. Minor-major gullying into local depressions. Vegetation dominated by *Sida petrophila*, with some chenopod shrubs *Maireana pyramidata*, *Atriplex vesicaria* with minor *Acacia victoriae* and *Cassia artemisiodes*.
CHpd 3	Light brown to red-brown quartzose, silts and sands, with sub-angular to rounded milky quartz with minor lithic clasts (10-50 mm) on a low topographical relief. Minor gullying into local depressions. Vegetation dominated by *Sida petrophila*, with some chenopod shrubs *Maireana pyramidata*, *Atriplex vesicara* with minor *Acacia victoria* and *Cassia artemisiodes*.
CHpd 4	Light brown to red-brown quartzose, silts and sands, with sub-angular to rounded milky quartz with minor lithic clasts (5-40 mm), and exposed well rounded granodiorite boulders on a low topographical relief. Minor gullying into local depressions and scattered rabbit warrens. Vegetation dominated by chenopod shrubs: *Maireana pyramidata*, *Atriplex vesicaria* with minor *Acacia victoriae* and *Sida petrophila*.
CHpd 5	Light brown to red-brown quartzose, silts and sands, with sub-angular to rounded milky quartz with minor lithic clasts (5-50 mm), and minor exposures of very well rounded granodiorite boulders on a low topographical relief. Minor gullying into local depressions, scattered rabbit warrens and relic gold diggings. Vegetation dominated by chenopod shrubs *Atriplex vesicaria*, *Maireana pyramidata*, with minor *Maireana sedifolia*, *Acacia victoriae* and *Ptilotus. ssp*.
CHpd 6	Light brown to red-brown quartzose, silts with minor red, very well-rounded quartzose sands, with sub-angular to rounded milky quartz with minor lithic clasts (10-150 mm) and minor metasediment exposures on a low topographical relief. Minor gullying into local depressions. Vegetation dominated by *Bassia. ssp*, with some chenopod shrubs *Maireana sedifolia*, *Maireana pyramidata* and minor *Acacia victoriae*.
CHpd 7	Light brown to red-brown quartzose, silts and sands, with sub-angular to rounded milky quartz with minor lithic clasts (<40 mm), and rounded granodiorite boulders on a topographical low. Minor gullying into local depressions. Vegetation dominated by chenopod shrubs *Maireana sedifolia*, *Sida petrophila*, with minor *Acacia victoriae* and *Cassia artemisiodes*.

FILL — *FILL*

Fm 1	Urban-Tibooburra township, surface lag are highly variable. Vegetation is variable and includes exotic species.

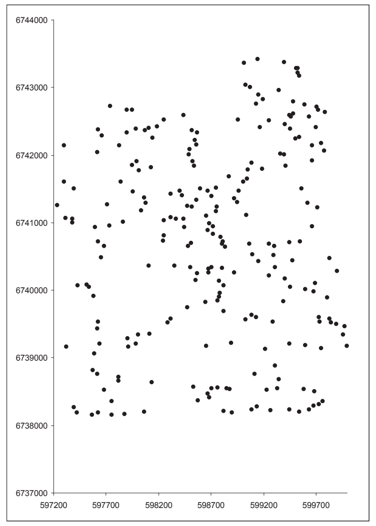
IN-SITU REGOLITH

SAPROLITH — *SAPROCK*

SSel 1	Slightly weathered bedrock, with micaecous fragments, red-brown, coarse angular quartzose sands, on a moderate relief (30-90 m) landsurface. Gullying into local depressions. Vegetation dominated by *Sida petrophila*, *Bassia. ssp*, with sparse chenopod shrubs *Maireana pyramidata*, *Atriplex vesicaria* and minor *Acacia victoriae* and *Acacia tetragonaphylla*.
SSel 2	Slightly weathered bedrock, displaying a preferred NW/SE orientation strike, with light brown to red-brown quartzose silts and sands, and slightly micaceous. Abundant sub-angular lithic clasts and ferruginous gravels with minor sub-angular milky quartz (10-70 mm), on a moderate relief (30-90 m) landsurface. Vegetation dominated by *Bassia. ssp*, with sparse chenopod shrubs *Maireana sedifolia*, *Maireana pyramidata* and *Acacia victoriae*.
SSer 1	Slightly weathered bedrock, with light brown to red-brown quartzose silts and sands, and slightly micaceous. Abundant sub-angular lithic clasts and ferruginous gravels with minor sub-angular to rounded milky quartz (10-70 mm), on a slight relief (9-30 m) landsurface. Minor gullying into local drainage depressions. Vegetation dominated by *Bassia. ssp*, with sparse chenopod shrubs *Maireana sedifolia*, *Maireana pyramidata* and *Acacia victoriae*.
SSer 2	Slightly weathered bedrock, with micaecous fragments, red-brown, coarse angular quartzose sands, on a slight relief (9-30 m) landsurface. Gullying into local depressions. Vegetation dominated by *Sida petrophila*, with sparse chenopod shrubs *Maireana pyramidata*, *Atriplex vesicaria* with minor *Acacia victoriae* and *Acacia tetragonaphylla*.
SSep 1	Slightly weathered bedrock, with micaecous fragments, red-brown, quartzose silts and sands, on a low relief (0-9 m) landsurface. Abundant very angular milky quartz (10-200 mm). Vegetation dominated by chenopod shrubs *Maireana pyramidata*, with minor *Acacia victoriae*.
SSep 2	Slightly weathered bedrock, with micaecous fragments, red-brown, coarse angular quartzose sands, minor well rounded granodiorite boulders, on a low relief (0-9 m) landsurface. Gullying into local depressions. Vegetation dominated by *Sida petrophila*, with some chenopod shrubs *Maireana pyramidata*, *Atriplex vesicaria* and minor *Acacia victoriae* and *Acacia tetragonaphylla*.
SMep 1	Highly weathered bedrock, orange to pale-yellow, slightly micaceous, with coarse angular lithic fragments. Minor rounded milky quartz (50-150 mm) and minor fragments of angular to sub-rounded ferruginous regolith, on a low relief (0-9 m) landsurface. Minor gullying into local drainage depressions. Vegetation dominated by chenopod shrubs *Maireana pyramidata* with minor *Sida petrophila*.

LANDFORMS

- a - Alluvial landforms
- ap - alluvial plain
- pd - depositional plain
- ed - drainage depression
- ar - alluvial channel
- ps - sandplain
- ep - erosional plain (0<9 m)
- er - erosional rise (9<30 m)
- el - erosional low hill (30<90 m)
- m - man made



FIELD SITE LOCATIONS

Figure 4.3: Continued Tibooburra (Racecourse Creek) Regolith-landform 1: 10 000 map legend.

Weathered Bedrock

Various grades of weathered bedrock are exposed within the mapping area, ranging from slightly too moderately weathered. The exposures are predominately associated with rises and hills in the Tibooburra town common, and it also underlies the transported regolith.

Slightly Weathered Bedrock (SS)

Most of the bedrock in the Racecourse Creek catchment is slightly weathered. This includes:

- Devonian Tibooburra Granodiorite and associated intrusives; and,
- Cambrian - Ordovician metasediments of the Easter Monday Beds (Thalhammer *et al.*, 1998).

The slightly weathered granodiorite mostly forms erosional rises covered by round tors (kopies), which are typically spheroidally weathered, with open joints and fractures. These bedrock exposures are predominately in the north and east of the area. In the south of the area, the metasediment exposures typically conform to rises with rounded convex slopes, with linear fractures striking NW/SE. These coherent rocks are characterised by the preservation of > 90 % of their primary minerals. They are generally characterised by minor red-brown ferruginous surface staining, particularly along open cleavage planes.

Slightly weathered bedrock is mainly expressed as erosional rises (er), with moderate topographic relief ranging between 9 – 30 m. Some exposures within the landscape are expressed as erosional plains (ep), with a low topographical relief ranging between 0 – 9 m. Two sites also included exposures as low hills (el), with a moderate to high topographical relief ranging between 30 – 90 m. The units are sub-divided based on their bedrock, weathering style, which is largely a function of bedrock lithology and structure.

Red-brown, coarse angular quartzose sands are deposited along margins of surface exposures and within the open fractures associated with the granodiorite. Light brown to red-brown quartzose silts; sands and slightly micaceous lithic fragments are also deposited along surface exposures, particularly within the cleavage planes.

The vegetation typically associated with the weathered granodiorite is dominated by *Sida petrophila*, *Bassia ssp*. with minor chenopod shrubs such as *Maireana pyramidata*, *Atriplex vesicaria*, with minor *Acacia victoriae* and *Acacia tetragonophylla*. The vegetation associated with the metasediment is dominated by *Bassia ssp* with sparse chenopod shrubs including *Maireana sedifolia, Maireana pyramidata* and minor *Acacia victoriae.*

Moderately Weathered Bedrock (SM)

Minor exposures of moderately weathered bedrock are in the north of the mapping area (e.g. Quarry Hill), where saprolite derived from slightly weathered granodiorite is exposed at the base of the sedimentary sections. This friable saprolite is characterised by > 20 % of the weatherable minerals being altered, whist still retaining fabric of the parent rock (granodiorite). The moderately weathered granodiorite is mostly composed of kaolinite and quartz with some slightly weathered granodiorite corestones. The moderately weathered bedrock is expressed as an erosional plain (ep), with a low topographic relief ranging between 0 – 9 m.

The vegetation associated with the moderately weathered bedrock is dominated by chenopod shrubs including *Maireana pyramidata,* with minor *Sida petrophila* within drainage depressions.

Colluvial Regolith-Landforms (C)

Colluvial sediments are widespread across the mapping area. They especially flank hills and erosional rises and accumulate within depositional landforms. In the mapping area colluvium is mostly deposited by sheetflow, with minor slope creep and rock fall within areas of high relief. Surficial contour banding is in low relief areas in the southwest of the mapping area associated with colluvial rises and depositional plains.

Sheet-flow sediments (CH)

Sheetflow regolith-landform units are associated with depositional plains (CHpd); erosional rises (CHer); and, erosional plains (CHep).

Sheetflow depositional landforms within the landscape include low relief, subtly undulating landforms in regions of deposition, with minor colluvial and alluvial drainage depressions and minor channels. The main types of CHpd units mapped in the area are shown in Table 4.1, and are sub-divided based on their surficial lag.

Table 4.1: A description of the sheet-flow depositional plains regolith-landforms units observed within the Racecourse Creek catchment (Tibooburra).

