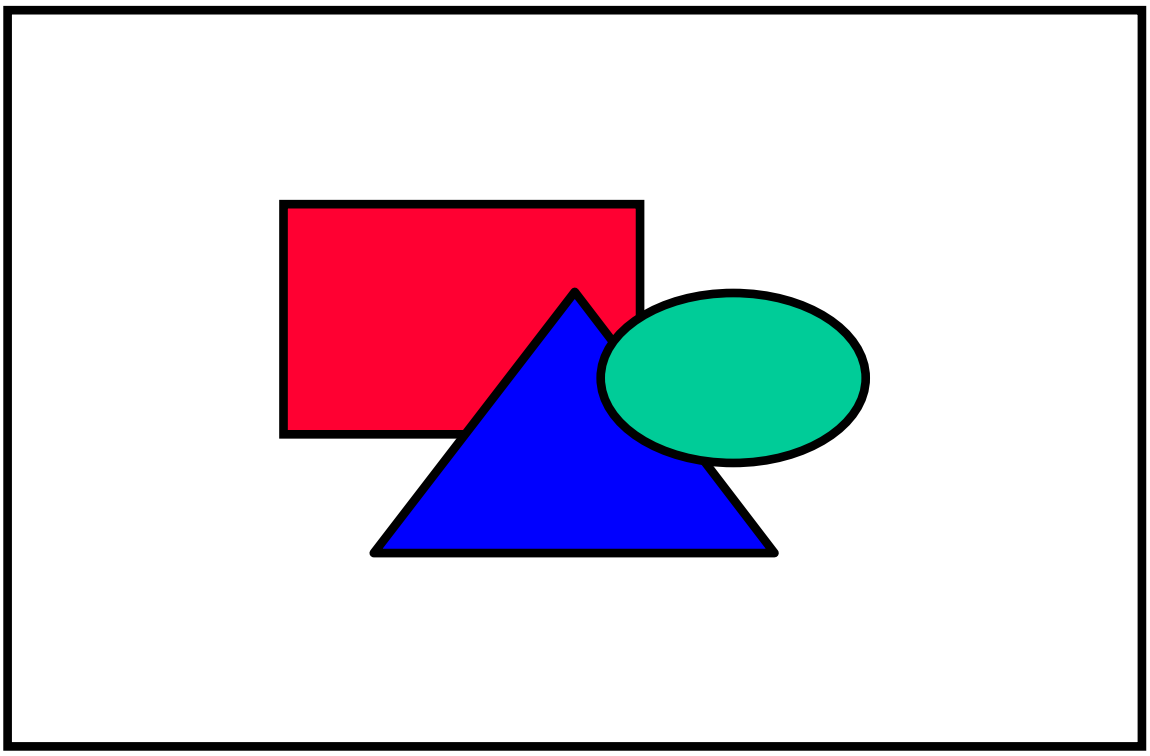
Draft

Revegetation Strategy

for the

Townsville City Council

Region



Draft report produced by Con Lokkers
for Townsville City Council 2000

Contents:

1. Scope of report

This report examines revegetation issues within the lands currently managed by the Townsville City Council. However, many important considerations, such as habitat connectivity and upstream and up-slope land use impacts, will require integration with other regions, including Thuringowa, Burdekin and Dalrymple shires.

Numerous other local planning documents should also be consulted, including:
Townsville Thuringowa Strategy Plan
Living Today For Tomorrow: An Environmental Conservation Strategy For Townsville
Castle Hill Management Plan
Ross River Recreation Master Plan
Community Natural Resource Management Plan (under development)
Townsville Thuringowa Pest Management Plan (under development)

As land uses and conditions vary markedly from the urban to rural areas of the region, this report covers management options over two scales - urban and non-urban. Urban areas comprise a small proportion of the total area of the region, but have the greatest levels of land modification and degradation, requiring large management inputs to revegetate most sites. Non-urban areas cover the majority of the region, and have generally been less degraded. Effective revegetation outcomes can be achieved in most sites by encouraging natural regeneration through fire management, weed control and other appropriate management tools.

2. Site description and natural resources

2.1. Geology

The geology of the Townsville region has been summarised by Tresize and Stephenson (1990) and Tresize *et al* (1989). A 1:100,00 map has been produced by Tresize *et al* (1986), and a 1:250,000 map by Wyatt *et al* (1970).

Numerous mountainous areas (eg Paluma Range, Many Peaks Range, Mt Cook, Castle Hill, Mt Louisa, Mt Bohle, Mt Stuart, Hervey Range, Pinnacles, Mt Muntalunga, Sisters Mountains, Mt Jack, Cape Cleveland, Mt Elliot, Mingela Range) were formed by episodes of volcanism and granitic intrusion during the late Carboniferous and early Permian periods (320 to 260 million years ago). Erosion processes since this time have exposed these features, and formed large areas of sediment deposits along the coastal plains. A period of crustal fracturing, from 100 to 65 million years ago, caused the opening of the Coral Sea Basin, and reduced the coastal plain to a position much closer to the present coastline. The escarpment formed by this fracture has been steadily eroded, forming the current coastal plains, and present escarpment of Hervey Range. Over the past 2 million years, changing climates and sea levels associated with ice ages have affected erosion processes, coastline development (such as the stranded beach ridges described by Hopley and Murtha, 1975) and marine coral reef development.

Present sea level has stabilised over the past 6000 years, and is close to the highest on record. Colluvial fans of sediment surround the escarpments and mountains, grading into the older coastal plain sediments, which may reach 50 metres in depth. Younger alluvial soils are found adjacent to present watercourses and along former stream channels (visible as slightly raised areas). Beach ridges have developed along protected areas of coastline, from anchor points such as Many Peaks Range, Castle Hill, Magazine Island (quarried to build rock walls for the harbour) and Cape Cleveland. The Burdekin, Haughton and Ross Rivers have been the primary sources of sand along the coast. Stranded beach ridges are found in parallel lines, up to one kilometre inland from the present coastline. Large areas of tidal mud flats commonly occur on the coastal fringe, reaching up to 10 km wide near Cape Cleveland. These large areas of tidal sediment have been cut off from the coast by development of beach ridges, except during extremely high tides.

2.2. Landforms

Landforms of the region were recently summarised and mapped in the Townsville Thuringowa Strategy Plan - Nature Conservation Draft Policy Paper (QDLGP, 1996). Broader scale descriptions are given by Hopley (1978), Bellamy (1972) and Stewart *et al* (1953).

The region can be divided into 5 broad landform zones – mountainous, colluvial, old plains, alluvial, and coastal zones. The mountainous landforms include the main escarpments (eg Paluma Range, Hervey Range) and isolated residuals (eg Many Peaks Range, Mt Cook, Castle Hill, Mt Louisa, Mt Bohle, Mt Stuart, Pinnacles, Mt Muntalunga, Sisters Mountains, Mt Jack, Cape Cleveland, Mt Elliot), dominated by granite, acid volcanic, and Julago intermediate volcanic rocks.

The colluvial landsystems are more gently sloping footslopes surrounding the mountainous areas, formed by the deposition of material eroded from the adjacent mountainous land, or in situ weathering of parent rock. They are distinguished primarily on the basis of parent rock material, including acid volcanics (eg below parts of Paluma Range and Hervey Range), Julago intermediate volcanics (eg surrounding Mt Louisa and parts of Mt Stuart and the Sisters Mountains) and granites (eg below parts of Paluma Range, Hervey Range, Mt Stuart and Mt Elliot).

The old plains landform was created by deposition of sediments over the coastal plain during the past 50 million years, sometimes reaching over 40 metres in depth, and is characterised by gentle slopes (gradient less than 3 m per km) and very old duplex soils. This landform comprises the majority of the developed land in the region. Distinctive landsystems within the old plains include areas of gilgai forming clays, and sandy granite outwash. “Gilgai clay” areas are characterised by clays which swell when wet and crack on drying, forming a distinctive micro-topography of low mounds and depressions (gilgai). Granite outwash landsystems are found extending from the footslopes of Hervey Range and Paluma Range, and consist of deep sandy soils derived from granitic rock.

Alluvial landsystems are associated with more recent deposition of sediments from active stream channels. Major delta alluvial deposits occur along the mouth of Ross River, with smaller bands of alluvials along presently active streams, overflow channels and recently in-filled streambeds. The alluvial landsystems contain the most fertile soils in the region.

Coastal province landsystems include beaches, beach ridges, mangroves, saltpans, saltwater couch meadows and brackish coastal swamps. This zone varies from a narrow fringe of beach (eg Magnetic Island bays, Strand) to the large coastal wetland systems seen in the Town Common and Cape Bowling Green National Park. A noteworthy feature of the coastal wetlands in the Townsville region is the extensive areas of saltpan with little vegetation. They are caused by extremely high levels of salt, which accumulate due to regular salt water inundation, high evaporation and limited leaching by the region’s relatively low rainfall levels. The salt flats appear to be replaced by mangrove forests in areas of higher rainfall.

2.3. Soils

Crossley *et al* (1996a,b) recently reviewed soils data for the Townsville region, to determine limiting factors for development. Detailed discussions and mapping of soil types are also given by Murtha (1975, 1982), Murtha and Reid (1992) and Stewart (1953).

The major determinants of soil types include parent rock material (eg granite, acid or intermediate volcanic) landform (eg slope, proximity to sea and streams), climate (eg rainfall quantity and intensity, temperature, wind), biological processes (eg plants, animals) and time. Human activities have also strongly affected soil structure. Aboriginal burning practices have altered vegetation cover, with potential consequences including reduced soil organic content, lower soil organism activity and increased erosion (Anderson *et al*, 1988). Widespread clearing and development during the past century have greatly accelerated erosion and soil loss. High stocking levels of cattle and other hoofed animals, and use of heavy machinery have caused soil compaction, particularly in areas with heavy clay subsoils (Buchanan, 1989). Changes in the underground water table level by excessive use of groundwater and irrigation have contributed to problems such as soil salination, acid sulphate soil production and vegetation die-back (White, 1997).

The soils of the Townsville region, being derived primarily from granites, are nutritionally poor. Fertility is further reduced by the great age of the soils of the colluvial and old plains landforms, and the rapid leaching rates caused by high intensity tropical rainfall. Soil phosphorous levels are particularly deficient, but levels of many nutrients (eg nitrogen, potassium, sulphur, iron, molybdenum) may also be sufficiently low to affect plant growth (Murtha, 1982).

The following soil descriptions are based on the Factual Key (Northcote, 1979), which classifies soils by profile development. Uniform soils show no change in soil texture with soil depth (ie no differentiation into upper and lower soil horizons). They range from coarse textured (ie sandy) to fine textured (ie clays). Gradational soils show a gradual increase in fine clay particles (ie increasingly fine texture) with depth. Duplex soils have an abrupt change in texture, with a coarser textured upper (A) horizon overlaying a fine clay lower (B) horizon.

Mountainous areas generally have very thin soils, except for basins or similar features that trap sediment. Soils typically have a coarse texture, with little profile development (uniform or weakly gradational). Some areas (eg the Sisters Mountains) may also contain substantial areas of duplex soils. The mineral fertility of mountain soils is often higher than the coastal plain, due to their young age and proximity to parent rock, but is easily lost through erosion and leaching in the steep terrain.

Colluvial areas contain a wide variety of soil types. Uniform sandy soils occur sporadically in the upper Ross River region, with a few pockets extending north east to Oak Valley. Gradational soils are commonly found in bands surrounding mountainous areas (eg Castle Hill, Mt Stuart, Cape Cleveland, Mt Elliot). Duplex soils are also common around the slopes of Mt Louisa, Mt Bohle, Mt Stuart, Mt Muntalunga and the Sisters Mountains.

The great majority of the old plains landsystems contain old duplex soils, characterised by a shallow (15-25 cm) medium textured upper (A) horizon over a yellow-grey to dark grey, heavy clay lower (B) horizon. Many local duplex soils have high levels of sodium in the upper B horizon (ie sodic). These soils become highly dispersive (soluble) when wet, and set extremely hard when dry. They are susceptible to gully erosion, especially when the sodic lower horizon is exposed. Substantial areas of gully erosion occur between Ross River and Mt Stuart, and small pockets occur throughout the region. The heavy clay lower horizon also impedes water movement through the soil profile, and, in combination with very low slopes, may cause water to pond on the soil surface for long periods after rain.

Gilgai forming soils are found sporadically throughout the old plains landsystem. Characterised by clays that expand when wet and crack on drying, these soils develop a surface micro-topography of small mounds (gilgai) and depressions. Gilgai are usually 1-2 metres across and up to 30 cm in height. Gilgai clay soils cause major problems in urban development, and limit potential vegetation to short-lived annual plants and those species whose roots can cope with the cycle of expansion and cracking. During the wet season, gilgai fill with water, and can become important breeding sites for some animals, such as frogs.

The alluvial landsystems contain much younger soils, which have been deposited by recent stream activity, and which have less profile development and higher fertility. The lower alluvial terraces usually contain uniform sands and sandy loams, while higher terraces and older infilled streambeds contain gradational soil profiles. Some older alluvial soils (eg around Ross River, Alligator Creek, Haughton River) have developed duplex profiles. Most

of the past and present market gardens in the region were established in these more agriculturally productive soils.

The coastal province landsystems include uniform sandy soils (eg beaches, beach ridges) and muds and clays of varying salinity (eg mangroves, salt pans, salt water couch meadows). Beaches and beach ridges are formed by coastal wave and wind processes, and are composed of uniform sand. Older beach ridges show some profile development, especially in depressions (swales), and are generally less salt affected. Where swales are low enough to allow regular tidal inundation, mangrove and other saline soils develop.

Mangrove areas are usually inundated daily by salt water, and are highly dynamic systems with highly variable soil profiles. The surface is generally dark mud, while underneath soils may contain mud, clay, sand, and/or layers of peat and organic material.

Salt pans are covered by salt water less often than mangroves, but the frequency of inundation varies considerably, from less than 10 up to 100 times per year. The soils vary from saline muds (similar to mangrove soils) to saline duplex soils with 2-10 cm of wind blown sand overlying heavy clay. Salt crystals are commonly seen on the soil surface when dry. Salt water couch meadows are slightly higher than salt pans, and are inundated up to 5 times per year by extremely high tides. They have duplex soils. The permanent water table of both salt pans and salt water couch meadows is usually only 50 to 80 cm below the surface. Heavy rains cause flooding for considerable times in both areas.

