6. Descriptions of the Wetland Types

Scope

The following descriptions of arid NT wetland types include the landform, longevity, salinity and dominant vegetation. Examples are given of important wetland types. Some wetland types are not individually described but are discussed along with other related types within the same ‘broad wetland type’. A photographic summary of wetland types in the arid NT is given in appendix 1. Additional information on characteristic plants is found in chapter 9. These descriptions are designed to stand alone, with minimal cross referencing to other sections of the report. Accordingly, there is some repetition of information presented elsewhere. The descriptions provide a basis for preparing wetland educational material, but in the present form are too technical and long for some uses.

It is important to stress that there is considerable variation within most types and some types may inter-grade with others. Also, many wetlands of one type will have elements of other types within them.

6.1 Saline Wetlands: Salt Lakes and Swamps

Saline wetlands have been loosely defined here as those with salinity greater than 3000 ppm total dissolved solids and semi-saline as those with between 1000 and 3000 ppm. However, salinity levels below 1000 ppm may also favour salt tolerant plants and water salinity often varies with the volume of water present. Consequently, saline swamps may be better identified on the basis of salt tolerant vegetation species than on somewhat arbitrary and preliminary threshold values of salinity. Future analysis of the soil and vegetation data from the wetlands survey may allow a more precise definition of semi-saline and saline to be incorporated into the definitions of saline wetland types.

Bare Salt Lakes

Predominantly bare saline lakes are classified as:

B1111 Highly Saline Lakes (Salt Lakes).

There are a wide variety of salt lakes; some very shallow, some several metres deep; some small and some huge. The vast salt lakes only fill infrequently, from about 4 to 10 times a century. When inundated they provide by far the largest area of wetlands and can support thousands of waterbirds. The patchy distribution of rainfall, even in the wettest years, means that the larger lakes are rarely full at the same time.

Some of the deeper and longer lasting salt lakes are several metres deep when full, such as Lake Lewis, and various lakes in the Karinga system including Lake Pulcura. At the other extreme are those that are typically very shallow (< 50 cm) such as Lake Bennett and Lake Amadeus. Lake Mackay, the fourth largest lake in Australia, is thought to be intermediate. Depth (maximum or typical) has not been included as a classification attribute since it is not known for many lakes.

Saline lakes are created by permanent or long-term groundwater discharge directly below the lake bed, resulting in areas of permanently saturated hyper-saline soils (brine). A chain of saline lakes (playas), extends 500km from Lake Hopkins in Western Australia to the Finke River at Idracowra and includes

Lake Neale and Lake Amadeus. It also includes a group referred to here as the Karinga Creek Paleodrainage System which consists of more than 100 smaller playas between Curtin Springs and Idracowra. The hydrology and landform of the entire chain has been relatively well studied, as summarised by Jacobson (1996). The area is known as the 'Central Australian Groundwater Discharge Zone'. It includes a group of lakes near Curtin Springs Roadhouse that may be the most saline in Australia with brines between 350,000 and 400,000 ppm TDS (Jacobson 1996). Another chain of salt lakes extends from Lake Lewis to Lake Bennett. Information on the hydrology of these is provided by Wischusen (1998).

The salinity and chemical composition of saline wetlands vary. The surfaces are typically a white halite crust, but many other minerals are also precipitated out of groundwaters. Some, but not all form substantial and visually dramatic salt crusts when dry while others have relatively minimal crusting. The degree of crusting may vary across a single lake. Parts of the bed of Lake Amadeus are dominated by brown gypsum whilst others have a white crust (Jacobson 1996). Water from a soil pit in Lake Bennett had a conductivity of 156,000μS/cm (lower limit for hypersaline c. 44,000μS/cm) yet it is reported that this lake only forms a minimal crust. Some lakes have significant proportions of gypsum (calcium sulphate) as well as sodium chloride and other minerals. As there is no quick field test for gypsum the distinction can be hard to make, but the presence of gypsum crystals in unsaturated soils is a good indicator.

The majority of saline lakes are not filled from a major drainage channel. Lake Lewis is the main exception. Most saline lakes are filled from relatively local runoff and minor channels. Sheet flow across the landscape may also be significant in widespread and intense rain events. Some inflow comes from springs on the edges of lakes. Many salt lakes function as a window on the watertable, which may be elevated after large regional rainfall events, resulting in increased groundwater discharge and sometimes also surface water. Elevated watertables in surrounding drylands and swamps may be manifested as surface water in the lakes which are at lower elevations.