Regolith-landform units	Distribution	Dominant regolith lithology	Surficial features	Minor attributes	Vegetation
CHpd$_1$	southwest	light brown to red-brown quartzose, and slightly micaceous silts and sands.	minor sub-angular to rounded milky quartz with minor lithic clasts (< 30 mm).	minor fragments of ferruginous regolith.	dominated by chenopod shrubs including *Maireana pyramidata*, *Atriplex vesicaria* with minor *Craspedia uniflora*.
CHpd$_2$	northeast, (surrounding the smaller exposures of the granodiorite).	light brown to red-brown quartzose, silts and sands.	minor sub-angular to rounded milky quartz and minor lithic clasts (approximately 50-100 mm).	minor exposures of rounded granodiorite boulders (tors) are widespread.	colonised by *Sida petrophilia*, with some chenopod shrubs including *Maireana pyramidata*, *Atriplex vesicaria*, with minor *Acacia victoriae* and *Cassia artemisiodes.*
CHpd$_3$	northeast, surrounding the large granodiorite body.	light brown to red-brown quartzose silts and sands.	sub-angular to rounded milky quartz and minor lithic clasts (10-50 mm).	minor fragments of ferruginous regolith.	colonised by *Sida petrophilia*, with some chenopod shrubs including *Maireana pyramidata*, *Atriplex vesicaria*, with minor *Acacia victoriae* and *Cassia artemisiodes.*
CHpd$_4$	northwest, associated with historical Au diggings.	light brown to red-brown quartzose, silts and sands.	sub-angular to rounded milky quartz with minor lithic clasts (5-40 mm).	rounded granodiorite boulders (tors).	dominated by chenopod shrubs including *Maireana pyramidata*, *Atriplex vesicaria*, with minor *Acacia victoriae* and *Sida petrophila.*
CHpd$_5$	northwest, flanking the northwestern margins of the aeolian sandplain.	light brown to red-brown quartzose, silts and sands.	sub-angular to rounded milky quartz and minor lithic clasts (5-50 mm).	rounded granodiorite boulders (tors).	dominated by chenopod shrubs including *Atriplex vesicaria*, *Maireana pyramidata* with minor *Maireana sedifolia*, *Acacia victoriae* and *Ptilotus. ssp*.
CHpd$_6$	southwest, chiefly associated with the weathered metasediment.	light brown to red-brown quartzose, silts with minor red,	sub-angular to rounded milky quartz and minor lithic clasts (10-150	Minor exposure of the metasediment is widespread.	colonised by *Bassia. ssp*, with some chenopod shrubs including *Maireana*

Regolith-landform units	Distribution	Dominant regolith lithology	Surficial features	Minor attributes	Vegetation
		well-rounded quartzose sands.	mm).		*sedifolia*, *Maireana pyramidata*, and minor *Acacia victoriae*.
CHpd$_7$	Northwest, bordering the northwest margins of the granodiorite and the northeast margins of the aeolian sandplains.	light brown to red-brown quartzose silts and sands.	sub-angular to rounded milky quartz with minor lithic clasts (<40 mm).	rounded granodiorite boulders (tors).	Dominated by chenopod shrubs including *Maireana sedifolia*, with some minor *Sida petrophila*, *Acacia victoriae*, and *Cassia artemisiodes*.

Sheet-flow erosional rise landforms are expressed as moderate topographical relief ranging between 9–30 m, incised by colluvial and alluvial drainage depressions and minor alluvial channels. The main types of CHer mapped in the area are shown in (Table 4.2), and are largely sub-divided based on their vegetation.

Table 4.2: A description of the sheet-flow erosional rises regolith-landform units observed within the Racecourse Creek catchment (Tibooburra).

Regolith-landform units	Distribution	Dominant regolith lithology	Surficial features	Minor attributes	Vegetation
CHer$_1$	southwest, where it forms a thin (<1m) cover.	light brown to red-brown quartzose silts and sands.	minor sub-angular to rounded milky quartz (50-100 mm), minor lithic clasts (< 50 mm).	minor fragments of ferruginous regolith.	dominated by chenopod shrubs including *Maireana pyramidata*, with minor *Atriplex vesicaria*, *Acacia aneura* and *Bassia. ssp.*
CHer	northeast	slightly micaceous well-sorted quartzose silts and sands.	minor sub-angular to rounded milky quartz (50-100 mm).	minor fragments of ferruginous regolith.	colonised by chenopod shrubs including *Maireana sedifolia*, with minor *Acacia aneura*, *Bassia. ssp* and *Acetosa vesicaria*.
CHer$_3$	southeast	light brown to red-brown quartzose silts and sands.	minor sub-angular to rounded milky quartz with minor lithic clasts (10-150 mm).	minor metasediment exposures.	dominated by *Bassia. ssp*, with some chenopod shrubs including *Maireana sedifolia*, *Maireana pyramidata*, with minor *Acacia victoriae*.

Sheet-flow erosional plain landforms are expressed as low topographical relief ranging between 0–9 m. They are incised by colluvial and alluvial drainage depressions and minor alluvial channels. The main types of CHep units mapped in the area are shown in Table 4.3 and are largely sub-divided based on their surficial lag.

Table 4.3: A description of the sheet-flow erosional plains regolith-landform units observed within the Racecourse Creek catchment (Tibooburra).

Regolith-landform units	Distribution	Dominant regolith lithology	Surficial features	Minor attributes	Vegetation
CHep$_1$	north and southwest.	light brown to red-brown quartzose silts and sands.	abundant sub-angular to rounded milky quartz (<70 mm).	minor lithic clasts and ferruginous gravels (<70 mm).	dominated by chenopod shrubs including *Maireana pyramidata*, and *Atriplex vesicaria*, with minor *Bassia ssp*.
CHep$_2$	south of the area, flanking the weathered metasediment.	slightly micaceous light brown to red-brown quartzose silts and sands.	abundant sub-angular lithic clasts and ferruginous gravels (<70 mm).	minor sub-angular to rounded milky quartz (<70 mm).	dominated by chenopod shrubs including *Maireana pyramidata*, with minor *Bassia ssp*, and *Acacia cana*.
CHep$_3$	southwest and southeast.	light brown to red-brown silts	minor sub-angular to rounded milky	minor fragments of	dominated by chenopod shrubs particularly

Regolith-landform units	Distribution	Dominant regolith lithology	Surficial features	Minor attributes	Vegetation
		and well rounded quartzose sands.	quartz (10-50 mm) and minor lithic clasts (< 10 mm).	ferruginous regolith.	*Maireana pyramidata*, with minor *Atriplex vesicaria*, *Acacia aneura* and *Bassia. ssp*.

Alluvial Regolith-Landforms (A)

Alluvial sediments are mostly associated with the major contemporary drainage network as erosional drainage depressions in topographically elevated areas. Alluvial landforms consist of alluvial channels (ACar), alluvial plains (Aap), alluvial depositional plains (Apd) and alluvial drainage depressions (Aed).

Alluvial sediments (A)

The main types of ACar in the mapping area are shown in Table 4.4 and are largely sub-divided based on their detrital components. Both units have straight to meandering channel morphologies attenuated by alluvial plains, grading into drainage depressions in headwaters sections.

Table 4.4: A description of the channel deposits alluvial channel regolith-landform units observed within the Racecourse Creek catchment (Tibooburra).

Regolith-landform units	Distribution	Morphology	Dominant regolith lithology	Surficial features	Vegetation
ACar$_1$	north to south major ephemeral channel, single thread reflecting a surrounding substrate control.	channel is approximately 44 m wide, incised up to 1 m adjacent the granodiorite and 2 m downstream adjacent the metasediment.	grey-brown to red-brown quartzose silts and sands.	angular to sub-angular lithic clasts and sub-angular to sub-rounded milky quartz (50-100 mm).	dominated by a riparian woodland of *E. camaldulensis* with minor *Eucalyptus terminalis* and *Eucalyptus microtheca*.
ACar	northeast, minor ephemeral sub-divides the granodiorite.	channel is approximately 30 m wide and is incised up to 30 cm.	grey-brown to red-brown quartzose, silts and sands.	angular to sub-angular lithic clasts and sub-angular to sub-rounded milky quartz (50-100 mm), derived from the weathered granodiorite.	dominated by riparian woodland of *E. camaldulensis* with minor *Eucalyptus terminalis* and *Eucalyptus microtheca*.

The alluvial plains are broad, slightly undulating low topographical relief landforms, with slightly incised channels and drainage depressions. The main types of Aap in the mapping area are shown in Table 4.5 and are largely sub-divided based on their dominant vegetation.

Table 4.5: A description of the alluvial sediments on alluvial plains regolith-landform units observed within the Racecourse Creek catchment (Tibooburra).

Regolith-landform units	Distribution	Dominant regolith lithology	Surficial features	Minor attributes	Vegetation
Aap$_1$	flanks exposed sections of the major ephemeral channel, and occasionally border the lower margins of drainage depressions.	red-brown to grey-brown quartzose, slightly micaceous silts and sands.	very minor sub-angular to rounded milky quartz with minor lithic clasts (10-30 mm)	minor fragments of ferruginous regolith	dominated by chenopods including *Maireana pyramidata*, as well as stands of *E. camaldulensis* with scattered *Acacia victoriae*, *Acacia clivicola* and *Acacia tetragonophylla*.
Aap$_2$	southwest margin of the southernmost ephemeral channel (Thomson Creek)	light brown to red-brown quartzose, slightly	minor sub-angular to rounded milky quartz with	minor fragments of ferruginous regolith.	dominated by *Acacia victoriae* with minor chenopod shrubs including *Atriplex vesicaria* and *Maireana pyramidata*, as

Regolith-landform units	Distribution	Dominant regolith lithology	Surficial features	Minor attributes	Vegetation
		micaceous silts and sands.	minor lithic clasts (10-30 mm)		well as small stands of *E. camaldulensis* and scattered *Myoporum montanum*.

The main three types of Aed units in the mapping area shown in Table 4.6 are upstream of major and minor alluvial channels, forming dendritic networks across the surrounding landforms and terminating in major channels. They are largely sub-divided based on their dominant vegetation.

Aed are elongated drainage depressions ranging from 3–10 m wide within a low relief land surface. They are characterised by heterogeneous regolith materials, which is a reflection of the local lithological units that it has eroded/incised. They are however predominately comprised of red-brown quartzose silts and sands, with minor sub-angular to rounded milky quartz with minor lithic clasts (<5 mm).

Table 4.6: A description of the alluvial sediments in drainage depressions regolith-landform units observed within the Racecourse Creek catchment (Tibooburra).

Regolith-landform units	Vegetation	Geohazard
Aed$_1$	dominated by *E. camaldulensis* with minor chenopod shrubs including *Atriplex vesicaria, Maireana pyramidata*, with small stands of *Eucalyptus microtheca*, and scattered *Acacia victoriae* and *Acetosa vesicaria*.	progressive gullying from surrounding landforms, and minor sink holes.
Aed$_2$	dominated by *Acacia victoriae* and *Sida petrophila* with minor chenopod shrubs including *Atriplex vesicaria, Maireana pyramidata*, and scattered *Cassia artemisiodes*, *Acetosa vesicaria*, and *Solanum ellipticum*.	progressive gullying from surrounding landforms, and minor sink holes.
Aed$_3$	dominated by *Eucalyptus terminalis*, with minor *Acacia victoriae*, *Casuarina cristata. ssp pauper*, with patches of *Solanum ellipticum* , *Sida petrophila*, and *Acetosa vesicaria*.	progressive gullying from surrounding landforms, and minor sink holes.

The main types of Apd units in the mapping area are shown in Table 4.7. They flank minor alluvial channels and have a low relief land surface with slightly incised channels and drainage depressions. They are largely sub-divided based on their regolith material.

Table 4.7: A description of the alluvial sediments depositional plains regolith-landform units observed within the Racecourse Creek catchment (Tibooburra).