2.4. Climate

Climatic summaries for the Townsville region are given by Christian and Slatyer (1953) and the Commonwealth Bureau of Meteorology (1970). The climate is warm and subhumid, with a hot wet summer period of variable duration and intensity, and a warm dry winter season.

Temperatures vary from an average maximum of 30.7°C and minimum of 24.6°C in January to a 24.4°C maximum and 15.4°C minimum in July. Average relative humidity (3 pm figure) varies from 69% in January to 59% in July. Moving inland, temperature ranges increase and humidity drops.

Rainfall is highly seasonal and varies greatly from year to year. Rain is generally associated with tropical cyclones and depressions, south easterly trade wind streams, and north easterly winds during the passage of troughs. The average annual rainfall is 1134 mm, with 80% falling during the period from December to March (ie the wet season). This rainfall is often concentrated into a relatively small number of high intensity rainfall events (eg during cyclonic depressions). Rainfall levels are higher near mountains (eg Paluma receives 2770 mm/year), while rainfall generally decreases moving away from the coast (eg Woodstock has 840mm/year). Christian and Slatyer (1953) estimated that the average growing season for agricultural crops in Townsville, based on an “adequate rainfall” criterion of 60mm/month, was about 17.4 weeks (ie about one third of the year).

Variability from year to year is high, with 10% of years experiencing less than 600mm of rainfall, and 10% receiving over 1800mm. Major droughts have occurred in the region during 1900-02, 1905, 1915, 1919, 1922-23, 1925-26, 1931-32, 1935, 1945-46, 1952, 1965-66 and 1968-69 (Bureau of Meteorology, 1970).

Winds are generally light to moderate, with occasional strong to gale force winds during storms and cyclones in the wet season and intense high pressure ridges in the cooler months. The dominant wind directions are from the south east and north east, with a north easterly afternoon sea breeze very common near the coast.

On average, cyclones affect the region about once every two years.

2.5. Flora

Skull (1996) recently mapped the vegetation of the Townsville City Council region and assessed conservation priorities by vegetation community. Lukas (1996) conducted a similar study for the region's wetlands. Isbell and Murtha (1972) and Perry (1953) have described the vegetation of the broader region. MacNae (1966) and Spencely (1978) have described the mangrove flora of eastern Australia. Sandercoe (1990) and Jackes (1987) have documented the flora of Magnetic Island. Information on specific sites is also available, including Castle Hill (Bill Carter *et al*,1994), Mt Stuart (C&B, 1997), Mt Muntalunga (Dames & Moore, 1996) and the Town Common (Rowlatt, 1982, DEH, 1987). A list of some of the local plant species and their occurrence by landform/soil type is given in Appendix B.

The present vegetation mosaic is a result of the past and present influences of numerous interacting factors, including climate, soils, salinity, topography, fire and human impacts. With a combination of markedly seasonal rainfall (with a long dry period), nutritionally poor soils and frequent fire regimes, the region has developed a dominant vegetation cover of fire-tolerant forests, woodlands and grasslands. The common vegetation communities of the region can be categorised by a combination of soil and landform types.

Mountain.
Rainfall generally rises with increasing elevation, allowing denser vegetation development. Exceptions occur in areas subject to intense fires or extreme weather conditions (eg high winds), or areas with extremely shallow soils. Eucalypt woodlands and forests are common, and are generally dominated by trees such as *Eucalyptus crebra*, *E. acmenoides*, *E. cloeziana*, *Allocasuarina torulosa*, and *Lophostemon confertus*. Mid-storey vegetation is sparse, often containing wattles (eg *Acacia flavescens*, *A. aulacocarpa*) and grass trees (*Xanthorrhea johnsonii*). A moderately dense and diverse ground cover of grasses (eg *Themeda triandra*, *Heteropogon contortus*) and herbs (eg *Grewia retusifolia*, *Rhynchosia minima*) is usually present.

Vine thickets and araucarian (ie hoop pine) forests are found in areas with higher moisture and fertility levels and protection from fires. They contain a wide diversity of tree species, forming a dense canopy, and often with many deciduous species. The mid and ground storey flora contain juveniles trees and a few grasses, herbs and shrubs adapted to low light levels.

Colluvial.
The younger, usually more fertile colluvial soils, in combination with good drainage, support a range of vegetation types from woodland to vine thicket. Woodlands and forests are dominated by eucalypts such as *E. crebra, E. platyphylla, E. acmenoides* and *E. tereticornis*, and contain numerous other distinctive trees including kapok (*Cochlospermum gillivraei*), bottle tree (*Brachychiton australis*) and red ash (*Alphitonia excelsa*). These communities have a dense ground storey of grasses and herbs. Colluvial vine thickets, similar to those of mountainous areas, are found in moister protected sites.

Old Plain.
These old soils support open eucalypt woodlands in better drained areas, and melaleuca/ quinine tree open woodlands in areas of poor drainage. Dominant trees in the eucalypt woodlands include *Eucalyptus platyphylla, Corymbia tesselaris, C. clarksoniana* and *Alphitonia excelsa*. Mid-storey plants include *Planchonia careya, Grevillea parallela, G. striata*, and a range of *Acacia* species. Numerous grass species (eg *Themeda triandra, Heteropogon contortus, H. triceus, Bothriochloa bladhii*) and herbs (eg *Sida* species, *Indigofera* species, *Grewia retusifolia*) form a dense ground cover.

Melaleuca open woodlands are dominated by *Melaleuca viridiflora* (and sometimes *Petalostigma pubescens*), with occasional emergent eucalypts such as *Corymbia clarksoniana, Eucalyptus platyphylla* and *E. crebra*. Mid-storey plants include *Xanthorrhea johnsonii, Grevillea* species, and *Acacia leptostachya*. The regularly waterlogged soils support a variety of grasses (eg *Cynodon dactylon, Themeda triandra, Heteropogon contortus*), sedges (eg *Cyperus* species, *Fimbristylis* species) and herbs (eg *Murdannia graminea*).

Recent alluvial.
These soils are among the most fertile of the region and support a wide diversity of flora. Vegetation structure varies from large extensive tracts of vine thicket and forest, to thin lines of riparian vegetation that are constrained by fire and/or other adverse conditions away from the streambank. Alluvial vine thickets are similar to those found in colluvial areas. Alluvial areas also contain a suite of characteristic riparian species, including *Nauclea orientalis, Lophostemon grandiflorus, Melaleuca leucadendra, M. fluviatilis, Casuarina cunninghamiana, Pongamia pinnata, Ficus racemosa* and *Pandanus whitei*.

Wetland.
Deep water wetlands contain a variety of aquatic plants, including waterlilies (eg *Nymphaea* species) and submerged plants such as *Hydrilla verticillata*. Shallower areas support a wide diversity of aquatic and semi-aquatic species (eg bulkuru, bulrush, club rush, nardoo). Wetlands may be fringed by riparian forests, woodlands, or grasslands.

Mangrove/salt pan.
This highly saline coastal environment shows a distinct zonation, with various mangrove associations, salt flats (either bare or with samphire plants) and saltwater couch grasslands. Small areas of open woodland may also occur on higher pockets of soil. Mangrove zones include a seaward fringe of forest containing *Avicennia marina* and *Sonneratia alba, Rhizophora* dominated forest, thickets comprised of *Ceriops tagal*, and a landward fringe of mixed mangrove species. Mangroves form a dense canopy, with a very sparse mid and ground storey.

Salt pan samphire vegetation contains a variety of low shrubs, such as *Halosarcia halocnemoides, H. indica, Suaeda australis* and *Sesuvium portulacastrum*. They are generally found in association with areas of bare salt pan. Saltwater couch grasslands occur in a zone slightly above salt pans, and are dominated by *Sporobolus virginicus*.

Beach fore dune.
The fore dunes support a characteristic zonation of plants adapted to sandy soils and salt laden winds. The seaward fringe contains ground storey vines (eg *Ipomea pes-caprae, Canavalia rosea*) and grasses (eg *Spinifex sericeus*). Behind this fringe, the dunes support a community of trees such as *Casuarina equisetifolia, Terminalia arenicola, Acacia crassicarpa* and

Thespesia populnea and shrubs including *Caesalpinia bonduc*, *Clerodendrum* species, *Dodonea viscosa* and *Scaevola taccada*. The ground storey contains grasses (eg *Cenchrus echinatus, Thuaria involuta*) and herbs (eg *Tribulus terrestris*, *Vitex rotundifolia*).

Beach ridge/swale.
Older stabilised beach ridges can support diverse woodland, forest or vine thicket ("beach scrub") communities. Swales can also contain small freshwater wetland habitats or saline mangrove habitats. Widespread trees in forests and woodlands include *Eucalyptus tereticornis*, *Corymbia tesselaris*, *Canarium australianum*, *Pleiogynium timorense* and *Alphitonia excelsa*. *Planchonia careya*, *Acacia* species, *Macaranga tanarius* and *Livistona decipiens* are common mid-storey species. Ground-storey plants include *Jasminium didymum*, *Heteropogon* species, *Imperata cylindrica* and *Themeda triandra*. Beach vine thickets are very diverse communities similar to those found in alluvial soils.

2.6. Fauna

Few published faunal lists are available for the Townsville City Council region. Lavery (1968) and Lavery and Johnson (1968) surveyed mammals and birds of the Townsville area. Weineke (1989) has published a comprehensive guide to Townsville birds. James *et al* (1994) have compiled a list of Townsville reptiles, and Hero *et al* (1996) have developed a similar list of frogs.

Faunal records based on these sources include 25 frogs (15 tree frogs, 10 southern frogs), 113 reptiles (2 crocodiles, 5 turtles, 66 lizards, 40 snakes), 365 birds and 47 terrestrial mammals (2 monotremes, 20 marsupials, 5 rodents, 19 bats, dingo).

2.7. Communities and species with high conservation significance.

QDEH (1995) have assessed the conservation status of Queensland's regional ecosystems, within 11 biogeographic regions. Each ecosystem, identified primarily by the major types of vegetation and landform, has been classified as endangered (< 5% of pre-European extent remaining), vulnerable (5-10% of pre-European extent remaining), of concern (10-30% of pre-European extent remaining) or no concern at present (>30% of pre-European extent remaining). The Townsville Plains Province contains 15 regional ecosystems which are listed as endangered, vulnerable or of concern (Appendix A.1)

Information on endangered, rare and vulnerable plant and animal species was compiled from Queensland Herbarium data, the Queensland Biodiversity Network vanishing flora and rare and threatened fauna databases (Griffith & Griffith, 1996), CSIRO list of Australian vertebrates (Stanger *et al*, 1998), Townsville City Council region-vegetation communities and conservation priorities (Skull, 1996) and Townsville Thuringowa Strategy Plan (QDLGP, 1996). These species and their present legislative status in the Queensland Nature Conservation Act are given in Appendix A.2.

The present distribution of most of these species is very poorly known. Where possible, a representative distribution record has been given for each species. The actual distribution and habitat requirements of these species will not be clear until detailed surveys and ecological studies are conducted.

2.8. Weeds and feral animals.

Substantial numbers of naturalised animals and plants occur in the region. Over 13% of the flowering plants recorded of Queensland (1153 of 8821 species) have been introduced from interstate or overseas (Queensland Herbarium, 1997). The Townsville flora probably contains a similar proportion of naturalised species.

Not all naturalised plants are necessarily serious environmental weeds. Humphries *et al* (1991) define environmental weeds as "those species that invade native communities and ecosystems", and serious environmental weeds as "those that cause major modification to species richness, abundance or ecosystem function". Potential impacts of environmental weeds listed by (Csurshes and Edwards, 1998) include:

- competition for resources (eg sunlight, moisture, nutrients)
- prevention of recruitment and/or seedling establishment (eg by shading, changes in soil conditions, allelopathic chemicals)
- alteration of geomorphological processes (eg beachfront dune structure)
- alteration of hydrological cycles (eg water tables)
- alteration of nutrient content and/or chemical characteristics of soil (eg pH, nitrogen level)
- alteration of fire regime (eg increased fuel loads)
- physical damage (eg uprooting of trees by weight of vines).

Weeds may also cause economic problems (eg weeds of agriculture or grazing pastures, poisonous to stock), create problems for the community (eg thorns, allergies), or reduce aesthetic values (eg unsightly, unpleasant odours).

Appendix C.1 lists 76 plants that are known or potential environmental weeds in the Townsville region, along with information on their occurrence by soil/landform type and some of the problems they cause. Based on this information and local expert knowledge and experience, each plant species has been categorized as a low, medium or severe weed problem. An estimate of the potential of plants to increase in abundance and/or distribution within the region has also been attempted.

The most prevalent and troublesome environmental weeds encountered in rehabilitation projects to date include:

Brachiara mutica (para grass)
Clitoria terneata (butterfly pea)
Cryptostegia grandiflora (rubber vine)
Eichornea crassipes (water hyacinth)
Lantana species (lantana)
Leucaena leucocephala (leucena)
Macroptilium atropurpureum (siratro)
Merremia dissecta (mile-a-minute)
Panicum maximum (guinea grass)
Passiflora foetida (stinking passionfruit)
Passiflora suberosa (corky passionfruit)
Stachytarpheta jamaicensis (snake weed)
Themeda quadrivalvis (grader grass)
Zizyphus mauritiana (chinee apple)

Methods to control these weed species are given in Appendix C.2. References providing further details are also listed, where available. A range of techniques have been developed including:

- mechanical (eg hand pulling, bulldozers, mowing/slashing)
- physical (eg fire, flame/steam weeders)
- chemical (eg foliar, basal bark or injected herbicides)
- biological (eg stem boring, seed or leaf eating insects, fungal pathogens)
- site management (eg controlled grazing levels, shading by restored tree canopy)

The most successful control programs use a combination of methods. For example, a dense infestation of rubber vine may be initially removed by fire or bulldozer, followed by spot spraying of regrowth with herbicide, and revegetation with native trees to shade out emerging grass weeds. The Townsville Thuringowa Pest Management Plan, currently under development, will provide more detailed information on distribution and control of pest species.