Most salt lakes are fringed by a distinctive suite of salt tolerant plants, many of which are succulent. Salt tolerant species can extend across parts of the lakebed to form a vegetated swamp. Species of *Halosarcia* typically dominate, forming a low shrubland known as samphire.

Some large salt lakes have adjacent freshwater pans perched above the saline watertable.

Vegetated Saline Basins

Vegetated saline basins are divided into those where inundation typically submerges vegetation (lakes), and those where the vegetation is emergent during full inundation (swamps). A further distinction is made in vegetated saline swamps and lakes, based on vegetation type, which may equate to level of salinity. The individual wetland types in vegetated saline basins are:

B1121 Saline Lakes / Samphire Swamps (vegetation can be fully submerged)

B1122 Saline Lakes / Non-Samphire Chenopod Swamps (vegetation can be fully submerged)

B2111 Samphire Saline Swamps (vegetation never fully submerged)

B2112 Non-Samphire Chenopod Saline Swamps (vegetation never fully submerged)

B2121 Saline Grassy Swamps (vegetation never fully submerged).

Saline basins that are predominantly vegetated with salt tolerant plants are broadly grouped as saline swamps but may be classified primarily as saline lakes if the vegetation is fully submerged when the basin is filled with water. Typically they are less saline than the bare salt lakes and there is a range in salinity values reflected in the plant species present. With lower salinity, samphire may be replaced by other chenopods or grasses as the dominant plants.

Most salt tolerant vegetation is less than 1m high. An exception is Oldman Saltbush (*Atriplex nummularia*) which occurs in some semi-saline areas but only occasionally in swamps.

Samphire species (*Halosarcia spp.*) are considered to be the most salt tolerant with others being less so, such as some *Atriplex spp.*, *Lawrencia spp.*, some *Chenopodium spp.*, some *Dysphania spp.*, *Eragrostis dielsii*, *E. falcata*, *Triodia salina* and *Osteocarpum spp.*. There is little data from which to describe the nature of Saline Grassy Swamps and this type may only occur as an element within multi-type wetlands or as patches within wetlands dominated by a single other type.

The vegetation of saline arid NT wetlands has much in common with coastal salt marshes. Indeed, the term salt marsh is sometimes applied to inland saline swamps including the fringes of salt lakes (Moore 1968, The Macquarie Dictionary 1981); however, it is usually used exclusively for coastal, intertidal areas, and therefore, it is not used here for inland areas. The vegetation of Australian salt marshes is summarised by Adam (1994) in the chapter on saltmarsh and mangroves, in *Australian vegetation* (Groves 1994), and includes a useful summary of the eco-physiology of saline wetland plants. A numerical analysis of salt marsh flora of Western Australia by Cresswell and Bridgewater (1998) also provides a useful comparison with arid NT saline swamps. Several of the species and genera listed as characteristic of coastal salt marsh in Adam (1994) and Cresswell and Bridgewater (1998) are also present in arid NT saline wetlands: *Juncus kraussii*, *Sporobolus virginicus*, *Halosarcia indica subsp. leiostachya* and *subsp. bidens*, *Hemichroa diandra*, *Lawrencia*, *Frankenia* and *Sclerostegia*.

Saline Channels

Additional saline wetlands that are often associated with saline basins are saline channels and saline springs. Springs are grouped separately in this classification. Highly saline channels occur on the margins of highly saline lakes but also at distances of kilometres from salt lakes, such as in the Sangsters Bore area of the Tanami Desert. They are recognised as a distinct wetland type:

WL2007 Highly Saline Channels.

Although this type is grouped with drainage line features in the classification (WL prefix), it is listed here because of the strong affinity with salt lakes.

6.2 Freshwater Basins: Claypans and Lakes

There is a great variety of freshwater basins. Basin is used here for water holding areas that are not part of a watercourse (although they may receive water from channels).

All basins with open surface water when inundated (little or only fringing emergent vegetation) are classed as open freshwater basins. This includes those substantially covered by vegetation which is submerged when the wetland is fully inundated. Two wetland types are recognised, separated on size, for compatibility with the Ramsar classification (> 8 ha or < 8 ha):

B1211 Large Freshwater Lakes and Pans; and

B1221 Small Freshwater Lakes and Pans.