Regolith-landform units	Distribution	Dominant regolith lithology	Surficial features	Minor attributes	Vegetation
Apd$_1$	northern margin of Thomson Creek.	light brown to red-brown quartzose, slightly micaceous silts and sands.	minor sub-angular to rounded milky quartz and minor lithic clasts (< 10 mm).	minor fragments of ferruginous regolith.	dominated by chenopod shrubs including *Maireana pyramidata*, minor *Eucalyptus microtheca*, and juvenile *E. camaldulensis* and *Craspedia uniflora*.
Apd$_2$	generally associated with the granodiorite in the northeast.	light brown to red-brown quartzose, slightly micaceous silts and red, rounded quartzose sands	abundant sub-angular to sub-rounded milky quartz with minor lithic clasts (<15 mm)	minor fragments of ferruginous regolith.	colonised by chenopod shrubs including *Maireana pyramidata*, and *Atriplex vesicaria*, with minor *Bassia. ssp*.
Apd$_3$	north-northwest, flanking Aed's associated with the aeolian sandplain and historic Au workings.	light brown to red-brown quartzose, slightly micaceous silts and red, rounded quartzose sands.	minor sub-angular to rounded milky quartz with minor lithic clasts (< 10mm).	minor fragments of ferruginous regolith.	dominated by chenopod shrubs including *Atriplex vesicaria*, *Maireana pyramidata*, and minor *Acacia victoriae* and *Bassia. Ssp*.

Aeolian Regolith-Landforms (I)
Aeolian deposits consist of sediments that have been transported and deposited by the wind. Five aeolian regolith-landform units were recognised across the mapping area. Aeolian sediments range from forming a minor component of all regolith materials on rises and hillcrests to forming their own landforms such as sandplains in the low-lying settings. Aeolian landforms consist of aeolian sand on sandplains (ISps) and aeolian sands on depositional plains (ISpd).

Aeolian sand (IS)
The main five types of ISps units in the mapping area are shown in Table 4.8 and Table 4.9 and occur across the northwestern margin of the mapping area. The ISps units are associated with a moderate relief, slightly undulating landforms with minor incised channels and drainage depressions. A prominent feature of the aeolian sandplains is the formation of coppice dunes, associated with the baffling and deposition of sands at the base of the vegetation. The ISps units have been largely sub-divided based on their surficial lags.

Table 4.8: A description of aeolian sediments sandplains regolith-landform units observed within the Racecourse Creek catchment (Tibooburra).

Regolith-landform units	Dominant regolith lithology	Surficial features	Minor attributes	Vegetation	Geohazard
$ISps_1$	red, well-rounded quartzose sands, with slightly micaceous silts	minor sub-angular to rounded milky quartz and minor lithic clasts (< 5 mm)	minor fragments of ferruginous regolith.	dominated by chenopod shrubs including *Maireana sedifolia*, with minor *Acacia aneura* and *Rhodanthe floribunda*.	minor-major gulling into Racecourse Creek and surrounding Aed units.
$ISps_2$	red, rounded quartzose sands	minor very angular milky quartz (5-30 mm).	minor fragments of ferruginous regolith.	dominated by *Acacia aneura*, *Maireana pyramidata*, with minor *Acacia victoriae*.	minor gulling with local bedrock exposures.

The following units **$ISps_3$, $ISps_4$ and $ISps_5$** are characterised by red, well-rounded quartzose sands with abundant iron-oxide stained sub-angular to rounded milky quartz clasts (5-30 mm). These units have been largely sub-divided based on their on their dominant vegetation.

Table 4.9: The description of aeolian sediments sandplains regolith-landform units observed within the Racecourse Creek catchment (Tibooburra).

Regolith-landform units	Vegetation	Geohazard
$ISps_3$	dominated by sparse *Acacia aneura* with minor chenopod shrubs including *Maireana pyramidata*, *Acacia tetragonophylla*, and scattered *Ptilotus. ssp*. and mitchell grasses.	minor gulling with local bedrock exposures.
$ISps_4$	dominated by dense communities of *Acacia aneura* with minor chenopod shrubs including *Maireana pyramidata*, *Acacia tetragonophylla*, and scattered *Ptilotus. ssp*. and mitchell grasses.	minor-major gulling with local bedrock exposures.
$ISps_5$	dominated by *Eremophila duttonii*, with minor *Acacia aneura*, *Bassia. ssp*, and *Ptilotus. ssp*.	minor gulling with local bedrock exposures.

A single $ISpd_1$ unit was recorded across the northwestern margin of the mapping area. It has a low relief land surface with slightly incised drainage depressions consisting of red, well-rounded quartzose sands with minor very angular milky quartz (5-50 mm), and minor fragments of ferruginous regolith. Vegetation is dominated by *Maireana sedifolia*, *Acacia clivicola*, and *Maireana pyramidata*, with minor *Rhodanthe floribunda*.

4.3 BIOGEOCHEMICAL ATLAS

The biogeochemical maps provide an efficient and convenient method for illustrating the spatial distribution of detectable elements in a regolith-landform context. Boxplots, histograms and cumulative frequency graphs provide statistical information in addition to the maps. To further aid in the interpretation of the maps a page, for each element, of 'background' information on the chemical characteristics, geochemical characteristics and biogeochemical characteristics is also included (Appendix D).

4.3.1 Statistical Analyses

Forty-three elements were analysed by INAA, ICP-MS and ICP-OES. The total chemical composition of the *E. camaldulensis* is included in Appendix E. The concentrations for the following elements were below analytical detection limits: Sb, Cs, Hf, Ir, Se, Ta, In, Te, TI, Th, V, U, Zr, Be, Bi, Pb, Mo, Eu, La, Yb, and Ga. The chemical composition of twenty-five elements was detectable from *E. camaldulensis* leaf tissue samples taken across the granodiorite and metasediment along Racecourse Creek, of which twenty elements had 75 % of their values above their detection limit. The Student's T-test is a statistical method that assesses whether the means of two groups are statistically similar or different from each other. The results revealed for the majority of the selected twenty elements (Table 4.11) that the null hypothesis **"There are no significant differences between the means and that both groups are derived from the same population",** at a significance level of 0.05 was rejected and that within the data there are multiple populations. These populations are thought to be defined as:

- Tibooburra (Racecourse Creek): *E. camaldulensis* adjacent to the granodiorite and those flanking the metasediment.

However, Ca, Rb, Cu, Mg, Mn and Sr supported the null hypothesis, suggesting that these elements are derived from one population. The similarity in the concentrations for the *E. camaldulensis* across the catchment, given the large difference between the whole rock chemistry, are most likely a response to the strong landscape control in the region. The elements Ca, Cu, Mg and Mn are generally considered to be essential, while Rb is generally considered an analog for Na; likewise Sr is an anolg for Ca, if either were a limiting factor.

Elements (ppm)	**Granodiorite RRG Leaves** (n=38)	**Metasediment RRG Leaves** (n=25)	**Granodiorite WR**	**Metasediment WR**
Ca	11996 (8110 – 22000)	12514 (7370 – 21100)	329	1708
Rb	2.82 (* - 10.40)	3 (* - 8)	11	221
Cu	4 (2.00 – 8.00)	3 (2 – 7)	4	50
Mg	2496 (1768 – 3925)	2731 (1984 – 3554)	326	17029
Mn	160 (73 – 344)	207 (71 – 600)	108	519
Sr	87 (50 – 192)	81 (46 – 166)	219	136

Table 4.10: Variations of Ca, Rb, Cu, Mg,Mn and Sr concentration in oven dried tissue (leaves) of individual river red gums (RRG) across two bedrock substrates. Metal concentration in whole rock (WR) chemistry of the granodiorite and metasediment. Initial value represents the mean value ± 1sigma; values in brackets() are the range of values. * denotes below detection limit. To calculate means, below detection limit values were taken as half the detection limit value. Values with a mean but no range recorded represent only one sample in that set. n= the number of samples recovered.

Element	Mean	Variance	Observations	df	t Stat	P(T<=t) two-tail
As (Granodiorite)	0.073	0.008	58	96	4.262632996	4.7E-05
As (Metasediment)	0.006	0.004	40			
Al (Granodiorite)	85	574	58	51	-7.296421508	1.9E-09
Al (Metasediment)	147	2493	40			
Ba (Granodiorite)	44	205	58	90	3.018052027	3.3E-03
Ba (Metasediment)	36	161	40			
Br (Granodiorite)	10	17	58	82	-2.684388826	8.8E-03
Br (Metasediment)	13	19	40			
Ca (Granodiorite)	11845	8781587	58	81	-0.261199644	7.9E-01
Ca (Metasediment)	12010	9887223	40			
Cu (Granodiorite)	4	3	58	96	1.172061748	2.4E-01
Cu (Metasediment)	4	1	40			
Fe (Granodiorite)	100	443	58	74	-5.308426569	1.1E-06
Fe (Metasediment)	126	628	40			
K (Granodiorite)	8591	1945245	58	62	-2.746435655	7.9E-03
K (Metasediment)	9643	4524123	40			
Mg (Granodiorite)	2518	240061	58	90	-1.554011899	1.2E-01
Mg (Metasediment)	2663	186970	40			
Mn (Granodiorite)	162	7180	58	86	-1.447150122	1.5E-01
Mn (Metasediment)	186	6736	40			
Na (Granodiorite)	290	165664	58	84	0.245541075	8.1E-01
Na (Metasediment)	269	164128	40			
Nd (Granodiorite)	0.08	0.0004	58	66	-6.598904176	8.3E-09
Nd (Metasediment)	0.12	0.00	40			
Ni (Granodiorite)	3	0.8	58	88	-3.87944322	2.0E-04
Ni (Metasediment)	3	0.7	40			
P (Granodiorite)	1295	194426	58	96	3.37151743	1.1E-03
P (Metasediment)	1047	82202	40			
Rb (Granodiorite)	2	7	58	81	0.060513344	9.5E-01
Rb (Metasediment)	2	8	40			
S (Granodiorite)	1059	11612	58	67	-3.689316203	4.5E-04
S (Metasediment)	1159	21269	40			
Sc (Granodiorite)	0.03	0.0001	58	74	-4.822512507	7.4E-06
Sc (Metasediment)	0.04	0.00008	40			
Sm (Granodiorite)	0.02	0.00002	58	78	-8.902751352	1.7E-13
Sm (Metasediment)	0.03	0.00002	40			
Sr (Granodiorite)	85	732	58	91	1.663196383	1.0E-01
Sr (Metasediment)	77	554	40			
Zn (Granodiorite)	22	107	58	89	-3.219374252	1.8E-03
Zn (Metasediment)	29	86	40			

Table 4.11: The two tailed t-statistical test for *E. camaldulensis* (Tibooburra) reveals that the majority of the elements have p-values less than 0.05, rejecting the null hypothesis of equal means.

In order to better define the popoulations within the data, the data were subjected to futher statistical analysis through the application of factor analysis (Principal components analysis). Charactersitics of principal components are as follows:

- the first component extracted accounts for a maximal amount of the total variance in the observed variables;
- the second component extracted will account for a maximal of variance in the data set that was not accounted for by the first component, and that it will be uncorrelated with the first component; and,
- the third component extracted will account for a maximal of variance in the data set that was not accounted for by the second component, and that it will be uncorrelated with the second component.

Using principal component analysis interrelationships (Table 4.12) within the data can be defined and provide a basis for explaination for these relationships.