Of the numerous feral animals in the region, few impact significantly on revegetation efforts. Feral pigs (*Sus scrofa*) can dig up large numbers of seedlings in recently planted sites, and can also damage existing native fauna and flora. Trapping is the best control method near urban areas, while baiting and hunting are used in less populated regions. Fencing can provide effective, if expensive, protection for revegetation sites. Fences can also protect young plants from other grazing animals, such as wallabies, cattle and horses.

3. Rehabilitation prioritisation model

Prioritisation of rehabilitation projects is important to maximise the benefits of rehabilitation works to the community. It allows effective allocation of resources and funds for projects, and improves coordination and timing of contributions from landowners, landusers, industry, government agencies and community groups. Important criteria for assessing the potential benefits of rehabilitation have been divided into 4 broad categories, which may often overlap:

- land and water conservation
- ecosystem viability
- community values
- council operations

The Department of Environment (1996) developed a range of criteria useful for assessing ecosystem viability (including biological diversity) and land and water management. The North Queensland Joint Board now uses these for assessing rehabilitation priorities for their Wet Tropics Rehabilitation Plans (NQJB, 1996, 1998). They are:

- **Land and water conservation:**
  - streambank stabilisation
  - erosion control (including coastal dunes)
  - soil infiltration, stream flows and flood mitigation
  - sediment and nutrient filtering capacity, and potential to enhance water quality
  - pest control (including weeds and feral animals)

- **Ecosystem viability:**
  - biological diversity
  - biological integrity
  - habitat for rare and threatened species
  - rare, restricted vegetation community or habitat type
  - ecofunctional area (eg corridor, refugial area, breeding area, disjunct community, ecotone).

Assessment of the community value of site rehabilitation is also important. A range of criteria has been developed from numerous sources, including North Queensland Joint Board Catchment Rehabilitation Plans (NQJB, 1996, 1998), Johnstone River Catchment Revegetation Strategy (Bell, 1996) and local workshops. They are:

- **Community values:**
  - community support and interest
  - demonstration site for public education on rehabilitation techniques (eg Weedbuster days)
  - community use for recreation or tourism (eg shade, scenic amenity, riverside nature parks, Tourist Information Centre interpretive trails)
  - cooperative support with other organisations (eg other government agencies, industry and business organisations, Landcare groups)
  - cultural heritage values

Local councils also require a range of operational criteria to assess priorities and suitability of sites for rehabilitation works. These include:

- **Council operations**
  - suitable tenure (eg public or committed private owner), with no incompatible landuse planned (eg in Townsville Thuringowa Strategy Plan)
  - visibility to public
  - access for necessary equipment and people
  - requirements and availability for resources and funding(eg suitable plant/seed supply)
  - high probability of rehabilitation success within realistic timeframe
  - effects on stormwater management

An assessment model based on these criteria has been adapted from the method used by the North Queensland Joint Board in their catchment rehabilitation plans (NQJB, 1996, 1998). Each of the above four categories (ecosystem viability, land and water conservation, community and council) contains five criteria. Each criterion has been divided into three levels, based on its importance to rehabilitation of the region. For each criterion, sites are classified from zero to two, as follows:

- sites of critical importance for the criterion score two
- sites which are significant but not critical for a criterion score one and
- sites with limited significance for a criterion score zero.

A list of the criteria, and the levels of importance used for assessing rehabilitation sites in the region are provided in Appendix D. As an example, a land and water conservation criterion is considered critically important if it plays a necessary role in continued, long-term functioning of the site. Without this, or with this attribute degraded or impaired, the normal functions required to maintain a healthy catchment are inhibited. These sites have high priority for rehabilitation. An example of an attribute which would be assessed as critically significant is a highly unstable riverbank which is prone to severe erosion. The combined score for the five criteria of the land and water conservation category can vary from 0 to 10.

This process is repeated for ecosystem viability, community and council operational criteria. The overall rehabilitation priority score, including land and water conservation, ecosystem viability, community value and council operational criteria, can thus range from zero (with minimal rehabilitation potential) to a maximum of 40 (for a site with critical ecosystem and conservation roles and strong community, business and council support). An assessment proforma is provided in Appendix E.

Previous reports have identified numerous high priority areas for retention and/or rehabilitation. These include:

- Rapid Identification of Key Environmental Sites (Townsville City Council, 1990)
- Townsville Thuringowa Community Natural Resources Management Plan (in prep)
- Townsville City Council Region: Vegetation Communities and Conservation Priorities (Skull, 1996)
- Wetlands of the Townsville Area (Lukacs, 1996)
- Townsville Thuringowa Strategy Plan: Nature Conservation Draft Policy Paper (QDLGP, 1996)
- Specific site reports, such as the Castle Hill Management Plan (Bill Carter *et al*, 1994)

High priority areas for rehabilitation have been compiled from these existing lists, workshop discussions and information from Landcare and environment groups, local experts and community members. These areas are listed in Appendix F.

A number of corridors linking areas of high ecosystem viability in the Townsville City Council region have been identified in Appendix G. These corridors have the potential to allow movement of wildlife and facilitate gene flow between isolated populations. A preliminary assessment of their status is provided, based on aerial photography, local knowledge and information from the reports listed above.

4. Implementation

To maximise the effectiveness of rehabilitation in the Townsville City Council region, sites need to be prioritised using land and water conservation, ecosystem viability, community and council operational criteria (Appendix D). Site-specific implementation plans should then be developed to maximise potential benefits of works to the environment and community, and allow accurate assessment of resources and funds required (Appendix I).

During a workshop held in February, 1997, a number of issues critical to this process were raised and discussed. These were:

- identification and prioritisation of numerous sites in the region requiring rehabilitation/revegetation (Appendix F)
- development and refinement of methods to enhance regeneration and revegetation in the dry tropics (eg fire, weed and water management, availability of local gene pool plant stock- see Appendix H and I)
- importance of effective site preparation and ongoing maintenance
- effective financial management (eg planning, record keeping, accountability) to maximise on-ground works and allow optimum feedback to funding sources
- compilation of accurate cost/benefit data to demonstrate effectiveness of revegetation and compare between techniques
- raising of awareness and education of the community
- sourcing and supporting of a broad base of volunteers

The following staged implementation strategy draws from these workshop issues, previous reports and the experiences of dedicated local revegetators.

4.1. Identification, compilation and prioritisation of sites.

Appendix F shows sites identified by previous studies and the revegetation workshop. These sites will be prioritised using land and water conservation, ecosystem viability, community and council operational criteria (Appendix D). Using this system, any future proposed sites can be assessed and incorporated into this strategy.

4.2. Development of appropriate local rehabilitation and revegetation techniques.

A range of successful methods for revegetation in the region are detailed in Appendix H. However, further trials are urgently required, to improve financial, resource and labour requirements of existing techniques, and to develop new techniques for rehabilitation of difficult sites. Some areas identified are:

- watering trials to determine minimum effective watering regimes in seasonal tropical habitats
- fertiliser trials
- direct seeding trials
- urban and rural fire management strategies
- alternative weed control strategies (eg fire) for problem weeds (eg para grass, leguminous vines, chinee apple)
- rehabilitation of wetlands
- technical workshops to discuss applied revegetation techniques

4.3. Raising of awareness and support for revegetation projects.

Most successful projects in the region have involved groups of dedicated locals who wished to restore an area of bush near them. They have obtained resources and funding by approaching community, business and/or government organisations. To date, however, only highly motivated and dedicated groups have achieved their goals.

An important component of this strategy is thus to motivate people interested in their local bushland to "adopt" an area, and assist them in its restoration. A number of methods to raise awareness and motivation have been used successfully, including:

- regular Landcare or similar newsletters
- high profile demonstration revegetation sites throughout the region (eg the Ross River Bushgarden near Aplins Weir, Mundingburra)
- public meetings advertised by media, door knocks and letter drops, near identified high priority sites, to encourage local residents and businesses to adopt sites

4.4. Development of site-specific implementation plans.

Each site to be revegetated is unique. Physical conditions such as slope and soils, biological factors like weeds and remnant native plants, and past land uses such as grazing or industry are just a few of the important considerations when deciding how and what to do when restoring a site. A site planning guide has been developed for the Townsville City Council region (Appendix I) to assist revegetation groups in the implementation planning process. The phases outlined in this guide are:

- **Site inventory**
  - landforms
  - soils
  - vegetation – communities, native and weed species
  - present degradation

- **Action plan**
  - aims
  - site preparation
  - planting – species list, propagation, design
  - maintenance – watering, weed and fire control
  - monitoring and evaluation
  - estimated funds, resources, labour required

These planning guides have been developed in consultation with various revegetation groups and Townsville City Council. Designed to be completed by community members (with assistance from Landcare, Greening Australia and/or government agencies), they aim to:

- improve participants' understanding and appreciation of the physical and biological processes of their site
- facilitate effective assessment of the resources, funds and time required
- facilitate development of appropriate techniques and scheduling of works, allowing community, business and government to work together efficiently
- improve financial management and accountability of works
- provide a framework for monitoring success of the project, and documenting innovative techniques, for the benefit of future revegetators.

Revegetation (and also the group which conducts it) is a dynamic, continuously changing system. To cope with these changes, plans need regular updating, preferably yearly, to function effectively.

5. Future consultation and research areas.

Numerous area requiring further work have been identified in this and previous reports, including:

- Public forum to further discuss issue priorities
- Detailed prioritisation of identified sites using model in Appendix D
- Detailed survey of flora and fauna of region
- Survey and mapping of degradation
- Ground truthing and assessment of viability of vegetation corridors (Appendix G)
- Development of regional local gene pool seed bank
- Development of suitable propagation techniques for local plants
- Development of local gene pool nursery for supply of local plants
- Development of alternative control methods for problem weeds
- Trials to enhance existing rehabilitation techniques and to develop new methods
- Inclusion of revegetation strategy into bioregional community natural resources strategy, currently in preparation

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8. Appendices

Appendix A. Threatened ecosystems, flora and fauna of the TCC region.

A.1. Regional ecosystems in Townsville plains province listed as endangered, vulnerable, or of concern by Department of Environment and Heritage.

Regional ecosystem	DEH Code
Endangered:	
Queensland grey ironbark/ghost gum woodland on alluvials	11.1.10
Softwood scrub on alluvials	11.1.16
Beefwood open woodland on alluvials	11.1.18
Vulnerable:	
Long fruited bloodwood/Moreton Bay ash woodland on alluvials	11.1.7
Bulloak low open woodland on alluvials	11.1.12
False sandalwood low open woodland on alluvials	11.1.13
Brown's box on alluvials	11.1.15
Of concern:	
Forest red gum/river red gum woodland on alluvials	11.1.4
Poplar gum/long fruited bloodwood woodland on alluvials	11.1.9
Ophiuros/bluegrass grassland on alluvials	11.1.11
Boree low woodland on alluvials	11.1.14
Broad leaved tea tree woodland on alluvials	11.1.17
River red gum/river she oak fringing woodland	11.1.27
Poplar gum woodland on acid rocks	11.10.10
Sedgelands in depressions on coastal floodplains	11.13.3
Vine forest on coastal dunes	11.14.3

A.2. Threatened flora and fauna potentially in Townsville City Council region, with legislative status in Qld Nature Conservation Act, and distribution record (if any).

Scientific name	Common name	Family	Status (Qld legislation)	Recorded locality
Flora				
Acacia jackesiana		Mimosaceae	rare	Magnetic I, (Bohle R)
Ac. longipedunculata		Mimosaceae	rare	?
Aponogeton queenslandicus		Aponogetonaceae	rare	Stuart Ck
Bonamia dietrichiana		Convolvulaceae	rare	Magnetic I
Calanthe triplicata	Christmas orchid	Orchidaceae	common	? (Paluma R)
Callitris columellaris	Coastal cypress pine	Cupressaceae	common	? (west)
Cassia queenslandica		Caesalpiniaceae	rare	Magnetic I
Croton magneticus		Euphorbiacea	vulnerable	Magnetic I
Cycas media	cycad	Cycadaceae	common	common
Dipodium ensifolium		Orchidaceae	rare	?
Dodonea uncinata		Sapindacea	rare	?
Eucalyptus leptoloma		Myrtaceae	vulnerable	? (Paluma R)
Euc. paedoglauca	Mt Stuart ironbark	Myrtaceae	vulnerable	Mt Stuart
Euc. raveretiana		Myrtaceae	vulnerable	Haughton R
Gahnia sieberiana	saw sedge	Cyperaceae	common	? (Paluma R)
Grewia graniticola		Tiliacea	rare	?
Gymnema brevifolium		Ascepidaceae	vulnerable	Magnetic I
Leucopogon cuspidatus		Epacridaceae	vulnerable	Magnetic I
Livistona drudei	cabbage palm	Arecaceae	vulnerable	? (north)
Myrmecodia beccarii	ant plant	Rubiaceae	vulnerable	scattered

Scientific name	Common name	Family	Status (Qld legislation)	Recorded locality
Platycerium veitchii	staghorn	Polypodiaceae	common	Magnetic I
Pomatocalpa macphersonii		Orchidaceae	common	?
Spathoglottis paulinae		Orchidaceae	vulnerable	?
Tephrosia leveillei		Fabaceae	vulnerable	?
Tylophora williamsii		Asclepiadaceae	vulnerable	Mt Stuart
Vittadina scabra		Asteraceae	rare	Magnetic I
Xanthorrhoea johnsonii	grass tree	Xanthorrhoeaceae	common	common

Fauna

(a) Mammals

Dasyurus maculatus gracilis	spotted-tailed quoll	Dasyuridae	rare	?
Macroderma gigas	ghost bat	Megadermatidae	rare	Oak Valley
Saccolaimus saccolaimus	bare-rumped sheathtail bat	Emballonuridae	rare	Mt Elliot
Tachyglossus aculeatus	echidna	Tachyglossidae	common	Ross R, Magnetic I
Taphozous australis	coastal sheathtail bat	Emballonuridae	vulnerable	Alligator Ck

(b) Birds

Accipiter novaehollandiae	grey goshawk	Accipitridae	rare	Mundingburra
Collocalia spodiopygius	white-rumped swiftlet	Apodidae	rare	Mt Elliot
Coracina maxima	ground cuckoo-shrike	Campephagidae	rare	Hervey R
Ephippiorhynchus asiaticus	black-necked stork	Ciconiidae	rare	Town Common
Erythrotriorchis radiatus	red goshawk	Accipitridae	endangered	Town Common
Esacus neglectus	beach stone-curlew	Burhinidae	vulnerable	Ross R mouth
Geophaps scripta	squatter pigeon	Columbidae	vulnerable	Serpentine lagoon
Haematopus fuliginosus	sooty oystercatcher	Haematopodidae	rare	Ross R mouth
Lophoictinia isura	square-tailed kite	Accipitridae	rare	Aitkenvale
Neochmia phaeton	crimson finch	Passeridae	vulnerable	Mt Stuart
Nettapus coromandelianus	cotton pigmy goose	Anatidae	rare	Ross R, Anderson Park
Ninox rufa queenslandica	rufous owl	Strigidae	vulnerable	Mt Stuart
Numenius madagascariensis	eastern curlew	Scolopacidae	rare	Ross R mouth
Podiceps cristatus	great crested grebe	Podicipedidae	rare	Ross R Dam
Poephila cincta cincta	black-throated finch (white-rumped form)	Passeridae	vulnerable	Mt Stuart
Rostratula benghalensis	painted snipe	Rostratulidae	rare	Town Common
Sterna albifrons	little tern	Laridae	vulnerable	Ross R
Tyto novaehollandiae kimberli	masked owl	Tytonidae	vulnerable	?