Rotated Component Matrix				
	Component			
	1	2	3	4
As	-0.375	-0.255	0.213	-0.069
Ba	-0.153	-0.067	0.897	0.077
Br	0.075	0.177	-0.052	0.079
Ca	-0.201	0.037	0.848	-0.115
Fe	-0.355	0.787	-0.051	-0.042
La	0.18	0.747	0.138	0.286
K	0.056	0.088	-0.24	0.819
Rb	-0.026	-0.013	0.173	0.764
Sm	0.182	0.803	0.08	-0.092
Sc	0.224	0.821	-0.185	-0.021
Na	0.023	0.049	0.035	-0.47
Th	-0.754	0.306	0.085	0.149
Al	0.855	0.318	-0.154	0.059
Cu	0.921	0.062	-0.042	0.051
Mg	0.954	0.092	-0.105	-0.041
Mn	0.865	0.151	0.011	0.068
Nd	0.918	0.28	-0.112	0.088
Ni	0.19	0.119	-0.003	0.081
P	0.919	0.027	-0.112	-0.008
S	0.957	0.079	-0.167	-0.03
Sr	0.93	0.05	0.036	-0.097
Zn	0.523	0.157	0.294	0.19
Au	-0.451	-0.103	0.165	-0.108
Ce	-0.819	0.264	0.192	-0.114
Mo	-0.345	-0.136	-0.015	-0.062

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a Rotation converged in 11 iterations.

Total Variance Explained			
	Initial Eigenvalues		
Componen	Total	% of Variance	Cumulative %
1	9.512	38.049	38.049
2	3.124	12.496	50.545
3	1.823	7.292	57.837
4	1.725	6.899	64.736

Table 4.12: Principal component analysis, the table lists the components in order of their eigenvalues, with the first component being the most relevant.

First component elements, Al, Cu, Mg, Mn, Nd, P, S and Sr, are chemical characteristics for both the granodiorite and metasediment as shown in Table 4.13. The results suggest that the *E. camaldulensis* are possibly more akin to being chemical "amalgamators" of their surrounds rather than chemical "penetrators" and only expressing the immediately underlying bedrock.

Table 4.13: Variations of Al, Cu, Mg, Mn, Nd, P, S and Sr concentration in oven dried tissue (leaves) of individual river red gums (RRG) across two bedrock substrates. Metal concentration in whole rock (WR) chemistry of the granodiorite and metasediment. Initial value represents the mean value ± 1sigma; values in brackets() are the range of values. To calculate means, below detection limit values were taken as half the detection limit value. Values with a mean but no range recorded represent only one sample in that set. n= the number of samples recovered.

Elements (ppm)	**Granodiorite RRG Leaves** (n=38)	**Metasediment RRG Leaves** (n=25)	**Granodiorite WR**	**Metasediment WR**
Al	87 (51– 166)	123 (55 – 206)	26930	90901
Cu	4 (2.00 – 8.00)	3 (2 – 7)	4	50
Mg	2496 (1768 – 3925)	2731 (1984 – 3554)	326	17029
Mn	160 (73 – 344)	207 (71 – 600)	108	519
Nd	0.083 (0.05 – 0.13)	0.11 (0.05 – 0.15)	12	39
P	1448 (924 – 3166)	978 (654 – 1574)	401	794
S	1046 (857 – 1291)	1157 (958 – 1464)	248	1490
Sr	87 (50 – 192)	81 (46 – 166)	219	136

The second component elements, Fe, La, Sm and Sc, are associated with Mn-oxides as they are particularly good scavengers, and resistate minerals (Table 4.14). Rare earth elements occur as trace elements in most rock forming minerals, such as those that constitue the granodiorite (apatite, zircon and feldspars) and metasediment (pryroxenes, zircon and apatite). In addition, these resistate minerals can become concentrated within the regolith, and the rare earth elements can become mobile when hosted by such minerals (Ackerman, 2005).

Table 4.14: Variations of Fe, La, Sm and Sc concentration in oven dried tissue (leaves) of individual river red gums (RRG) across two bedrock substrates. Metal concentration in whole rock (WR) chemistry of the granodiorite and metasediment. Initial value represents the mean value ± 1sigma; values in brackets() are the range of values. To calculate means, below detection limit values were taken as half the detection limit value. Values with a mean but no range recorded represent only one sample in that set. n= the number of samples recovered.

Elements (ppm)	**Granodiorite RRG Leaves** (n=38)	**Metasediment RRG Leaves** (n=25)	**Granodiorite WR**	**Metasediment WR**
Fe	100 (56 – 139)	119 (88 – 147)	4364	56343
La	0.10 (0.06 – 0.18)	0.116 (0.07 – 0.17)	16	45
Sm	0.025 (0.018 – 0.032)	0.031 (0.021 – 0.039)	2	7
Sc	0.032 (0.015 – 0.049)	0.038 (0.029 – 0.053)	2	17

The third component elements, Ba and Ca, are associated with the carbonates Table 4.15 shows that the metasediment has the greatest concentration of both Ba and Ca compared to the granodiorite. However, the *E. camaldulensis* trees adjacent to both outcrops are similar.

Table 4.15: Variations of Ba and Ca concentration in oven dried tissue (leaves) of individual river red gums (RRG) across two bedrock substrates. Metal concentration in whole rock (WR) chemistry of the granodiorite and metasediment. Initial value represents the mean value ± 1sigma; values in brackets() are the range of values. To calculate means, below detection limit values were taken as half the detection limit value. Values with a mean but no range recorded represent only one sample in that set. n= the number of samples recovered.

Elements (ppm)	**Granodiorite RRG Leaves** (n=38)	**Metasediment RRG Leaves** (n=25)	**Granodiorite WR**	**Metasediment WR**
Ba	44 (21 - 77)	40 (17 – 89)	104	1240
Ca	11996 (8110 – 22000)	12514 (7370 – 21100)	329	1708

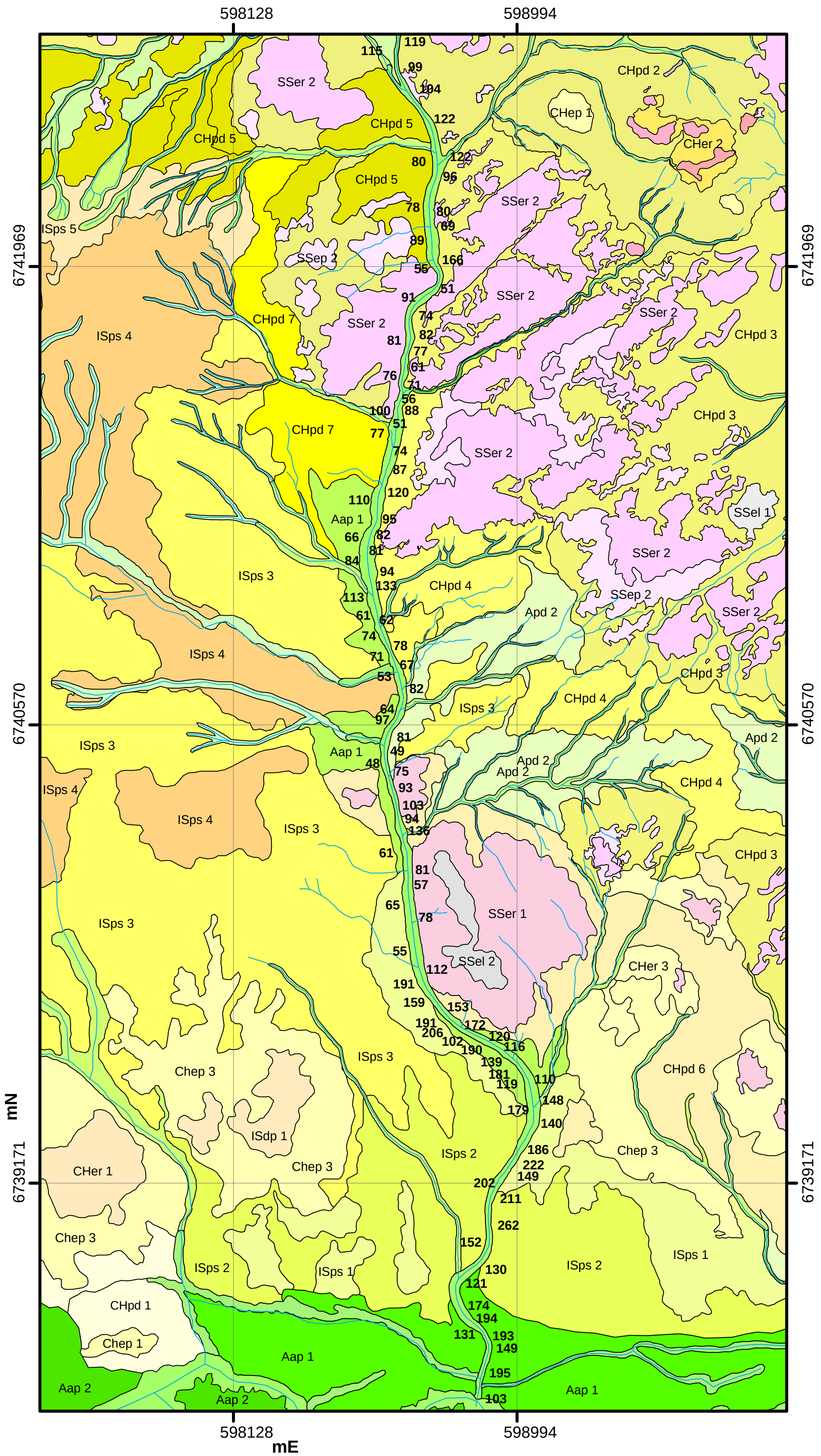
4.3.2 Biogeochemical Analyses

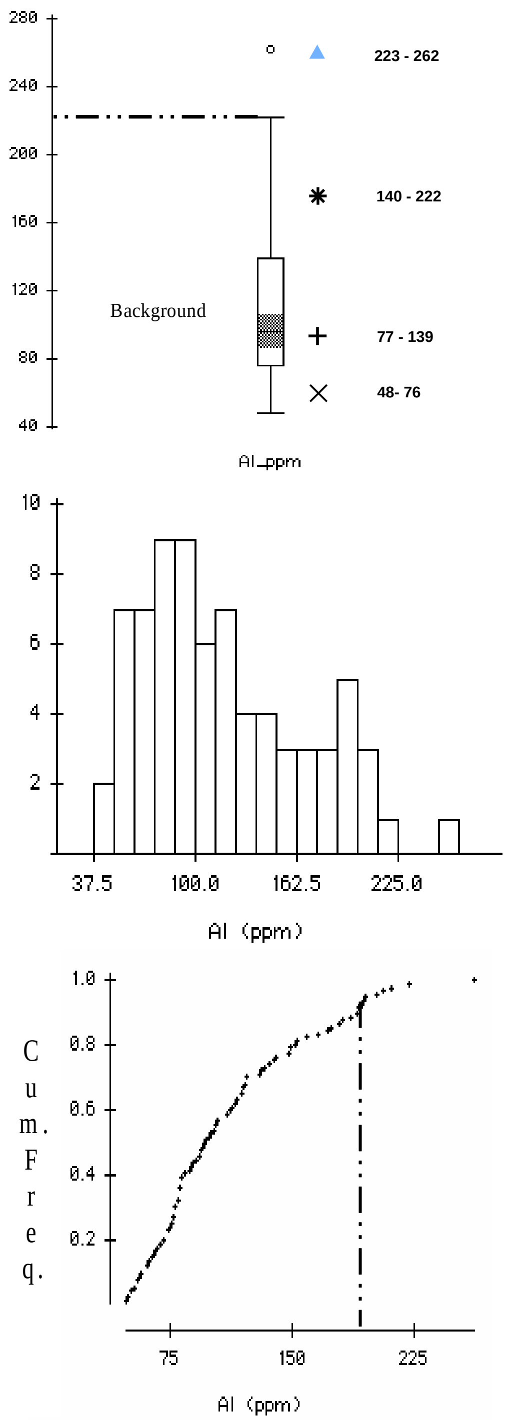
The biogeochemical patterns for the elements highlighted by the principal componet analysis to display interrelationship (Table 4.12) are described with the aid of elemental scatter plots, boxplot comparisons and biogeochemical maps. Results are in order of eigenvalues, with the first component being the most relevant. A total of eight maps are provided in regards to the first component, followed by one map representative for each other component. For all other elements (biogeochemical maps) see appendix F.

4.3.3 Eucalyptus camaldulensis

There are few linear elemental relationships derived from the *E. camaldulensis* leaf analytical results. The rare earth elements (REEs), such as La, Nd and Sm, have strong linear relationships with Fe and Sc, with correlation co-efficients ranging between Fe; $r_s = 0.754$ – 0.827 and Sc; $r_s = 0.740$ - .758. Other elements also showed strong positive relationships, such as: Ca – Sr ($r_s = 0.906$); Fe – Sc ($r_s = 0.964$); Fe – Th ($r_s = 0.704$); Fe – Al ($r_s = 0.777$); Al – Sm ($r_s = 0.754$); Sc – Th ($r_s = 0.729$); Sc – Al ($r_s = 0.770$); and, Al – Nd ($r_s = 0.746$). The results of ninety eight *E. camaldulensis* leaves generally did not reveal biogeochemical patterns for the changes in underlying bedrock lithologies, however there appears to be a significant regolith-landform association reflected in the results. Tables 4.16 – 4.25 and accompanying biogeochemical maps (all even numbered figures between – Figure 4.22) and assay results relative to their landscape setting (all odd numbered figures between Figure 4.5– Figure 4.23) summarises the *E. camaldulensis* element assays for Racecourse Creek. All

E. camaldulensis (leaves) Biogeochemistry
Racecourse Creek Tibooburra W/NSW - (Al)

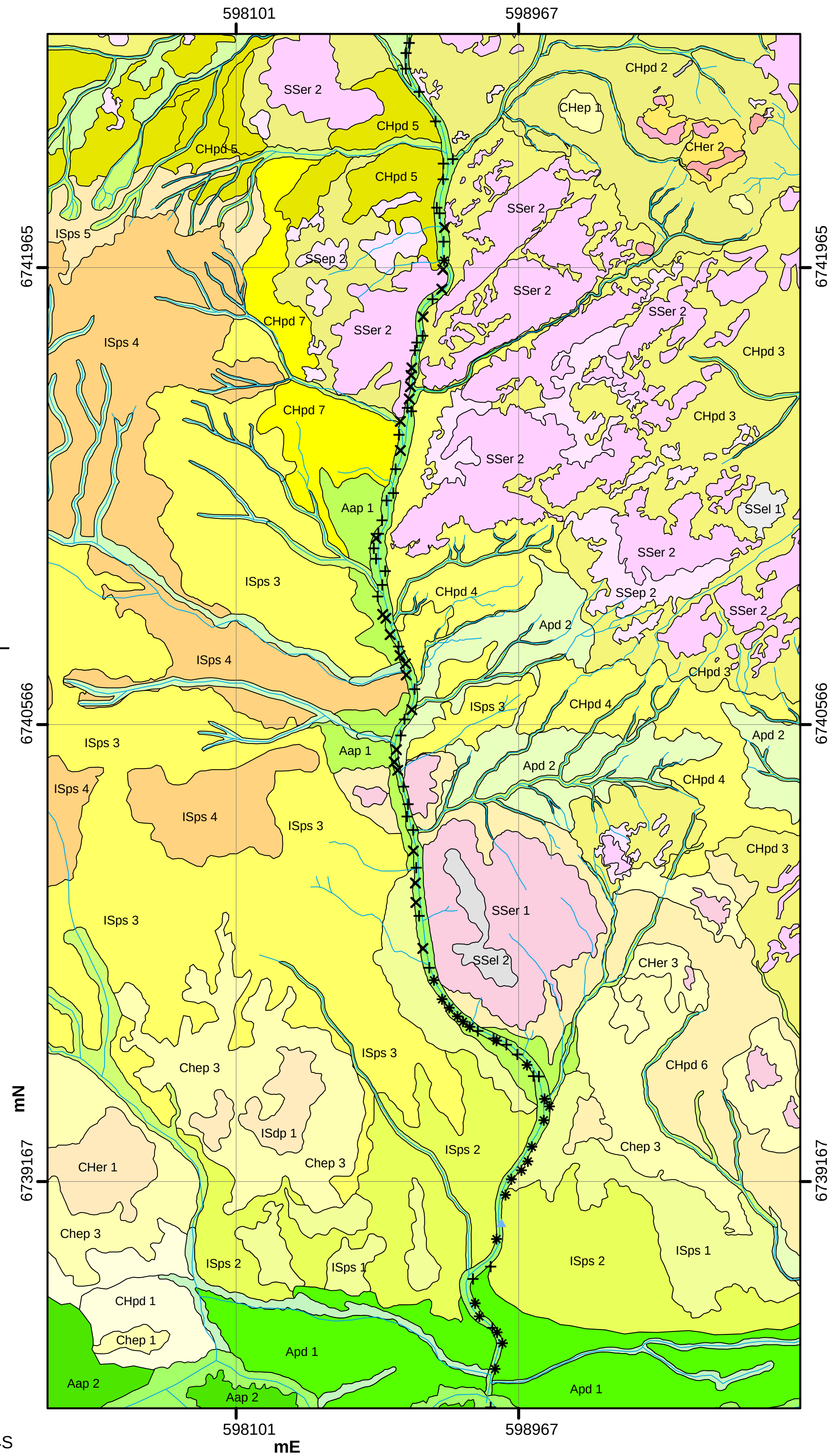




Al ppm

Summary Statistics

Count	98
Max	262
Min	48
Mean	110
Median	96
StdDev	48
StdErr	5
Range	214
Det Limit	20 ppm



HORIZONTAL DATUM: WGS84, UTM ZONE 54S

Figure 4.4: Raw data and spatial distribution of detectable Al in *E. camaldulensis* (leaves) down Racecourse Creek with accompanying boxplots, histogram, cumulative frequency plot and summary statistics.

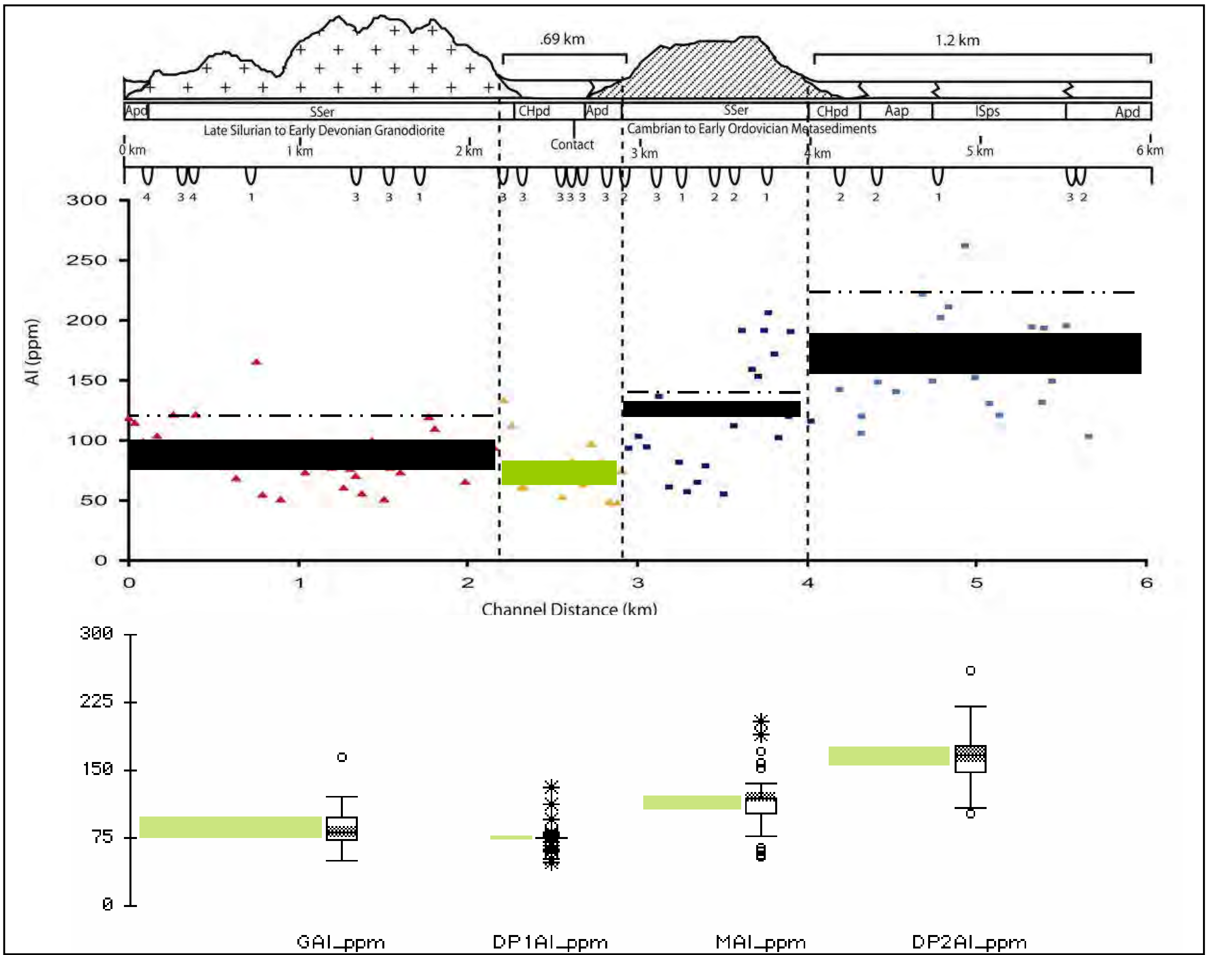
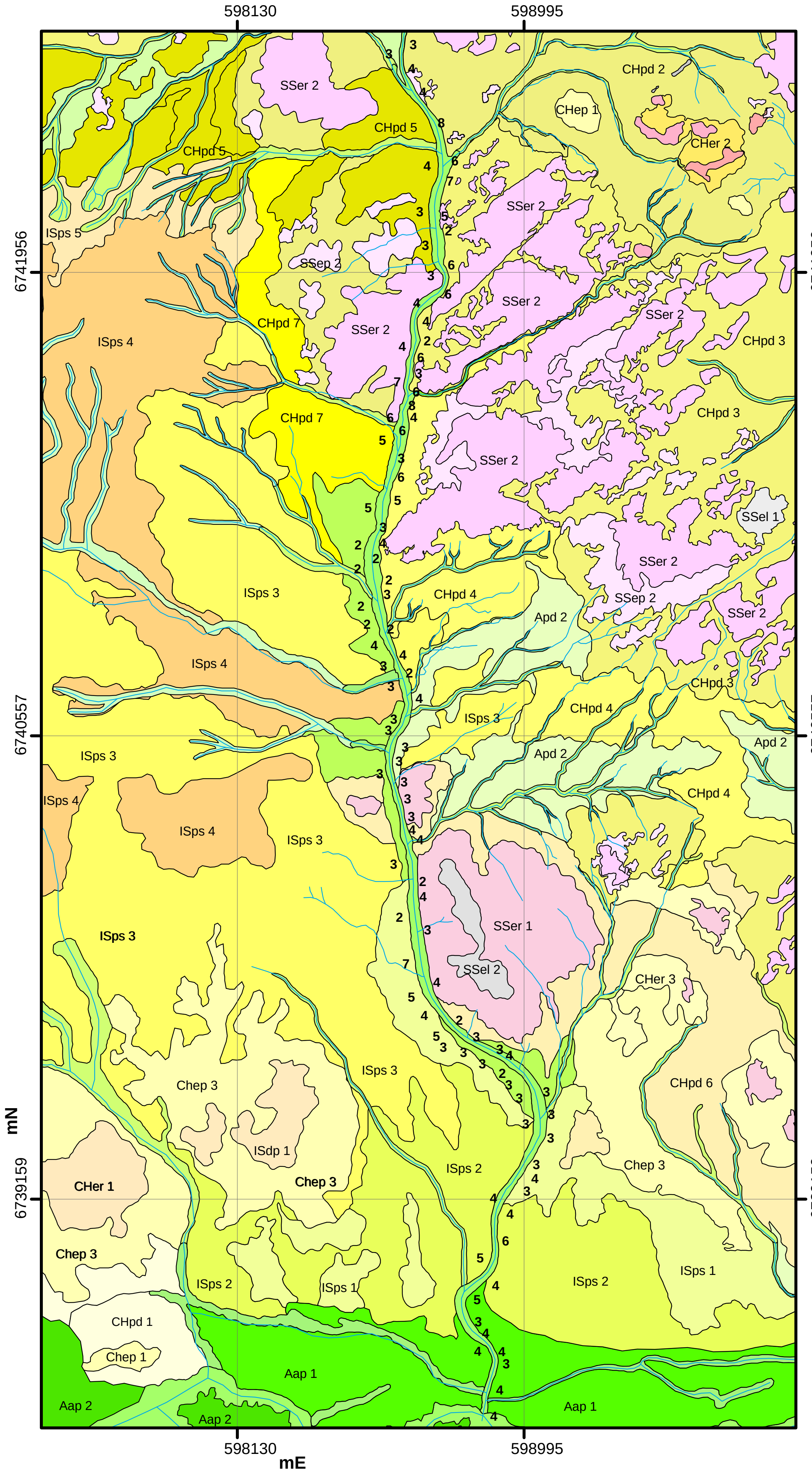