(c) Reptiles

Acanthophis antarcticus	common death adder	Elapidae	rare	scattered
Crocodylus porosus	saltwater crocodile	Crocodylidae	vulnerable	estuaries
Delma labialis	single-striped delma	Pygopodiae	vulnerable	Magnetic I
Furina barnardi	yellow-naped snake	Elapidae	rare	?
Lampropholis mirabilis	rock skink	Scincidae	rare	Magnetic I
Lerista allanae	Allan's lerista	Scincidae	endangered	?
Simoselaps warro	northeastern burrowing snake	Elapidae	rare	Hervey R

(d) Amphibians

Cophixalis mcdonaldi	Mt Elliot frog	Microhylidae	rare	Mt Elliot

Appendix B. Local plant species suitable for revegetation in the TCC region.

Data on plant form, occurrence by landform/soil and approximate fruiting season are given, where available.
* plant has been successfully propagated and established in local revegetation projects.

Species name	Common name	Form	Fruiting season	Occurrence by soil types (o – occasional , c – common)							
				old plain	recent alluvial	wetland	beach front	mangrove /salt pan	beach ridge/ swale	colluvial	mountain
Abelmoschus moschatus	native rosella	herb	Summer	o	c					o	
Acacia aulacocarpa	hickory wattle	tree	Winter							o	o
Acacia bidwillii	fern leaf wattle	shrub	Summer	o	o					o	
Acacia crassicarpa *	beach wattle	shrub/tree	Winter-Spring		o		c		c	o	
Acacia fasciculifera	wattle	tree	Autumn-Winter		o					c	
Acacia flavescens *	wattle	tree	Winter	c	c					c	
Acacia holosericea *	silver leaf wattle	shrub	Winter	c	c					c	o
Acacia jackesiana	Betsy's wattle	shrub		o	o					o	
Acacia leptostachya	Townsville wattle	shrub/tree	Winter	c	c						
Acacia mangium	salwood	tree	Winter		o					o	
Acacia polystachya	wattle	tree	Autumn-Winter		o						
Acacia simsii *	wattle	shrub	Summer-Autumn		o					c	c
Adenanthera pavonina	red bead tree	tree	Summer-Autumn		o					o	
Aglaia elaeagnoidea	droopy leaf	shrub/tree	Summer		o				o		
Aidia racemosa	native cherry	tree	Summer-Autumn		c				c	o	
Albizia procera	forest siris	tree	Spring	o	o						
Alectryon connatus	alectryon	shrub/tree	Summer-Autumn		o				o		
Allocasuarina torulosa	forest sheoak	tree	Winter							o	c
Alphitonia excelsa	red ash	tree	Summer-Winter	o	c		o	o	c	c	o
Alpinia caerulea	ginger	shrub	irregular		o					o	o
Amorphospermum antilogum	brown pearwood	tree	Summer		c				o	c	
Antidesma parvifolium	black currant bush	bush	Autumn		c					c	
Araucaria cunninghamii	hoop pine	tree							o	o	o
Archontophoenix alexandrae	Alexander palm	palm	irregular		o					o	c
Aristolochia tagala	native dutchman's pipe	vine	irregular		o					o	o
Arytera divaricata	rose tamarind	tree	Spring		o					o	

Species name	Common name	Form	Fruiting season	Occurrence by soil types (o – occasional , c – common)							
				old plain	recent alluvial	wetland	beach front	mangrove /salt pan	beach ridge/ swale	colluvial	mountain
Atalaya hemiglauca	whitewood	tree	Summer-Winter	o	o					o	
Austromyrtus bidwillii	python tree	tree	Summer		o				o	o	
Avicennia marina	grey mangrove	tree	Winter-Spring		o			c			
Bothriochloa decipiens	pitted bluegrass	grass	Autumn-Winter	c						o	
Brachychiton australis *	bottle tree	tree	Spring							o	o
Breynia oblongifolia	coffee bush	shrub	irregular		c					c	
Buchanania arborescens	native goosberry tree	tree	Summer		o				o		
Bursaria incana	prickly pine	shrub/tree	Winter	c						o	o
Bursaria tenuifolia *	bursaria	shrub/tree	Spring		c						
Caesalpinia bonduc	mother-in-law vine	bush	Spring				c		o		
Cajanus reticulatus	furry rattlepod	shrub	Autumn-Winter	o	o					o	
Callistemon viminalis	weeping bottlebrush	shrub/tree	Summer-Autumn		c						
Calophyllum inophyllum	beach laurel	tree	Summer-Winter						c		
Canarium australianum *	mango bark	tree	Winter-Spring	o	c				c	o	
Canavalia maritima *	coastal jack bean	vine	irregular		o		c				
Canthium odoratum	sweet susie	shrub/tree	irregular		o				o	o	o
Capparis arborea	native pomegranate	shrub	Autumn		o				o		
Capparis sepiara	bumble	shrub	Summer-Autumn		c				o	o	
Carallia brachiata	freshwater mangrove	tree	Spring-Summer		o				o		
Carissa ovata	currant bush	shrub	Summer	o	o				o	o	
Cassine melanocarpa	black olive plum	bush/tree	irregular		c				o		
Casuarina cunninghamiana *	river she oak	tree	Autumn		c						
Casuarina equisetifolia *	coastal she oak	tree	Autumn-Winter				c	o	o		
Ceriops tagal	yellow mangrove	shrub/tree	Summer-Autumn					c			
Chamaecrista mimosoides	five leaf cassia	herb	Autumn-Winter	o	c				o	o	o
Chionanthus ramiflorus *	native olive	tree	Winter-Spring		c						
Citriobatus spinescens	native orange	shrub	Autumn		o						
Clerodendrum floribundum	lolly bush	shrub/tree	Winter-Spring		o				c	o	
Clerodendrum inerme	beach lolly bush	bush	Winter-Spring				c		o		
Cochlospermum gillivraei *	kapok	tree	Spring-Summer		c					c	c
Colubrina asiatica	beach berry bush	shrub	Winter						o		
Commelina diffusa	native wandering jew	herb	Summer-Autumn		c	o			c	o	
Cordia dichotoma *	glue berry	tree	Spring-Summer		o						

Species name	Common name	Form	Fruiting season	Occurrence by soil types (o – occasional , c – common)							
				old plain	recent alluvial	wetland	beach front	mangrove /salt pan	beach ridge/ swale	colluvial	mountain
Cordia subcordata *	sea trumpet	shrub/tree	Winter				o	o	o		
Cordyline cannifolia	palm lily	herb			o						o
Corymbia clarksoniana *	bloodwood	tree	Winter	o	o	o					
Corymbia dallachiana	ghost gum	tree	Summer	o	o					o	
Corymbia erythrophloia	red barked bloodwood	tree	Winter	o						o	
Corymbia tessellaris *	Moreton Bay ash	tree	Spring-Summer		c				c		
Crinum angustifolium	river lily	herb	Autumn		o	c			o		
Crotalaria aridicola	Chillagoe horse poison	herb	Autumn-Winter		o		o		c	o	
Crotalaria verrucosa	blue flower rattlepod	herb	Autumn-Winter		o					o	
Croton arnhemicus	hard cascarilla	shrub/tree	Autumn		o				o	o	
Cryptocarya triplinervis	brown laurel	tree	Summer		o					o	o
Cupaniopsis anacardioides	tuckeroo	tree	Spring		c				c		
Cycas media	cycad	shrub	Autumn-Winter	o						o	
Cynodon dactylon	couch	grass	Autumn-Winter	o	c						
Darlingia darlingiana	brown silky oak	tree			o						o
Deplanchea tetraphylla	golden bouquet	tree	Spring-Summer		o					o	o
Dianella caerulea	blue flax lily	herb	irregular	o	c	o			o	o	o
Dioscorea bulbifera	aerial yam	vine	Winter	o	o				o	o	
Diospyros geminata *	native ebony	tree	Spring-Summer		o				o	o	
Dodonaea viscosa *	sticky hop bush	bush	Autumn-Winter		o		o		c	o	o
Dolichandrone heterophylla	lemonwood	shrub	Winter	o	o						
Drypetes deplanchei *	yellow tulipwood	tree	Spring-Summer		c				c	c	
Dysoxylum gaudichaudianum	ivory mahogany	tree	Spring-Summer		o						
Elaeocarpus grandis	blue quandong	tree	Winter-Spring								c
Erythrina vespertilio *	bat wing coral tree	tree	Summer		o					o	o
Eucalyptus acmenoides	white mahogany	tree	Spring-Summer							c	
Eucalyptus cloeziana	Gympie messmate	tree	Winter-Spring							c	
Eucalyptus crebra *	ironbark	tree	Winter-Spring	o						c	o
Eucalyptus exserta *	Qld peppermint	tree	Autumn-Winter							o	
Eucalyptus paedoglauca	Mt Stuart ironbark	tree	Autumn-Winter								o

Species name		Common name	Form	Fruiting season	Occurrence by soil types (o – occasional , c – common)							
					old plain	recent alluvial	wetland	beach front	mangrove /salt pan	beach ridge/ swale	colluvial	mountain
Eucalyptus platyphylla	*	poplar gum	tree	Spring-Summer	c						o	
Eucalyptus raveretiana		black ironbox	tree	Summer-Autumn		o						
Eucalyptus tereticornis	*	blue gum	tree	Spring-Summer		c	o			c	o	o
Eugenia reinwardtiana	*	Cedar Bay cherry	shrub	Summer-Autumn		c				c	o	
Eupomatia laurina		native guava	tree	Winter								o
Euroschinus falcata		ribbonwood	tree	Summer		c						
Excoecaria agallocha		blind your eye mangrove	tree	Summer					c			
Exocarpus latifolius		native cherry	tree	irregular		c	o			c	c	o
Ficus hispida		boombil	tree	irregular		o					o	o
Ficus opposita	*	sandpaper fig	shrub/tree	irregular	o	c				c	o	
Ficus platypoda		rock fig	tree	irregular		o				o	o	c
Ficus racemosa	*	cluster fig	tree	irregular		c	c			o		
Ficus virens	*	white fig	tree	irregular		c				o	o	o
Fitzalania heteropetala			shrub	Summer-Autumn		c				o	o	
Flueggia virosa		white currant bush	shrub	Spring-Autumn	o	c				o		
Gahnia aspera		saw sedge	herb	irregular		c						c
Ganophyllum falcatum	*	red scaly ash	tree	Summer		c				c		
Geijera salicifolia var. latifolia		scrub wilga	tree	Spring-Summer		c				c	o	
Glochidion disparipes		cheese tree	tree	Spring		o						
Glochidion lobocarpum		cheese tree	shrub/tree			o					o	
Glycosmis trifoliata		pink lime	shrub	Summer		o				o	o	
Grevillea hilliana		Hill's silky oak	tree	Spring-Summer		o					o	
Grevillea parallela		silver oak	shrub/tree	Summer	o	o					o	
Grevillea pteridifolia	*	golden grevillea	shrub/tree	Winter-Spring	o	o				o		
Grevillea striata		beefwood	shrub/tree	Spring	o	o					o	
Grewia retusifolia		emu berry	shrub	Autumn	o	o					o	
Haemodorum coccineum		scarlet bloodroot	herb	Summer	o	o	o			o	o	
Harpullia pendula		tulipwood	tree	Autumn-Winter		o						
Helichrysum rupicola		yellow button	herb	Autumn-Winter							o	
Heteropogon contortus	*	black speargrass	grass	Autumn-Winter	c	o				o	c	o
Heteropogon triticeus		giant speargrass	grass	Autumn-Winter	c						c	