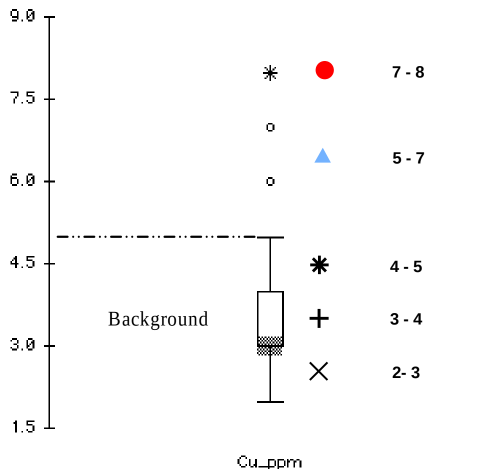
Figure 4.5: Al concentrations within *E. camaldulensis* leaves flanking different landform settings along Racecourse Creek, G (granodiorite), DP1 (depositional 1), M (metasediment) and DP2 (depositional 2). Green region denotes 'values below the mean' and the dashed line indicates the 90th percentile.

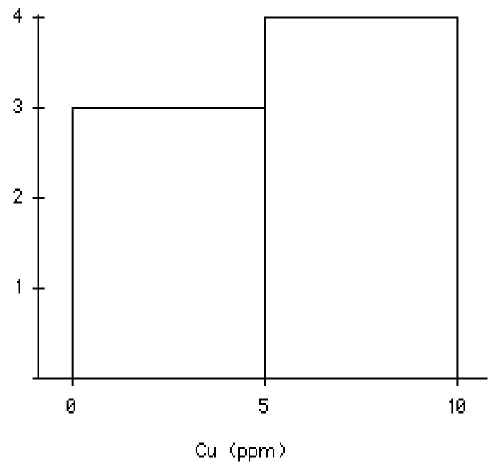
Element (ppm) [detection limit] Analytical Method	Parameters	Total data set (C) n=98	Setting				Data set comparison
			Granodiorite (SSer) (C) n=38	Upper catchment depositional (CHpd and Apd) (C) n=16	Metasediment (SSer) (C) n=25	Lower catchment depositional (CHpd, Aap, ISps and Apd) (C) n=19	
Al [20] ICP-OES	Concentration range (Mean)	48-262 (110)	51-166 (87)	48-133 (75)	55-206 (120)	103-262 (164)	Regolith-landforms units associated with the granodiorite & upper catchment depositional similar at the 5% Sig Level in their median conc^{n}.
	25^{th} - 75^{th} percentile	76-139	74-99	61.5-81.5	103-120	149-179	
	95% confidence level	10	8	12	22	17	
	>90th percentile (outliers), # of samples	262 (1)	166 (1)	113-133 (2)	190-206 (4)	262 (1)	Regolith-landforms associated with the metasediment & lower catchment depositional different at the 5% Sig Level in their median conc^{n}.
	E. camaldulensis position with the greatest concentration.	northern part of Racecourse Ck	northern margin of granodiorite	northern margin & down stream of intersecting Aed unit	southern margin	central & adjacent to flanking Aeolian sand plain	

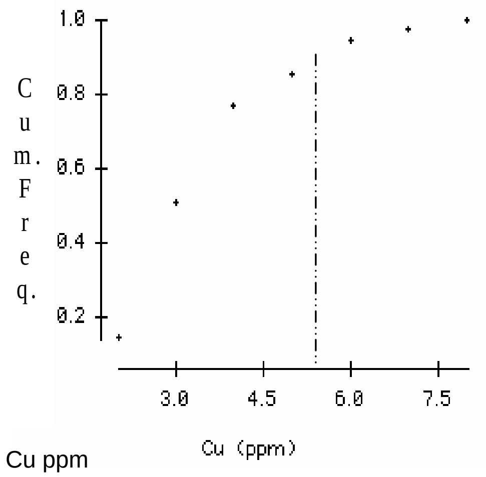
Table 4.16: Variation of Al concentrations within *E. camaldulensis* s (river red gums), flanking different land-form settings along Racecourse Creek. Initial values concentration range, 25^{th} - 75^{th} percentile concentration range, 95 % confidence level, >90^{th} percentile (outliers) C= composite sample.

E. camaldulensis (leaves) Biogeochemistry
Racecourse Creek Tibooburra W/NSW - (Cu)





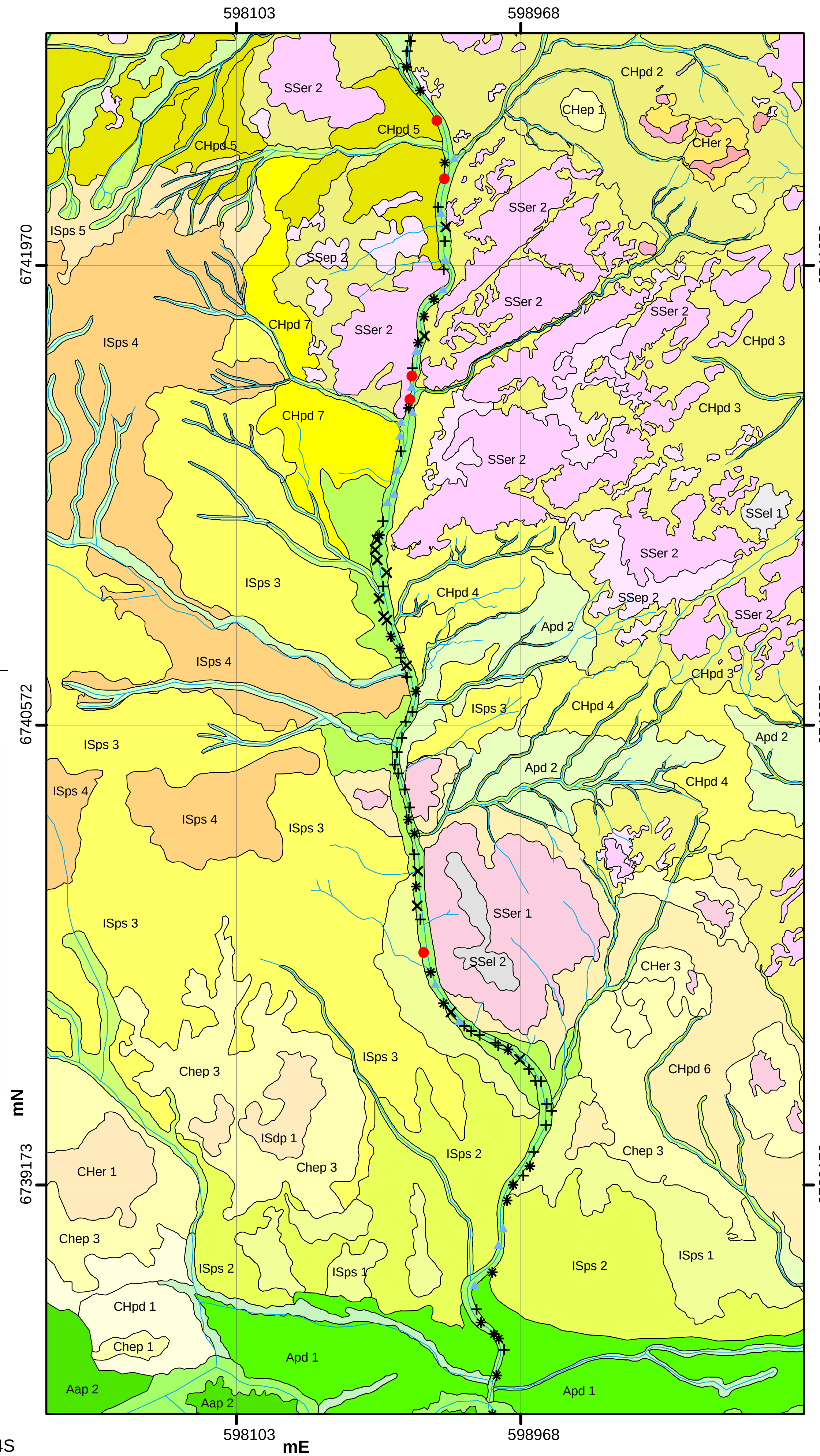




Cu ppm

Summary Statistics

Count	98
Max	8
Min	2
Mean	4
Median	3
StdDev	1
Range	6
Det Limit	1 ppm



HORIZONTAL DATUM: WGS84, UTM ZONE 54S

Figure 4.6: Raw data and spatial distribution of detectable Cu in *E. camaldulensis* (leaves) down Racecourse Creek with accompanying boxplots, histogram, cumulative frequency plot and summary statistics.

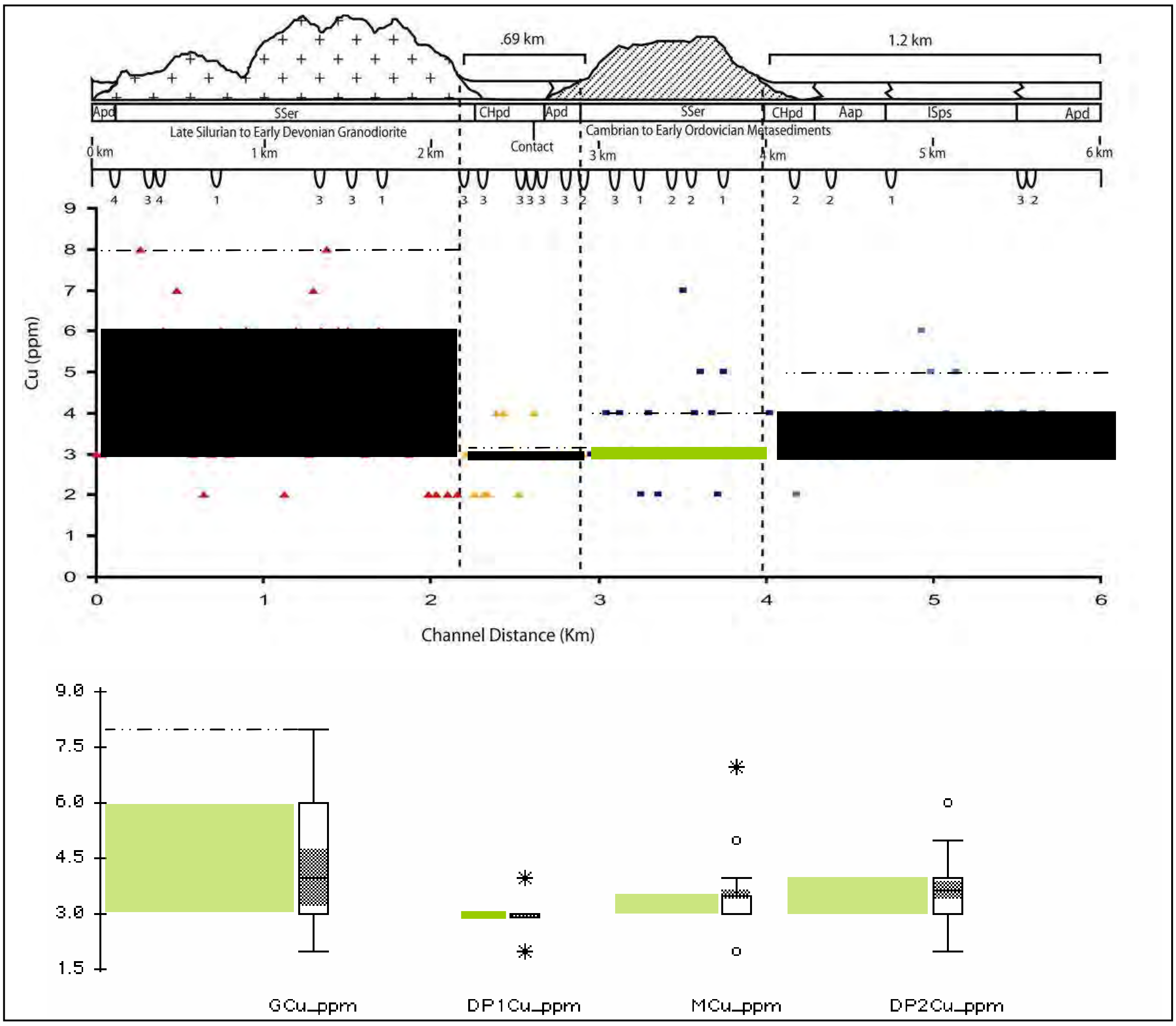
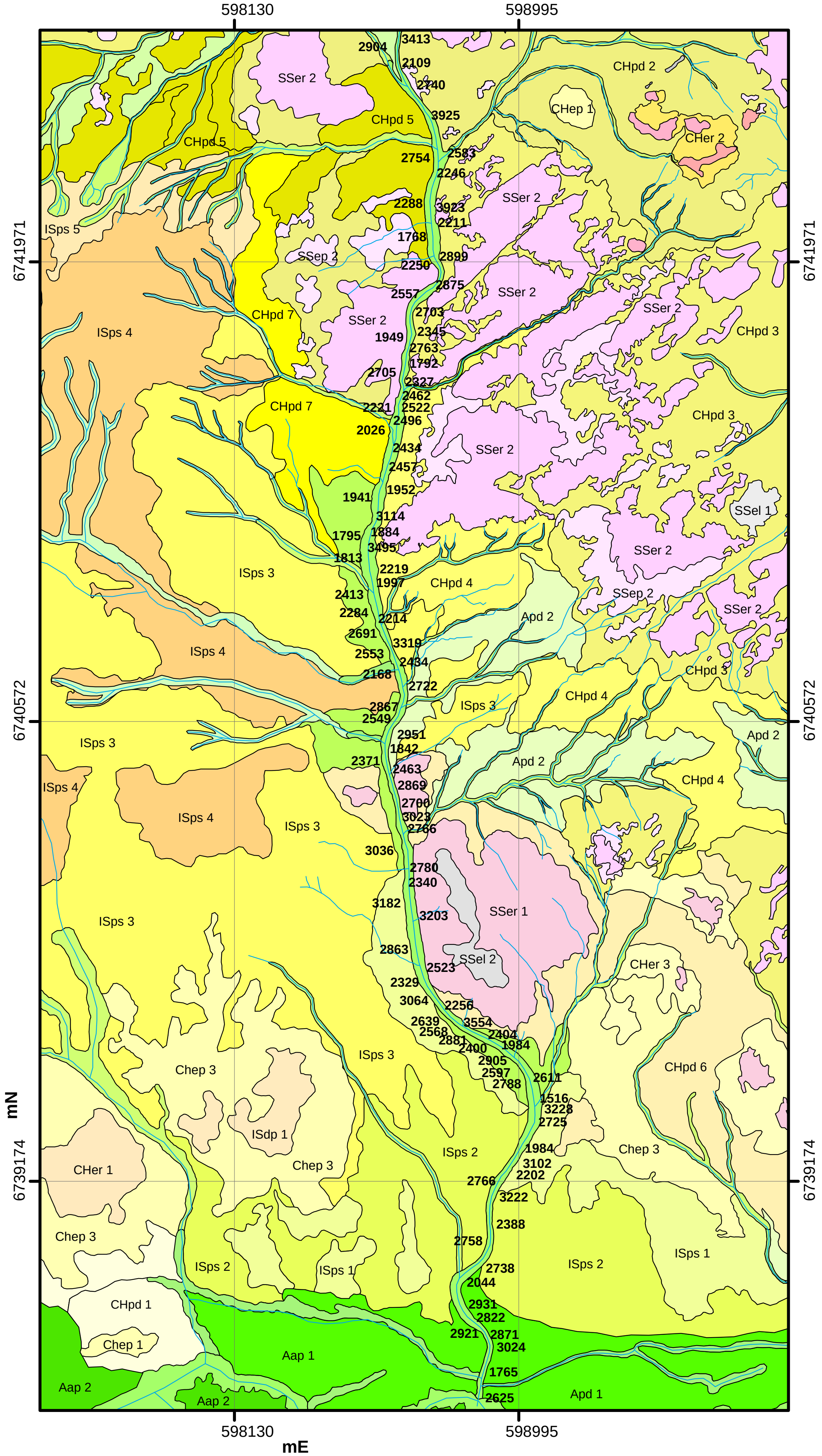


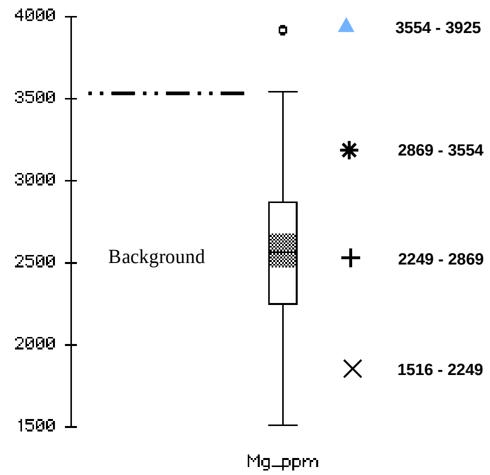
Figure 4.7: Cu concentrations within *E. camaldulensis* leaves flanking different landform settings along Racecourse Creek, G (granodiorite), DP1 (depositional 1), M (metasediment) and DP2 (depositional 2). Green region denotes 'values below the mean' and the dashed line indicates the 90th percentile.

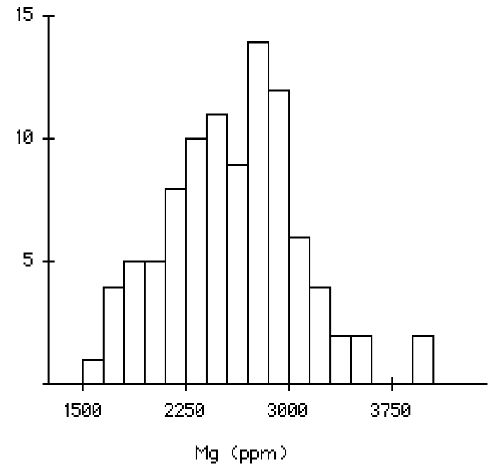
Element (ppm) [detection limit] Analytical Method	Parameters	Total data set (C) n=98	Setting				Data set comparison
			Granodiorite (SSer) (C) n=38	Upper catchment depositional (CHpd and Apd) (C) n=16	Metasediment (SSer) (C) n=25	Lower catchment depositional (CHpd, Aap, ISps and Apd) (C) n=19	
Cu [1] ICP-OES	Concentration range (Mean)	2-8 (4)	2-8 (4)	2-4 (3)	2-7 (3)	2-6 (4)	Regolith-landform units associated with the granodiorite, metasediment & lower catchment depositional display similarities at approximately the 5 % Sig level.
	25^{th} - 75^{th} percentile	3-4	3-6	2.5-3	3-3.5	3-4	
	95% confidence level	0.3	0.6	0.4	0.5	0.4	
	>90th percentile (outliers), # of samples	6-8 (14)	No outliers'	4 (1)	7 (1)	6 (1)	While the upper catchment depositional has a major difference at the 5 % significance level between all other regolith-landforms.
	E. camaldulensis position with the greatest concentration.	northern part of Racecourse Ck	northern & central margin of granodiorite, flanked by CHpd3, CHpd4 & CHpd5	central & down stream of intersecting Aed unit	central & adjacent to flanking ISps1	central & adjacent to flanking ISps2	

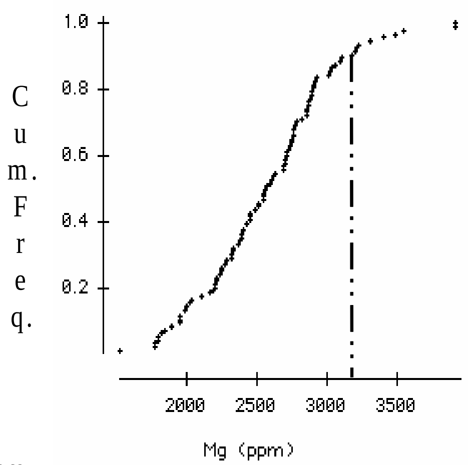
Table 4.17: Variation of Cu concentrations within *E. camaldulensis* s (river red gums), flanking different land-form settings along Racecourse Creek. Initial values concentration range, 25^{th} - 75^{th} percentile concentration range, 95 % confidence level, $>90^{th}$ percentile (outliers) C= composite sample.