Species name	Common name	Form	Fruiting season	Occurrence by soil types (o – occasional , c – common)							
				old plain	recent alluvial	wetland	beach front	mangrove /salt pan	beach ridge/ swale	colluvial	mountain
Hibbertia scandens	climbing guinea flower	vine	Summer		o					o	
Hibiscus divaricatus	native hibiscus	herb	Autumn-Winter	o							
Hibiscus meraukensis	white hibiscus	herb	Autumn-Winter	o	o						
Hibiscus tiliaceus *	beach cottonwood	shrub/tree	Summer-Winter		o		c	o	c		
Imperata cylindrica	blady grass	grass	Winter	o	o					c	
Indigofera hirsuta	hairy indigo	herb	Summer-Autumn	o	o				o	o	o
Ipomea pes-caprae *	beach morning glory	vine	irregular				c				
Jagera pseudorhus	foam bark	tree	Autumn-Winter		o				o	o	
Jasminium didymum	native jasmine	vine	irregular		c	c			c	c	
Jasminium simplicifolium	stiff jasmine	vine	Winter		c				c	o	
Lagunaria patersonii	Norfolk Island hibiscus	shrub/tree	Autumn-Winter		o					o	
Larsenaikia ochreata *	native gardenia	shrub	irregular	o	c				o	o	
Litsea glutinosa	scrub laurel	tree	Autumn-Winter		c				c	o	
Livistona decipiens *	cabbage palm	palm	Autumn-Winter		o	c			c		
Livistona drudei	cabbage palm	palm	Spring		c	c			o		
Lomandra longifolia *	spiny headed mat rush	herb	Spring-Summer		c	c			o	o	o
Lophostemon confertus	brush box	shrub/tree	Summer								c
Lophostemon grandiflorus *	swamp box	tree	Summer-Autumn		c	c			o		
Lophostemon suaveolens	coastal swamp box	tree	Summer		o				o	o	
Lysiphyllum hookerii *	native bauhinia	tree	Summer	o	c				o		
Macaranga involucrata *	cottonwood	shrub/tree	Spring-Summer		c				c		
Macaranga tanarius *	cottonwood	shrub/tree	Spring-Summer		c				c		
Mackinlaya macrosciadia	dwarf umbrella bush	shrub	Winter		o					o	o
Mallotus discolor	yellow kamala	tree	Summer-Autumn		o					o	
Mallotus philippensis	red kamala	bush/tree	Spring-Autumn		c				c	o	
Melaleuca dealbata	silver leaf paperbark	tree	Spring-Summer		c	c			c		
Melaleuca fluviatilis *	pendulous paperbark	tree	Winter-Spring		c					o	
Melaleuca leucadendra *	weeping paperbark	tree	Winter-Spring		c	c			o		
Melaleuca nervosa	woodland paperbark	tree	Autumn-Spring	o						o	
Melaleuca viridiflora *	broad leaf paperbark	tree	Winter-Spring	c		c		o	o		

Species name	Common name	Form	Fruiting season	Occurrence by soil types (o – occasional , c – common)							
				old plain	recent alluvial	wetland	beach front	mangrove /salt pan	beach ridge/ swale	colluvial	mountain
Melia azedarach	white cedar	tree	Autumn		o				o		
Melicope (Euodia) elleryana	corkwood	tree									o
Micromelum minutum	lime berry	shrub	irregular		o				o		
Mimusops elengi *	red coondoo	tree	Autumn-Spring		c				c		
Morinda citrifolia *	cheese fruit	shrub/tree	irregular		c				c		
Murraya paniculata	mock orange	shrub	Autumn-Winter		o					o	
Nauclea orientalis *	Leichardt tree	tree	Spring-Autumn		c	c			o		
Pandanus whitei *	pandanus	tree	Winter-Spring		c	c			c	o	
Pandorea pandorana	wonga vine	vine	Spring-Summer		o					o	o
Paraserianthes toona	Mackay cedar	tree	Spring		c				o	o	
Passiflora aurantia	native passionfruit	vine	Summer-Winter		c				c		
Persoonia falcata	geebung	shrub/tree	Spring-Summer		o					c	c
Petalostigma pubescens	quinine bush	shrub/tree	Summer-Autumn	c	o	o					
Phyllanthus fuernrohrii		herb	Autumn-Winter	o							
Phyllanthus lamprophyllus		shrub	Spring-Summer		o						
Phyllanthus novae-hollandae	phyllanthus	shrub/tree	Summer		o					o	
Pipturus argenteus	native mulberry	shrub/tree	irregular		o				o	o	
Pittosporum ferrugineum	rusty pittosporum	shrub	Winter						o	o	
Planchonia careya	cocky apple	shrub/tree	Spring-Summer	c	c				c	o	
Pleiogynium timorense *	burdekin plum	tree	Autumn-Winter	o	c				c	o	
Pogonolobus reticulatum	dye bush	shrub	Autumn-Winter		o				o	o	o
Polyalthia nitidissima	canary beech	tree	Autumn		o				c		
Polyscias elegans	celery wood	tree	Winter		o				o		o
Pongamia pinnata *	pongamia	tree	Autumn-Winter		c	o			c		
Pouteria pohlmaniana	yellow boxwood	tree	Autumn		o				c		
Pouteria sericea	native plum	tree	irregular		c				o		
Premna serratifolia *	creek premna	shrub/tree	irregular		o				o		
Proiphys amboinensis	Cardwell lily	herb	Summer-Autumn		o					o	
Randia fitzalanii *	brown gardenia	tree	irregular		c						
Rhizophora stylosa	red mangrove	tree	irregular					c			
Scaevola taccada *	sea lettuce	shrub	irregular				c		c		
Sesbania cannabina	sesbania pea	shrub	Autumn-Winter		c	c			c		

Species name	Common name	Form	Fruiting season	Occurrence by soil types (o – occasional , c – common)							
				old plain	recent alluvial	wetland	beach front	mangrove /salt pan	beach ridge/ swale	colluvial	mountain
Spinifex sericeus *	beach spinifex	grass					c		o		
Sporobolus virginicus *	saltwater couch	grass	Autumn-Winter					c			
Sterculia quadrifida *	peanut tree	tree	Winter-Spring		c				c	c	
Syzygium australe	river cherry	tree	Summer		o						
Tabernaemontana orientalis	orange banana bush	shrub	Summer-Autumn		c				o		
Tacca leontopetaloides	native arrowroot	herb	Summer-Autumn		o				o	o	
Terminalia arenicola	beach damson	tree	Summer-Winter						c		
Terminalia catappa *	beach almond	tree	Summer-Autumn				c		c		
Terminalia melanocarpa	damson	tree	Summer-Autumn		o				o		
Terminalia muelleri *	damson	tree	Autumn-Winter		c				c		
Terminalia sericocarpa *	damson plum	tree	Summer-Autumn		c						
Themeda triandra *	kangaroo grass	grass	Autumn-Winter	c	c				o	c	c
Thespesia populneoides *	beach hibiscus	shrub/tree	Autumn-Winter				o		c		
Timonius timon	timonius	tree	Spring-Summer		o					o	
Trema tomentosa	poison peach	shrub/tree	Autumn-Winter		o				o	o	o
Turraea pubescens	orange star bush	shrub/tree	Autumn-Winter		o				o		
Vitex rotundifolia	beach vitex	vine	irregular				o		o		
Vitex trifolia	beach vitex	vine	irregular						o		
Xanthorrhoea johnsonii	grass tree	shrub	Winter-Spring	c						c	c
Xylocarpus granatum	cannonball mangrove	tree	Winter					o			
Xylopia maccreai		tree	Spring-Summer		o						
Xyminia americana	marzipan bush	shrub/tree	Summer		o						

Appendix C. Environmental weeds of the Townsville City Council region.

Information compiled from experience of local botanists and revegetators, and references cited in Appendix C.2.

Appendix C.1. Occurrence, weed status and problems caused by environmental weeds of the TCC region.

Problems caused: (2-observed problem in region, 1-potential problem)
sa-strangling/choking adult plants
ss-strangling/choking seedling plants
m-forms virtual monocultures, excluding almost all other plants
f-generates large fuel loads
n-nuisance to humans (eg thorns, dermatitis)
w-harmful to wildlife (eg poisonous, reduces dissolved oxygen levels)

Occurrence by soil/landform types: (o-occasional, c-common)
old pl-old plain
rec all-recent alluvial
wetlnd-wetlands
bch fnt- beach front
mgv sp- mangrove and salt pan
bch rg/s-beach ridge and swale
col- colluvial
mtn-mountain

Current weed status:
s-severe weed problem
m-medium importance
l-low importance
P-DNR declared plant in Townsville area
P2-all plants to be destroyed
P3-numbers to be reduced

Distribution and/or abundance status:
2-distribution and/or abundance actively increasing
1-high potential for distribution and/or abundance to increase
0-distribution and abundance stable, with limited potential for increase

Species name	Common name	Form	Problems caused (2-observed, 1-potential)						Current weed status	Distrib. abund. status	Occurrence by soil/landform types (o–occasional, c–common)							
			sa	ss	m	f	n	w			old pl	rec all	wet lnd	bch fnt	mgv sp	bch rg/s	col	mtn
Acacia farnesiana	mimosa	shrub/tree					2		l	1	o	o						
Acacia nilotica	prickly acacia	shrub/tree		1	1	1	1		m, P2	1	o	o				o		
Acanthospermum hispidum	star burr	herb		1			2		l	0	o	o						
Albizia lebbek	Indian siris	tree		2	1				m	2		o					c	
Alternanthera bettzikiana	Alternanthera	herb		1	2	2			m	0	c	c				c	c	
Antigonon leptopus	coral vine	vine	2	2	1				m	1		o				c	o	
Argemone mexicana	Mexican poppy	herb					2		l	0		o					o	
Argyreia nervosa	wood rose	vine	2	2					l	1		o						
Bauhinia spp	bauhinia	shrub/tree		1					l	1	o	o						
Bidens pilosa	cobblers peg	herb					2		l	0	o	o					o	
Bougainvillea sp	bougainvillea	vine	1				2		l	0		o				o		
Brachiara mutica	para grass	grass		2	2	2			s	2		c	c			o		

Species name	Common name	Form	Problems caused (2-observed, 1-potential)						Current weed status	Distrib. abund. status	Occurrence by soil/landform types (o–occasional, c–common)							
			sa	ss	m	f	n	w			old pl	rec all	wet lnd	bch fnt	mgv sp	bch rg/s	col	mtn
Bryophyllum spp	mother of millions	herb		1	2				l	1				o		o		
Cassia fistula	golden cassia	tree		1	1				l	1		o					o	
Catharanthus roseus	periwinkle	herb		2	2				m	0				c		c		
Cenchrus ciliaris	buffel grass	grass		1	1	2			m	1	o					o	o	
Cenchrus echinatus	Mossman river grass	grass					2		l	0		o		c		c		
Clitoria terneata	butterfly pea	vine	2	2	1		2		s	1	o	c					c	
Chloris virgata	purple-top chloris	grass		1		1			l	0	c	c				c	c	
Cryptostegia grandiflora	rubber vine	vine	2	2	2	2			s, P3	2	o	c	c			o	o	
Cyperus rotundus	nut grass	grass		2					l	0	c	c	c			c	c	
Desmodium tortuosum	Florida beggar weed	herb		1					l	0	o	c					c	
Eichornia crassipes	water hyacinth	aquatic		2	2			2	s,P3	1			c					
Eucalyptus torelliana	cadaghi	tree						1	l	0		o					o	o
Euphorbia cyathrophora	dwarf poinsettia	herb		1	1				l	0		o						
Euphorbia heterophylla	milkweed	herb		1	1				l, P3	1		c	c					
Gomphrena celosioides	gomphrena	herb		1		1			l	0	c	c						
Grewia asiatica	grewia	shrub							l	0		o					c	
Hymenachne amplexicaulis	hymenachne	grass	2	2	2	1		2	s	2		o	c					
Hyptis suaveolens	mintweed	herb		2	2	2	2		m	0	c	c				c	c	
Ipomea quamoclit	star of bethlehem	vine	1	1					l	1		o				o		o
Jatropha gossypifolia	bellyache bush	shrub		1	2			1	s	2	o					o	c	
Lantana spp	lantana	shrub	2	2	2	2	2		s	0	o	c	c			o	c	c
Leucaena leucocephala	leucena	shrub/tree		2	2	2			s	2	o	c				c	o	
Macroptilium atropurpureum	siratro	vine	2	2	2		2		s	1	o	c	c			c	c	
Macroptilium lathyroides	phasey bean	herb		1					l	0		o					o	
Mangifera indica	mango	tree		1					l	0		o						
Martynia annua	devils claw	herb					1		l	0		o						
Melinis repens	red Natal grass	grass		1	2	2			m	0	c	c				c	c	
Merremia dissecta	mile-a-minute	vine	2	2					m	0		c				c		
Muntingia calabura	strawberry tree	tree		1					l	1		o						
Neonotonia wightii	glycine	vine	2	2	1		2		m	1		c						
Opuntia stricta	prickly pear	cactus		1	1		1		l, P3	0	o			o		o		
Panicum maximum	guinea grass	grass		2	2	2			s	2	o	c	c			c	c	o

Species name	Common name	Form	Problems caused (2-observed, 1-potential)						Current weed status	Distrib. abund. status	Occurrence by soil/landform types (o–occasional, c–common)							
			sa	ss	m	f	n	w			old pl	rec all	wet lnd	bch fnt	mgv sp	bch rg/s	col	mtn
Parkinsonia aculeata	parkinsonia	shrub		2	1		2		s, P2	2	o	o			c	o		
Parthenium hysterophorus	parthenium weed	herb		1	1	1	1		m, P2	2	o	o						
Passiflora foetida	stinking passionfruit	vine	2	2	1		2		s	0	o	c	c				c	
Passiflora suberosa	corky passionfruit	vine	2	2	1		2		s	0	o	c	c				c	
Pistia stratiotes	water lettuce	aquatic			1			1	l, P3	1			o					
Psidium guajava	guava	shrub		1	1				l	0		o				o		
Ricinus communis	castor oil plant	shrub		1	1		1	1	m	1		o						
Salvinia molesta	salvinia	aquatic		2	2			2	m, P3	1			c					
Samanea saman	rain tree	tree		1					l	1		o					o	
Schinus terebinthifolia	Brazilian pepper tree	shrub/tree		1					l	1		o						o
Senna alata (Cassia alata)	candle bush	shrub		1					l	1	o	o					o	
Senna occidentalis	coffee senna	shrub		1	1				l	1	o	o						
Sida rhombifolia	Paddy's lucerne	herb		2	2				l	0	c	c				c	c	c
Solanum seaforthianum	Brazilian nightshade	vine	1	1					l	0		o				o	o	
Solanum torvum	devils fig	shrub		1			1		l	0		o				o		
Spathodea campanulata	African tulip tree	tree		1					l	1		o						o
Stachytarpheta jamaicensis	snake weed	herb		2	2				m	0	c	c				c	c	
Stylosanthes humilis	Townsville stylo	shrub		2	2				m	0	c	c						
Syzygium cumini	Javan plum	tree		1					l	0		o						
Tamarindus indica	tamarind	tree		1					l	0		o				o		
Tecoma stans	yellow bignonia	shrub		2	2				m	1		o				c		
Themeda quadrivalvis	grader grass	grass		2	2	2			s	2	c	c						
Thevetia peruviana	yellow oleander	shrub		2	1		1	1	m	1		c					o	
Thunbergia spp	thunbergia	vine	2	2	1				m, P2	1		o						
Tithonia diversifolia	Japanese sunflower	herb		1	1				m	1							o	
Tridax procumbens	tridax daisy	herb		1					l	0	c	c				c	c	
Triumfetta spp	chinese burrs	herb/shrub		1	1		1		l	0	o	o				o	o	
Urena lobata	urena burr	herb/shrub		1	1		1		l	0	o	o				o	o	
Urochloa mosambicensis	sabi grass	grass		2	2	2			m	2		c						
Wedelia trilobata	Singapore daisy	vine	1	1	1				m	1		o				o		
Xanthium pungens (Xanthium strumarium)	noogoora burr	shrub		1	1		1		l, P3	0		c				o		
Zizyphus mauritiana	chinee apple	tree		2	2	2	2		s, P3	2	c	c				o	c	

Appendix C.2. Control methods for environmental weeds of the TCC region.