E. camaldulensis (leaves) Biogeochemistry
Racecourse Creek Tibooburra W/NSW - (Mg)









Mg ppm

Summary Statistics

Count	98
Max	3925
Min	1516
Mean	2577
Median	2576
StdDev	471
StdErr	48
Range	2409
Det Limit	20 ppm

HORIZONTAL DATUM: WGS84, UTM ZONE 54S

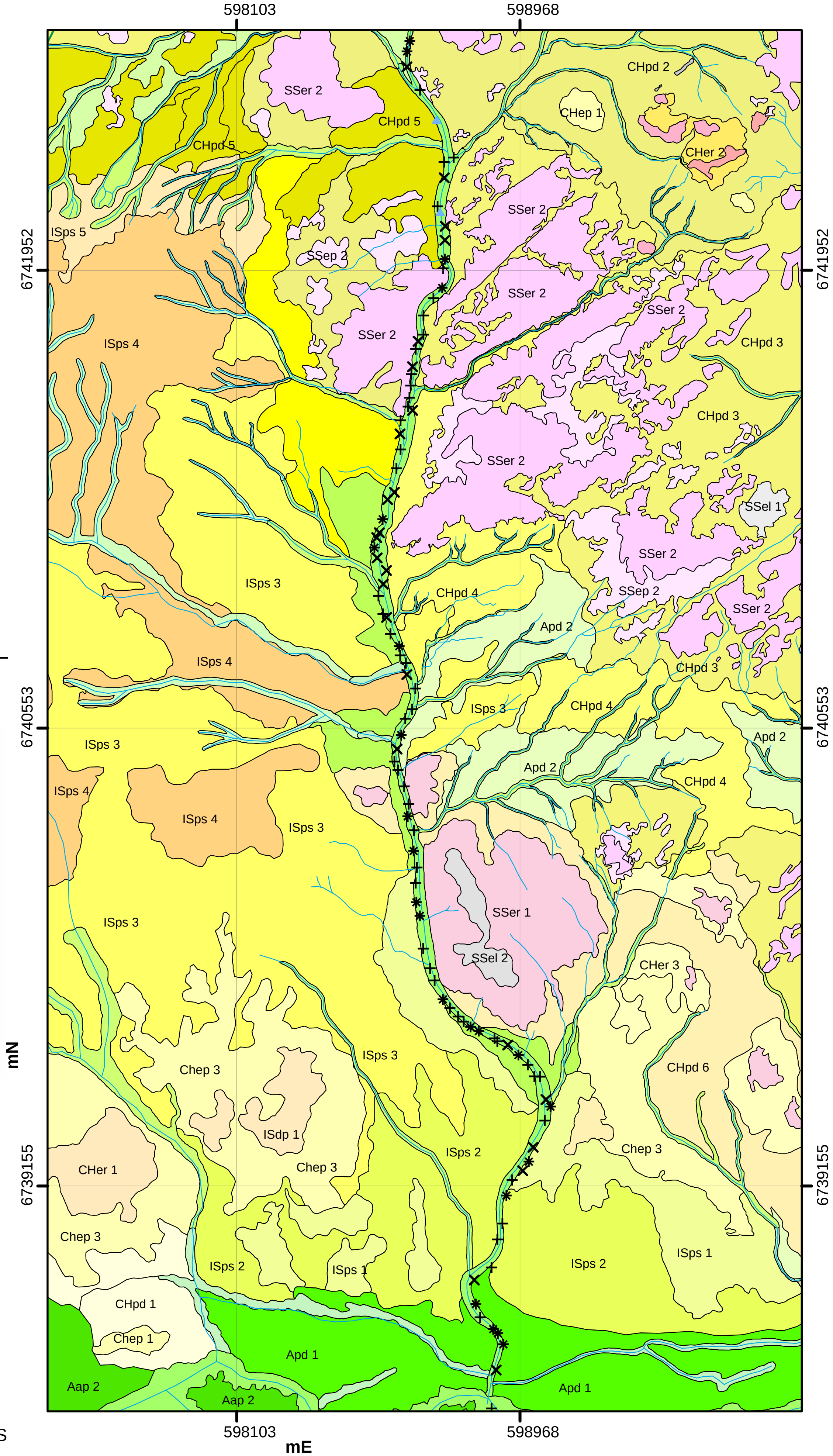


Figure 4.8: Raw data and spatial distribution of detectable Mg in *E. camaldulensis* (leaves) down Racecourse Creek with accompanying boxplots, histogram, cumulative frequency plot and summary statistics.

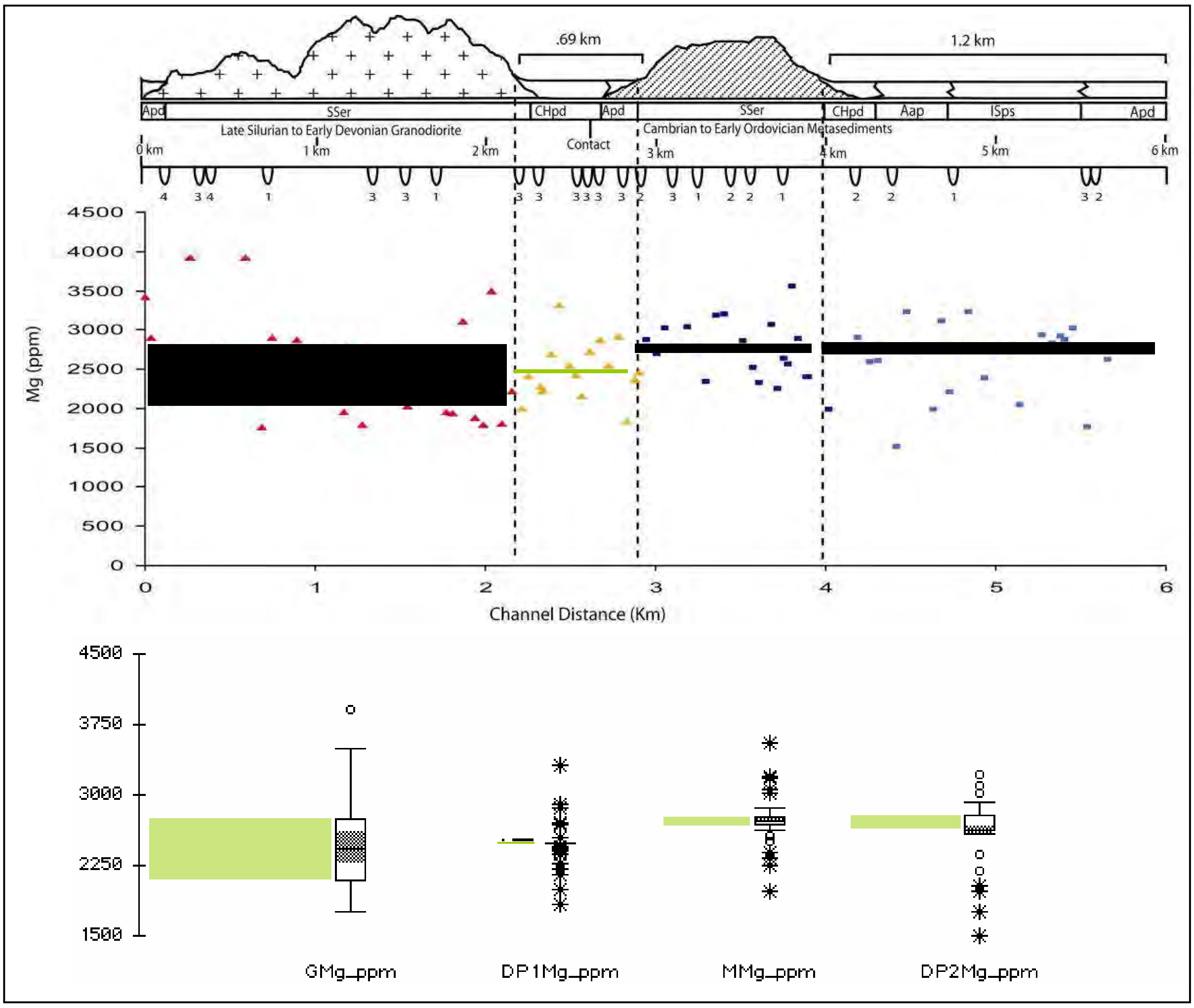


Figure 4.9: Mg concentrations within *E. camaldulensis* leaves flanking different landform settings along Racecourse Creek, G (granodiorite), DP1 (depositional 1), M (metasediment) and DP2 (depositional 2). Green region denotes 'values below the mean' and the dashed line indicates the 90th percentile.

Element (ppm) [detection limit] Analytical Method	Parameters	Total data set (C) n=98	Setting				Data set comparison
			Granodiorite (SSer) (C) n=38	Upper catchment depositional (CHpd and Apd) (C) n=16	Metasediment (SSer) (C) n=25	Lower catchment depositional (CHpd, Aap, ISps and Apd) (C) n=19	
Mg [20] ICP-OES	Concentration range (Mean)	1516-3925 (2557)	1768-3925 (2469)	1842-3319 (2487)	1984-3554 (2731)	1516-3228 (2631)	Regolith-landforms units associated with the granodiorite & upper catchment depositional similar at the 5% Sig Level in their median conc^{n}.
	25th - 75th percentile	2250-2871	2109-2754	2284-2691	2700-2780	2656-2788	
	95% confidence level	94	180	195	171	195	
	>90th percentile (outliers), # of samples	3923-3925 (2)	3923-3925 (2)	No outliers'	3023-3554 (6)	2881-3554 (6)	Regolith -landforms associated with the metasediment & lower catchment depositional different at the 5% Sig Level in their median conc^{n}.
	E. camaldulensis position with the greatest concentration.	northern margin of Racecourse Ck	northern margin of granodiorite	central & down stream of an easterly intersecting Aed unit	evenly scattered down the length of the metasediment	northern margin	

Table 4.18: Variation of Mg concentrations within *E. camaldulensis* s (river red gums), flanking different land-form settings along Racecourse Creek. Initial values concentration range, 25th - 75th percentile concentration range, 95 % confidence level, >90th percentile (outliers) C= composite sample.