References:

p- Department of Natural Resources, 1997, Pest Facts.
n- Parsons & Cutbertson, 1992, Noxious weeds of Australia.
c- Mitchell and Hardwick, 1995, Animal and weed pests of Cape York Peninsula (CYPLUS).
s- Kleinschmidt, 1991, Suburban weeds.
b- Swarbrick & Skarratt, 1994, Bushweed 2 database of environmental weeds.
e- Csurshes & Edwards, 1998, Potential environmental weeds in Australia.
l- local experience of revegetators

Species name	Common name	Current weed status	References	Weed control techniques
Acacia farnesiana	mimosa	l	p,b	As for *A. nilotica.*
Acacia nilotica	prickly acacia	m, P2	p,n,c,b	Mechanical grubbing (cut roots 30cm below surface); injection, basal bark or cut stump application of triclopyr/picloram or fluroxypyr, avoid stock grazing on mature pods, current biological control agents have had little impact as yet.
Acanthospermum hispidum	star burr	l	n,b	Hand removal; shading; foliar spray with 2,4-D or glyphosate.
Albizia lebbek	Indian siris	m	b,l	injection, basal bark or cut stump application of triclopyr/picloram.
Alternanthera bettzikiana	kahki weed	m	l	Hand removal (ensuring roots are also removed), foliar spray with glyphosate, triclopyr/picloram or 2,4-D probably effective.
Antigonon leptopus	coral vine	m	e	Hand removal (difficult due to regrowth from tuberous roots), herbicide susceptibility unknown .
Argemone mexicana	Mexican poppy	l	n,s,b	Hand removal or mowing before seeding, foliar spray with glyphosate or 2,4-D.
Argyreia nervosa	wood rose	l	l	Hand removal, herbicide susceptibility unknown.
Bauhinia spp	bauhinia	l	b,c	Injection, basal bark or cut stump application of triclopyr/picloram or glyphosate.
Bidens pilosa	cobblers peg	l	s,b	Hand removal or mowing before flowering, foliar spray with glyphosate or 2,4-D.
Bougainvillea sp	bougainvillea	l		Injection, basal bark or cut stump application of triclopyr/picloram probably effective.
Brachiara mutica	para grass	s	b,l	Very difficult to control; combination of techniques usually required, including mechanical or hand removal, foliar application of glyphosate, carefully managed burn. Shading is best long term solution. Effectiveness of limited grazing currently unknown, trials being planned.
Bryophyllum spp	mother of millions	l	p,c,s,b	Hand removal (strong regrowth from leaf fragments, so bury or burn plant material), foliar spray with triclopyr/picloram, 2,4-D or fluroxypyr (using extra wetting agent to penetrate waxy cuticle).
Cassia fistula	golden cassia	l	b	Injection or cut stump application of triclopyr/picloram or glyphosate probably effective.
Catharanthus roseus	periwinkle	m	b,e	Hand removal, foliar spray with glyphosate before flowering probably effective.
Cenchrus ciliaris	buffel grass	m	b	Mowing, foliar spray with glyphosate probably effective, fire increases infestation.
Cenchrus echinatus	Mossman river grass	l	p,n,c,s,b	Mowing, hand removal, foliar spray with glyphosate, avoid vehicle & pedestrian access when seeding.
Chloris virgata	purple-top chloris	l	s,b	Mowing, foliar spray with glyphosate probably effective.
Clitoria terneata	butterfly pea	s	e,l	Hand removal (ensuring roots are also removed), low herbicide susceptibility.

Species name	Common name	Current weed status	References	Weed control techniques
Cryptostegia grandiflora	rubber vine	s, P3	p,n,c,b	Mechanical and hand removal, basal bark and cut stump application of triclopyr/picloram. Hot fires will kill rubber vine, but may also kill native trees. Two biological controls, a fungal rust and a moth, are both multiplying in the region, but their effectiveness is so far unknown.
Cyperus rotundus	nut grass	l	n,s,b	Foliar spray with glyphosate will kill aerial shoots; however, strong regrowth occurs from tubers. Shading by larger plants is best long term solution.
Desmodium tortuosum	Florida beggar weed	l	l	Hand removal, herbicide susceptibility unknown.
Eichornia crassipes	water hyacinth	s,P3	p,n,c,b	Mechanical or hand removal, foliar spray with 2,4-D and various other herbicides (not recommended due to contamination of waterways). Introduced weevils, moths and native fungi provide some control.
Eucalyptus torelliana	cadaghi	l	b	Injection, basal bark or cut stump application of triclopyr/picloram
Euphorbia cyathrophora	dwarf poinsettia	l	s,b	Hand removal, foliar spray with triclopyr/picloram (or glyphosate?)
Euphorbia heterophylla	milkweed	l, P3	n,c,s,b	Hand removal, foliar spray with triclopyr/picloram (or glyphosate?)
Gomphrena celosioides	gomphrena	l	s,b	Hand removal, foliar spray with glyphosate or 2,4-D
Grewia asiatica	grewia	l	c,e	Basal bark or cut stump application of triclopyr/picloram, resistant to fire, spread by birds.
Hymenachne amplexicaulis	hymenachne	s	e	Mechanical or hand removal, herbicide susceptibility unknown.
Hyptis suaveolens	mintweed	m	n,c,b	Hand removal (ensuring roots also removed), foliar spray with 2,4-D or picloram, avoid vehicle & pedestrian access when seeding.
Ipomea quamoclit	star of bethlehem	l	e	Hand removal, herbicide susceptibility unknown, may be susceptible to fire.
Jatropha gossypifolia	bellyache bush	s	p,n,c,e,b	Mechanical or hand removal, repeated slashing, controlled burn, foliar spray with fluroxypyr or triclopyr/picloram or glyphosate, reduce grazing pressure.
Lantana spp	lantana	s	p,n,c,b	Mechanical or hand removal (removing as much of lateral roots as possible), basal bark or cut stump application of triclopyr/picloram or 2,4-D. Controlled burn or slashing will remove aerial shoots, but regrowth must be controlled (eg spray with glyphosate or 2,4-D) or infestation will increase. Numerous biological control agents have been introduced, but give only limited control.
Leucaena leucocephala	leucena	s	e,b,l	Injection, basal bark or cut stump application of triclopyr/picloram. Young seedlings can be controlled by glyphosate or flame weeder. An accidentally introduced beetle and a psyllid have been observed in the area, but their effects are unknown as yet.
Macroptilium atropurpureum	siratro	s	s,e,b,l	Hand removal (ensuring roots are also removed), foliar spray with 2,4-D (or fluroxypyr?), resistant to glyphosate at normal rates.
Macroptilium lathyroides	phasey bean	l	s,b	Hand removal, foliar spray with 2,4-D or fluroxypyr.
Mangifera indica	mango	l	b	Injection, basal bark or cut stump application of triclopyr/picloram or glyphosate.
Martynia annua	devils claw	l	c,b	Hand removal, foliar spray with glyphosate, 2,4-D or triclopyr/picloram.
Melinis repens	red Natal grass	m	s	Mowing, foliar spray with glyphosate probably effective.
Merremia dissecta		m	b,l	Hand removal, herbicide susceptibility unknown.

Species name	Common name	Current weed status	References	Weed control techniques
Muntingia calabura	strawberry tree	l	b	Injection, basal bark or cut stump application of triclopyr/picloram or glyphosate probably effective.
Neonotonia wightii	glycine	m	e	Hand removal (ensuring roots are also removed), herbicide susceptibility unknown.
Opuntia stricta	prickly pear	l, P3	p,n,b	Introduced Cactoblastis moth and cochineal bug are very effective biological control agents, limiting prickly pear to small isolated populations. Spot spray with roundup or triclopyr/picloram.
Panicum maximum	guinea grass	s	c,s,b	Hand removal is effective for small populations Larger infestations can be slashed or burnt, followed by foliar spray with glyphosate or hand removal. Shading is the best long term solution.
Parkinsonia aculeata	parkinsonia	s, P2	p,n,c,b	Mechanical removal followed by foliar spray of regrowth with triclopyr/picloram. Basal bark or cut stump application of triclopyr/picloram. Beetles and a bug have been introduced, but their impact is unknown as yet. Exclude stock when pods mature.
Parthenium hysterophorus	parthenium weed	m, P2	p,n,b	CAUTION: This plant can cause severe dermatitis and hay fever. Pasture spelling and careful management to avoid overgrazing limit entry and spread. Machinery, stock, feral animals and people can all spread seed. Strict quarantine procedures, including washing down of equipment used in infested areas, will limit spread. Foliar spray with glyphosate, picloram or 2,4-D. Biological control, using 7 insects and a fungal rust, has so far had limited success.
Passiflora foetida	stinking passionfruit	s	s,b,l	Hand removal (ensuring roots are also removed), herbicide susceptibility unknown.
Passiflora suberosa	corky passionfruit	s	s,b,l	Hand removal (ensuring roots are also removed), herbicide susceptibility unknown.
Pistia stratiotes	water lettuce	l, P3	p,n	Mechanical or hand removal. Two introduced weevils provide good control in many areas. Glyphosate has been used successfully, but is undesirable in waterways.
Psidium guajava	guava	l	e,b	Cut stump application of triclopyr/picloram or glyphosate effective for large plants (> 3cm diameter trunk), smaller plants can be basal barked with triclopyr/picloram.
Ricinus communis	castor oil plant	m	p,n,c,b	Mechanical or hand removal, foliar spray of small plants with glyphosate or 2,4-D, basal bark or cut stump application of larger plants with triclopyr/picloram.
Salvinia molesta	salvinia	m, P3	p,n,c,b	Biological control with an introduced weevil provides excellent control of large infestations. Small populations can be removed mechanically or by hand.
Samanea saman	rain tree	l	l	Injection, basal bark or cut stump application of triclopyr/picloram probably effective.
Schinus terebinthifolia	Brazilian pepper tree	l	s,b	Hand removal of young plants. Injection, basal bark or cut stump application of triclopyr/picloram on larger plants, coppices rapidly after fire.
Senna alata (Cassia alata)	candle bush	l	n,c,e,b	Hand removal effective if roots also removed. Slashing at flower stage prevents seed set. Foliar spray or cut stump application with triclopyr/picloram or glyphosate probably effective.
Senna occidentalis	coffee senna	l	n,c,b	Hand removal, foliar spray with triclopyr/picloram, 2,4-D/picloram or glyphosate
Sida rhombifolia	Paddy's lucerne	l	n,c,b	Mechanical or hand removal, foliar spray with glyphosate or fluroxypyr. Numerous insects have been introduced, with some success.
Solanum seaforthianum	Brazilian nightshade	l	b	Hand removal, herbicide susceptibility unknown.

Species name	Common name	Current weed status	References	Weed control techniques
Solanum torvum	devils fig	l	b,l	Cut stump application with glyphosate, or basal bark or cut stump application with triclopyr/picloram probably effective.
Spathodea campanulata	African tulip tree	l	b	Injection, basal bark or cut stump application of triclopyr/picloram.
Stachytarpheta jamaicensis	snake weed	m	p,n	Common in overgrazed pastures. Foliar spray with glyphosate or 2,4-D most effective on young plants. Pasture spelling and management to avoid overgrazing are important in limiting entry and spread of snakeweed.
Stylosanthes humilis	Townsville stylo	m	b	Hand removal, herbicide susceptibility unknown.
Syzygium cumini	Javan plum	l	l	Injection, basal bark or cut stump application of triclopyr/picloram probably effective
Tamarindus indica	tamarind	l	l	Injection, basal bark or cut stump application of triclopyr/picloram probably effective
Tecoma stans	yellow bignonia	m	e,b	Injection or cut stump application of triclopyr/picloram or glyphosate probably effective
Themeda quadrivalvis	grader grass	s	n,c,b	Foliar spray with glyphosate, before annual seed set. Shade ground to prevent germination. Fires and overstocking increase infestations.
Thevetia peruviana	yellow oleander	m	e,b	Injection, basal bark or cut stump application of triclopyr/picloram probably effective.
Thunbergia spp	thunbergia	m, P2	p,n,c,e,b	Foliar spray with imazapyr (eg Arsenal 250A) will kill aerial shoots and underground tubers. Young plants can be controlled with glyphosate or 2,4-D.
Tithonia diversifolia	Japanese sunflower	m	c,s,b	Hand removal, foliar spray with 2,4-D, basal bark or cut stump application of triclopyr/picloram or fluroxypyr.
Tridax procumbens	tridax daisy	l	s,b	Hand removal, foliar spray with 2,4-D.
Triumfetta spp	chinese burrs	l	c	Hand removal, slashing, foliar spray with 2,4-D (or glyphosate?).
Urena lobata	urena burr	l	c,b	Hand removal, slashing. Young plants can be controlled by foliar spray with 2,4-D or glyphosate.
Urochloa mosambicensis	sabi grass	m		Slashing, foliar spray with glyphosate probably effective.
Wedelia trilobata	Singapore daisy	m	s,e	Hand removal, mowing very close to ground, foliar spray with metsulfon methyl (eg Brush-off).
Xanthium pungens (Xanthium strumarium)	noogoora burr	l, P3	p,n,c,b	Hand removal or controlled burning before seed set. Foliar spray with glyphosate or 2,4-D, most effective on young plants. Introduced insects (seed fly, stem boring beetles and stem galling moth) and a fungal rust provide some control in moist tropical regions.
Zizyphus mauritiana	chinee apple	s, P3	p,n,c,l	Heavy infestations can be cleared with a bulldozer (most effective if roots removed to 25 cm depth), and regrowth controlled with triclopyr/picloram. Basal bark or cut stump application of triclopyr/picloram effective on individual trees.

Appendix D. Assessment of rehabilitation priorities for sites in TCC region.

1. Land and water conservation criteria:

Criterion	Critical importance (score 2)	Medium importance (1)	Low importance (0)
Streambank stabilisation	Actively eroding streambanks subject to moderate erosion under normal flow conditions and severe erosion during high flow periods	eroding streambanks mainly subject to erosion during high flow periods	relatively stable streambanks that erode only during severe conditions eg major floods, cyclones
Erosion control (including coastal dunes)	actively eroding area subject to moderate erosion under normal conditions and severe erosion during storm events	area subject to minor erosion under normal conditions, but may suffer moderate to severe erosion during storm events	relatively stable area that erodes only during severe conditions eg major floods, cyclones
Soil infiltration, stream flows and flood mitigation	high levels of overland water flow, no detention of flood waters entering watercourses and flood waters severely impeded by blockages in watercourses	moderate levels of overland water flow, limited detention of floodwaters entering watercourses and some watercourse blockages	limited overland water flow, moderate detention of flood waters entering watercourses and limited blocking of drainage
Sediment/nutrient filtering capacity, water quality	no existing sediment/nutrient filtering capacity in areas where adjacent landuse may generate high levels of sediments/nutrients	some sediment/nutrient filtering capacity	high sediment/nutrient filtering capacity
Pest management	infestations of aggressive noxious weeds with effective chemical, mechanical or biological control methods (eg chinee apple, rubber vine, salvinia) infestations of pest animals with high potential for ecological agricultural or commercial impacts	infestations of weeds that are either less aggressive or with uncertain control methods infestations of pest animals with moderate potential impacts	only non-problematic weeds present, with little potential for infestations of aggressive weeds; infestations of pest animals with limited impacts

2. Ecosystem viability criteria.

Criterion	Critical importance	Medium importance	Low importance
Biological diversity	high number of native species, impacted by external factors	good diversity of native species; some external impact	few native species
Biological integrity	relatively intact ecosystem; threatened by external factors without immediate rehabilitation measures	moderately impacted ecosystem; retains significant level of ecosystem function, but requires active rehabilitation to avoid further degradation	ecosystem heavily impacted by external factors; limited potential to reconstruct intact ecosystem
Habitat of rare & threatened (R&T) species	main habitat of R&T species, with very little other suitable habitat	habitat used by R&T species; other suitable habitats used by species	habitat infrequently used by R&T species, or habitat intact and widespread
Rare & restricted vegetation community/habitat type	rare community/habitat type heavily impacted by external factors	rare community/habitat type with low impact from external factors or still relatively intact	community/habitat type not rare

Ecofunctional areas	important linkage connecting disjunct habitat remnants, allowing effective gene flow; refugial area, migration path, breeding area, ecotonal area; with external factors currently impairing ecofunctional role	ecofuntional area whose function is threatened but not yet impaired by external factors	not ecofunctional area

3. Community criteria.

Criterion	Critical importance	Medium importance	Low importance
Community support/interest	strong involvement by members of the wider community in planning, rehabilitation and maintenance of site	involvement by community in some aspects of project	little community interest
Demonstration/ education	used by numerous community groups and individuals for demonstration and environmental education	some use	little potential for educational or demonstration value
Community use	used widely by community for recreation and/or scenic values	used by local community or small proportion of wider community	little community use
Cooperative support	substantial technical, financial, labour and/or resource support from other organisations (eg government agency, business sponsorship)	some support and advice available	no cooperative support
Cultural heritage values	project will enhance known cultural significance of site, supported by local cultural group(s)	some cultural significance	little cultural significance

4. Council operational criteria.

Criterion	Critical importance	Medium importance	Low importance
Tenure and landuse	Government tenure with no current or planned incompatible landuse	Private land with no current or planned incompatible landuse	non-compatible landuse
Site access and visibility	site with high public visibility and good access for people and equipment	site with some visibility, reasonable access	site seen by few people or has difficult access
Funding/resources requirements and availability	project requires minimal financial/resource support, or support available from other sources (eg government funds, business sponsorship, suitable seed/plant supplies))	some council funding/resources required	high level of council support required
Stormwater management	markedly enhance potential of site for safe detention or improved passage of stormwater	some improvement in stormwater management	little effect or impairment
Probability of successful outcome	using proven rehabilitation methodology, high probability of rehabilitation success in relatively short time frame	reasonable probability of successful outcome	untried techniques, or rehabilitation work required over long time period

Appendix E. Rehabilitation assessment form for sites in TCC region.

Site name: _____

Site location: _____

Assessed by: _____ Date of assessment: _____

	Criterion	Assessment score (0-2)		Criterion	Assessment score (0-2)
A.	**LAND AND WATER CONSERVATION**		**C.**	**COMMUNITY VALUES**	
	Streambank stabilisation	❑		Community support/interest	❑
	Erosion control (including coastal dunes)	❑		Demonstration/ education	❑
	Soil infiltration, stream flows and flood mitigation	❑		Community use	❑
	Sediment/nutrient filtering capacity, water quality	❑		Cooperative support	❑
	Pest management	❑		Cultural heritage values	❑
B.	**ECOSYTEM VIABILITY**		**D.**	**COUNCIL OPERATIONS**	
	Biological diversity	❑		Tenure and landuse	❑
	Biological integrity	❑		Site access and visibility	❑
	Habitat of rare & threatened species	❑		Funding/resources requirements and availability	❑
	Rare & restricted vegetation community/habitat type	❑		Stormwater management	❑
	Ecofunctional areas	❑		Probability of successful outcome	❑
				TOTAL SCORE	❑ /40

Appendix F. Rehabilitation sites identified in TCC region.

ACTFRa: Townsville City Council region: Vegetation communities and conservation priorities. (Skull, 1996)
ACTFRb: Wetlands of the Townsville area. (Lukacs, 1996)
RIKES: Rapid identification of key environmental sites. (TCC, 1990)
RW: Revegetation workshop, February 1997 (Lokkers, 1997)
TTSP: Townsville Thuringowa strategy plan (QDLGP, 1996)

Site	Identified in:	Values
A. Mountain		
Mt Louisa	RIKES, ACTFRa	habitat, fauna, erosion control
Castle Hill	RIKES, ACTFRa, TTSP, RW	habitat, flora, fauna, erosion control, recreation
Cape Pallarenda	RW	habitat, flora, fauna, erosion control, recreation
Mt Stuart	RIKES, ACTFRa, TTSP, RW	habitat, flora, fauna, corridor, erosion control, recreation
Mt Jack corridor	ACTFRa, TTSP	habitat, flora, corridor
Muntalunga Range	ACTFRa, TTSP	habitat, flora, corridor
Woodstock Hill corridor	ACTFRa, TTSP	habitat, corridor
Sisters Mountains	ACTFRa, TTSP	habitat, flora, fauna, corridor
Mt Elliot Gorge	ACTFRa, TTSP	habitat, flora, fauna, corridor
Western and southern slopes of Mt Elliot	TTSP	habitat, flora, water quality
Black Mt, Brown Mt, Mt Flagstone	ACTFRa, TTSP	habitat, flora, erosion control, water quality, recreation
Limestone Hills corridor	ACTFRa	habitat, flora, erosion control, corridor
South Double Hill, Artillery Hill	ACTFRa	habitat, corridor
B. Riparian		
Gustav Ck	RW	habitat, corridor, fauna, drainage, erosion control, recreation
Bohle R	RIKES, ACTFRa,b, TTSP	habitat, corridor, fauna, breeding site, erosion control, drainage
Mundy Ck	RW	habitat, corridor, fauna, drainage, erosion control, recreation
Louisa Ck (Pee wee Ck)	RIKES, ACTFRa,b, TTSP	habitat, corridor, fauna, drainage, erosion control, recreation
Aitkenvale-Lakes drainage	RW	habitat, drainage, water quality, erosion control, recreation
Ross R (and tributaries)	RIKES, ACTFRa,b, TTSP, RW	habitat, corridor, fauna, breeding site, drainage, erosion control, recreation
Ross Ck	TTSP, RW	habitat, drainage, erosion control, recreation
Stuart Ck (including Stoney Ck)	RIKES, ACTFRa,b, TTSP, RW	habitat, corridor, fauna, drainage, erosion control, recreation
Sandfly Ck	RIKES	habitat, corridor, fauna, drainage, recreation
Alligator Ck	ACTFRa,b, TTSP	habitat, flora, corridor, drainage, erosion control, recreation
White's Ck	ACTFRa,b, TTSP	habitat, flora, corridor, drainage, erosion control
Slippery Rocks Ck	ACTFRb, TTSP	habitat, flora, corridor, drainage
Killymoon Ck	ACTFRa,b, TTSP	habitat, flora, corridor, drainage, erosion control
Sachs Ck	ACTFRa,b, TTSP	habitat, flora, corridor, drainage, erosion control, water quality
Antill Plains Ck (especially upper)	ACTFRa,b, TTSP	habitat, flora, corridor, water quality, recreation
Landsdowne Ck (including Toonpan Ck)	ACTFRa, TTSP	habitat, corridor, water quality, recreation
Major Ck (including Sandy Ck)	ACTFRa, TTSP	habitat, flora, drainage, corridor, erosion control, recreation
Serpentine Ck	TTSP	
Haughton R	ACTFRa, TTSP	habitat, flora, drainage, erosion control, corridor
Reid R	ACTFRa, TTSP	habitat, flora, erosion control, corridor
C. Coastal		
Magnetic Island foreshores	RIKES, ACTFRb, TTSP, RW	habitat, fauna, breeding site, erosion control, recreation
Pallarenda Rowes Bay foreshore	RIKES, ACTFRa,b, TTSP, RW	habitat, fauna, breeding site, erosion control, recreation,
Town Common	RIKES, ACTFRa,b, TTSP, RW	habitat, fauna, breeding site, migration path, recreation
Kissing Point	RIKES	habitat, recreation
South Bank coastal complex (including coastal forests to Mt Muntalunga)	RIKES, ACTFRa,b, TTSP, ANCA, RW	habitat, fauna, breeding site, migration path, erosion control, recreation
Western Cape Cleveland	ACTFRa, TTSP	habitat, flora, fauna, recreation
Cungulla	ACTFRa, TTSP, ANCA, RW	habitat, flora, fauna, migration path, corridor, erosion control,
Undeveloped islands	RIKES	habitat, fauna, breeding site, recreation
D. Wetlands		
Horseshoe Bay lagoons	RIKES, ACTFRb, TTSP, RW	habitat, fauna, breeding site, recreation
Nelly Bay lagoon	RW	habitat, fauna, breeding site
Blakey's Crossing and Mt St John swamps	RIKES, ACTFRa,b, TTSP, RW	habitat, fauna, breeding site, loss of similar habitat, drainage, water quality
Lakes stage 1 &2	RIKES	potential habitat, fauna, drainage, recreation
Idalia swamps	ACTFRb, TTSP, RW	habitat, fauna, drainage
Ross River weirs	ACTFRb, TTSP	habitat, fauna, recreation
Ross River Dam	ACTFRb, TTSP, ANCA	habitat, fauna, breeding site, water quality, recreation
Toonpan lagoon, McDonalds Dams	ACTFRb, TTSP	habitat, fauna, drainage, water quality
Serpentine lagoon	ACTFRa,b, TTSP	habitat, flora, fauna, breeding site

Site	Identified in:	Values
Sand hole swamps	ACTFRb, TTSP	habitat, fauna
E: Other		
Dalrymple Rd easement	RW	habitat, corridor, recreation, urban forestry
Bicentennial Park	RW	habitat, corridor, recreation
Ross River Dam catchment	ACTFRa, TTSP	habitat, flora, corridor, erosion control, water quality
Muntalunga footslopes-north of Julago-Mt Elliott footslopes	ACTFRa	habitat, corridor
Elliot toe corridor	ACTFRa, TTSP	habitat, corridor

Appendix G. Existing and potential corridors linking habitats in the TCC region.

Corridor	Habitats linked	Status
Gustav Ck	Magnetic Island National Park-Nelly Bay	degraded
Mundy Ck/William St	Lakes-Rowes Bay Castle Hill-Town Common	semi-artificial drainage, major road crossings, fragmented, degraded
Louisa Ck	Mt Louisa-Town Common	fragmented, degraded, major road crossings
Ross River	South Bank–Mt Stuart (via Campus Ck, Annandale drainages) South Bank–Ross Ck (via Bicentennial Park) Cleveland Bay-Ross R Dam Cleveland Bay-Mt Flagstone	fragmented, degraded, weirs and dam fish barriers
Ross Ck/Dalrymple Rd	Ross R-Mt Louisa	fragmented, degraded, artificial habitat, major road crossings
Stuart Ck	South Bank-Mt Stuart (via Stoney Ck) South Bank-Sisters	fragmented, degraded, major road crossing
Coastal forests south of South Bank	South Bank-Mt Muntalunga	intact, some weeds
Sandfly Ck	South Bank-Mt Muntalunga	fragmented, degraded
Alligator Ck	Cleveland Bay-Mt Elliot NP (coastal)-Mt Elliot Cleveland Bay-Mt Muntalunga (via Whites Ck) Cleveland Bay- Sisters (via Slippery Rocks Ck)	fragmented, degraded
Woodstock Hill corridor	Mt Elliot-Mt Elliot NP (coastal)	degraded, major road crossing
Killymoon Ck	Mt Elliot-Mt Elliot NP (coastal)	some weeds, major road crossing
Salmon Ck corridor	Mt Elliot-Cungulla	degraded, major road crossing
Feltham Cone corridor	Mt Elliot-Cungulla	degraded, major road crossing
Mt Jack corridor	Mt Stuart-Mt Muntalunga	fragmented, degraded, major road crossings
Julago corridor	Mt Muntalunga-Sisters	fragmented, degraded, major road crossing
Mt Elliot Gorge	Mt Elliot-Sisters	fragmented, degraded
Sachs Ck	Mt Stuart-Ross R Dam	degraded
Antill Plains Ck	Mt Elliot-Ross R Dam	degraded, major road crossing
Landsdowne Ck	Mt Flagstone-Ross R Dam Mt Elliot-Ross R Dam (via Toonpan Ck)	degraded, major road crossing
Elliot Toe corridor	Mt Elliot-Ross R (above dam)	some weeds, major road crossing
South Double Hill/Artillery Hill	Mt Elliot-Major Ck	some weeds
Major Ck	Mt Elliot-Haughton R Mt Elliot-Limestone Hills (via Sandy Ck)	degraded
Serpentine Ck	Mt Elliot-Serpentine Lagoon-Major Ck	degraded
Limestone Hills corridor	Brown Mt-Haughton R	some weeds
Haughton R	Cungulla-Reid R	degraded
Reid R	Haughton R-Dalrymple Shire	some weeds

Appendix H. Revegetation guidelines.

Guidelines compiled by C. Lokkers, 1998, for Townsville Thuringowa region.

CONTENTS:

1. Identify physical attributes.

Soil type(s) -sand, loam, silt, clay, or combinations of these. Soil type influences many important factors, including fertility, moisture and nutrient holding abilities, drainage and susceptibility to problems such as erosion and weed infestation.

Drainage -large areas of this region have heavy and impermeable clay subsoil layers which cause poor drainage. Other areas with potential for impeded drainage include low-lying swales between coastal dunes, mangroves, salt flats, and secondary drainage lines.

Geography -location of a site (eg beachfront, creek bank)

Topography -slopes improve drainage, but increase the risks of erosion, fire and wind damage. Soil depth usually decreases with increasing slope. Aspect will influence seasonal levels of solar radiation; slopes facing north receive most sun in winter, and southern facing slopes receive most in summer.

2. Identify potential problems and risks.

Some of the more common problems for this region are listed, and some possible solutions suggested.

Poor drainage-causes waterlogging, low oxygen levels for roots.
-select tolerant plants.
-deep ripping to break through impermeable soil layer.
- gypsum or lime application to improve soil structure.
-plant on soil mounds.

Salinity -high salt levels in soil or salt spray is toxic to most plants.

-select tolerant plants.
-plant on soil mounds.
-use water with low dissolved salt levels when watering to help flush salts away from roots.

Steep slopes -little soil, high erosion potential
-high risk of fire and wind damage (if facing prevailing winds).
-often very dry due to high drainage and little soil.
-select tolerant plants.
-build swales or retaining structures to hold soil and moisture.

Windy sites -causes high water loss, structural damage (especially to young plants).
-plant a variety of wind tolerant species in direction of prevailing wind to produce windbreak .

Fire risk areas-areas with high fuel loads eg open woodlands, grasslands, industrial areas.
-sloping ground, particularly slopes facing prevailing winds.
-maintain firebreaks.
-keep fuel loads in site low by regular weeding and mowing (cut weeds can also be used as mulch, although seeds may be a problem).
-organise low intensity patch burns during early dry season.

3. Identify planned use(s) for site.

Planting strategies will depend on the uses proposed for the site, such as storm water management, sports requiring open spaces, social activities or scenic appreciation.

4. Generate site plan.

Using the information above, strategies for site preparation, composition and arrangement of planting, and maintenance can be developed.

Identify ecological zones (eg creek bank with fine silty soil, alluvial flat with sandy soil, shallow hill slope with clay soil). A map of the site showing zones is a very useful tool for planning and easy reference.

For each zone, select suitable plant species. As well as the information already collected, other criteria to consider include ecological functions such as wildlife habitat and food (eg nectar for birds and butterflies, hollows for arboreal animals), rehabilitation purposes (eg erosion or weed control, windbreak), production (eg timber or food) amenities (eg shade or screening), structural considerations (eg proximity to powerlines and buildings) and aesthetic values.

Densities of planting will depend on ecological factors, and on any planned uses for the site (eg sporting activities). Natural tree densities in the region vary from 1 plant/m^2 (1m between plants) in vine thicket along creek banks to less than 1 plant/25m^2 (over 5m between plants) in open woodland on dry clay soils.

Plant arrangement may be determined by maintenance considerations. For example, if a tractor slasher is to be used for mowing grass between trees, relatively straight rows of trees may be required. Irrigation lines will also dictate plant positions to a fair extent. A random arrangement produces a more natural appearance.

Planting trees in clusters is an effective compromise between these extremes - a slasher can be used between clumps, and manual weeding effort, watering, and mulch can be concentrated within each clump. Slashed grass can also be used for mulch, reducing one ongoing maintenance cost.

Planting time will be influenced by availability of materials and people. Best times for optimum survival are probably during the wet season (low water stress, assuming a good wet!) or mid winter (low heat stress), but good results can be achieved at other times if good preparation and follow up maintenance is practised.

5. Site preparation.

Physical:

Some soils in this region are relatively acidic (pH lower than 5.5), and could benefit from the addition of lime or dolomite.

Lime, dolomite and gypsum are also useful for breaking up heavy clay soils, and improving soil structure and drainage. Rates of 10 tonnes/hectare (1 kg/m^2) are recommended. Another technique (often used in conjunction with gypsum) for breaking up compacted and heavy soils is deep ripping (0.4 - 1 m depth), using a tractor with a suitable implement. Ripping also reduces competition from nearby trees by severing their surface feeder roots. In sloping ground, rips should be made following the contours, to improve moisture retention and minimise erosion.

In boggy areas, mounds of soil may be constructed to reduce waterlogging. However, this is a very labour intensive and costly exercise, and should be considered only in exceptional circumstances (eg a particular feature tree).

On sloping ground, swales dug following the contour of the slope improve moisture retention, and reduce erosion potential. Steeper slopes and eroded creek banks may require more extensive earthworks, such as construction of retaining walls or gabions (rock filled wire baskets placed over eroded surfaces).

Biological:

Weed control is a major factor contributing to the success of any revegetation project, both before planting and during subsequent maintenance. Weeds may adversely impact on plantings by various means, such as competing for water, nutrients and light, increasing fire risk, producing toxic (allelopathic) chemicals, or strangling. Weeds are encouraged by disturbance (eg fire, feral animals, intensive site preparation), and high levels of nutrients, moisture and light - conditions often produced during the process of revegetation! A highly successful, although labour intensive, method of natural bush regeneration, the Bradley method, utilises minimum disturbance methods of weed removal to allow natural regeneration

processes to restore bushland. However, this technique has limited application in the highly modified urban environment.

The following methods of weed control have been used in this region, in varying combinations:

Manual weeding
-using mattocks, shovels, cane knives, hand pulling.
-easiest when ground is moist.
-effective, low disturbance, but very labour intensive.
-removed weeds can be used as mulch (keeping roots away from ground to stop regrowth).

Mowing
-using brushcutter, lawnmower, or tractor slasher.
-relatively low disturbance, some soil compaction from tractor.
-most weeds will regrow very quickly from bases.
-cuttings can be used as mulch.

Fire
-controlled burn during cool dry season.
-clear around existing trees to reduce scorching.
-obtain expert advice and relevant permits from fire service.
-may induce germination of native and/or weed seeds.

Herbicide
-either knockdown (eg glyphosate) or residual (eg simazine).
-very effective for large areas, very invasive weeds, woody weeds.
-chemicals may harm animals (eg frogs), or plantings.
-obtain expert advice on suitability and safe handling procedures.

Scalping
-A technique successfully used in southern direct seeding revegetation projects, scalping, involves the use of a bulldozer or grader to remove the top 2 to 10 cm of topsoil, which contains most of the weed roots and seeds. Although scalping removes the most fertile layer of soil, this method has produced good results, and would be worth trialling in our tropical climate.

If the site will be left for some time before planting, the bare soil should be covered to minimise weed regrowth, with mulch or weed control mat.

6. Planting.

Plant as soon as possible after site preparation is complete.

Pre-water planting sites so soil is moist.

Dig hole at least twice size of pot. In heavy clay soils, watch out for “polished” edges on hole. May need to gouge edges of hole with side of shovel or bar.

Remove plant from container. Place hand over top of pot, invert pot, and plant will usually slide out with root ball intact. May need to gently shake or tap pot to free plant.

Examine root ball for circling roots. If these are left, they may eventually strangle the growing plant. Cut or tease out these roots.

Place seedling so soil level of root ball is slightly lower than level of surrounding soil

Ensure roots are not doubled over or buckled.

While holding plant in position, backfill hole with soil dug from hole. Firm down soil, but do not compact soil excessively (especially if soil is very wet).

In most sites, fertiliser will improve growth rates, but is not essential. If using fertiliser, the following points should be considered. Do not apply excessive amounts of fertiliser, or place fertiliser directly on roots, as the sensitive growing roots may be burnt. Place fertiliser below the soil surface, to reduce loss of fertiliser by rain and irrigation. Some people advocate adding fertiliser in a shallow ring or a few shallow holes around the plant. This is particularly effective for vine thicket and rainforest species, which develop a dense network of shallow feeder roots. However, the fertiliser will also be readily available to shallow rooted grasses and other weeds. Other revegetators advise placing the fertiliser at the base of the planting hole, followed by a thin layer of soil to avoid direct contact with the plant roots. Both techniques are used widely and produce good results. Recommended fertiliser doses are 100 g (one handful) of organic fertiliser (eg dynamic lifter), 50 g (half a handful) of inorganic fertiliser (eg Crop King 88, Q5), or one slow release tree fertiliser tablet.

Water in well, to settle the soil and remove air-pockets. 10 to 20 litres of water is recommended.

Lay mulch around plant, preferably at least 15 cm thick, and at least 1 m radius around plant. Ensure mulch does not touch plant stem to avoid stem rot.

To reduce water stress and wilting, some of the plant’s leaves can be removed. Advisable for plants with large leaf area in hot weather, or if roots disturbed (eg circling roots cut).

7. Mulching.

Organic mulch - leaves, wood chips, grass cuttings, other plant material, animal manures
Mulch provides many benefits to growing plants. It reduces water loss from the soil dramatically, so less watering is required. Soil temperatures are more stable, and erosion from rain and wind are reduced. Decomposition of most mulches provides a steady supply of nutrients, although certain nitrogen poor mulches (eg sawdust) can cause a net depletion of nitrogen (watch for yellowing of oldest leaves if this problem is suspected; add nitrogen fertiliser such as urea or manure if necessary). Certain materials, such as eucalypt leaves and some tree chips, may also contain toxins which impair tree growth (composting of these materials usually breaks down the toxins).

Another important function of mulch is the suppression of weed growth. A thick (15 to 20 cm) layer of mulch will stop all but the most invasive weeds, but will need to be regularly renewed to keep up with the decomposition rate (probably 1 to 3 times per year).

When using organic mulch, lay around plant preferably at least 1 m radius, and at least 15 cm thick. Ensure that mulch does not touch the plant stem, as this may encourage stem rot. Renew regularly.

Artificial mulch mats - biodegradable (eg wool, jute) or woven plastic.
These mats are easier and faster to place, but provide fewer benefits to the plant. They suppress weed growth and reduce water loss, but provide little or no nutrient, or soil temperature buffering. The biodegradable mats will last 1-2 years, and the plastic mats somewhat longer, depending on sunlight exposure. These mats are also more expensive than organic mulch.

8. Maintenance.

Regular, thorough maintenance is an **essential** element of a successful revegetation program. Many thousands of seedlings have been planted by enthusiastic workers, only to succumb to such fates as lack of water, swamping by weeds or a wildfire. These losses are preventable by developing and implementing a suitable maintenance plan, over a 2 to 5 year period. A maintenance plan should address the following issues:

Watering technique

Manual	-bucket, hose. -cheap, but very labour intensive.
Irrigation	-piped water, with drippers or sprayers. -very efficient use of water. -expensive, and requires reticulated or pumped water to site.
Water trucks	-used extensively by Councils. -no infrastructure needed on site. -high water delivery rate can damage plants and mulch layer, and may not penetrate into heavy soils effectively. -expensive.

Watering schedule

Infrequent heavy waterings are better than frequent light waterings, as the former promotes deep root growth and improves drought tolerance. However, soil drainage must also be considered. A free draining sandy soil will dry out much faster than a heavy clay soil, and requires less water to become fully saturated. Well drained soils thus require more frequent, lighter waterings than poor draining clay soils. Temperature and rainfall also alter watering requirements.

These variables make a standard prescription for the watering schedule of plantings impossible. However, as a rough guide to watering requirements for local native plantings in this region, the following schedule may provide an initial plan, to be modified as necessary:

- 2 to 3 waterings per week for the first 4 weeks,
- weekly for a further 8 weeks,
- as required thereafter.

Weed control

Weed invasion is probably the largest single cause of failure in revegetation projects. The methods of weed control discussed in site preparation - manual removal, mowing, fire (when trees are well established), and herbicide - may also be used during maintenance work. Mulch or mulch mats help suppress weeds, and improve plant growth, so should be maintained as long as possible.

Firebreaks

Yearly maintenance of suitable firebreaks is recommended for sites containing high fuel loads, or adjacent to areas with high fuel loads. Firebreaks should be constructed immediately after the wet season, and need to be maintained regularly. When trees become large enough to withstand some heat, sites with a fuel load could occasionally be given a low intensity controlled burn during the cool dry season. Expert advice should be obtained when preparing firebreaks or planning a controlled burn.

Fertilisation

Slow release fertiliser blocks for trees provide a simple and effective method to fertilise plants for up to a year. Alternatively, organic fertilisers (eg animal manures, dynamic lifter) or inorganic fertilisers (eg Crop King 88) could be used every few months. Many local native plants are adapted to cope with low nutrient levels, and may grow quite well without supplementary fertiliser, particularly in areas with more fertile alluvial soils. Some plants, including many species in the family Proteaceae, are especially sensitive to phosphorous.

Plant guards

If wind or grazing is a potential problem, plant guards may be necessary. White plastic tubes, held with 3 stakes, have been used effectively. However, they may cause problems in some environments, such as coastal dunes.

Pests and diseases

Regular inspections of plants should be made to assess major attacks or dieback. Expert advice is recommended before any pesticides are applied to the site. Most episodes of insect herbivory are usually controlled naturally by a build-up of predators, so chemical control may be an unnecessary expense. Numerous local plants also naturally drop their leaves each year, a process which is unrelated to pest attack.

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Appendix I. Implementation planning guide for revegetation sites.