The distinction between open freshwater basins (lakes) and those with emergent vegetation (swamps) is often not clear for a particular wetland due to many variations and intergrades. It is often difficult to estimate maximum potential water depth, so a wetland might be classified as a swamp because it has been observed with emergent vegetation but does in fact function as a lake during deeper inundations.

Wide variations occur in landform, vegetation and water regime, but a meaningful subdivision into finer wetland types has not yet been created. Numerical analysis of survey data may assist in that task. The main variations are described below.

Claypans, Gibber Pans and Herbaceous Pans

Open freshwater basins that are predominantly bare when dry are often called claypans but that term is used quite variably and so has not been included in the names of any wetland types. Shallow wetlands such as claypans are often called playas. All playa wetlands in the arid NT are assumed here to have a high clay content in either the surface or sub-soil and typically have hard clay or stony clay surfaces. Those that were sampled in our survey were variously salt crusted (see salt lakes above), stony, sandy or with clay of various cracking patterns on the surface. Surface clay varied from clay loam to light clay with occasional heavy clays (soil texture according to McDonald *et al.* 1990). Those that were sandy on top invariably had a clay layer at depth and sometimes had central areas of exposed clay. Non-saline pans with a sandy surface generally had more vegetation cover than those with hard setting clay surfaces. Surface sand may indicate erosion of surrounding sandy landscapes.

Some claypans are fringed by Coolabah trees (*Eucalyptus coolabah subsp. arida* & *Eucalyptus victrix*) on one side or in a complete ring. Other claypans are fringed by Inland Teatree (*Melaleuca glomerata*), various other shrub species or have no woody vegetation. Some have patches of Swamp Canegrass (*Eragrostis australasica*) which can form dense thickets. Swamp Canegrass usually occurs in shallow areas and so is emergent. Where patches of Swamp Canegrass cover a significant portion of a pan the wetland can be classified as a swamp rather than an open freshwater basin.

Claypans occur in various landscapes including adjacent to mountain ranges, adjacent to rivers, in sanddunes and sandplains, in gibber plains and with rare examples in the black soil plains of the Mitchell Grass Downs bioregion (for example Bell Waterhole). Claypans in sanddune swales are typically small, but some claypans are vast, measuring kilometres long and wide.

Some pans are formed by slackwater deposits of fine sediments from extreme river flows and may occur in areas where there are no longer any active river channels. Erosion by wind (deflation) is an important force in maintaining and developing playas, with the bare surfaces allowing acceleration of winds across them; in both claypans and salt lakes. In some situations, fringing sand banks or dunes are deposits of material scoured by wind from the playa surface. Wind erosion may also cut through permeable surface soils to expose less permeable surfaces and thus form water holding pans.

There is a large range in the inundation regimes of claypans and other open freshwater basins. Waters may last several months to longer than a year (rarely). Water may come from adjacent hills, minor creeks and possibly also over-bank flow from large rivers. Some pans only receive water from direct rainfall and very localised runoff. In low rainfall areas in the south, these may be very rarely inundated. In the north of the arid NT the higher, more seasonal and slightly more reliable rainfall means that these isolated pans may hold water relatively frequently.

Some parts of the Simpson Desert have stony surfaces of closely packed gibber stones on plains and sometimes on low undulating hills, which produce substantially much more runoff than sanddunes. The distribution of the gibber is summarised by Purdie (1984) who notes that they are extremely impermeable to water. Gibber surfaced playas are distinguishable from gibber plains in general by being a depression with a surface lower than the surrounding landscape. They are typically very shallow, whereas some pans exceed 1 to 2 metres in depth.

Aggregations of claypans and swamps may be important waterbird habitats, with examples in the Finke bioregion (for example Palmer River area), Simpson Strzelecki Dunefields and the Great Sandy Desert bioregions.

Interdune Lakes

The deepest freshwater lakes occur in areas with large sanddunes and in some the water is apparently confined by ancient, relatively impervious land surfaces, of rock rather than clay. The main example is a series of very large inter-dune lakes in the Simpson Desert, which fill from Snake Creek. These are part of the greater floodout system of the Finke River and some have been measured at 9 to 10 metres deep with inundation lasting over two and a half years in places. Another large interdune lake was surveyed in the Great Sandy Desert Bioregion to the east of Lake Mackay. It was over 2km long and had an estimated maximum depth of 1.5 m, but the frequency of inundation is likely to be much less than the lakes at Snake Creek, as there is no coordinated drainage in the area.

The large freshwater lake fed by Salt Creek is partially confined by sand dunes, and inundation in 2000 lasted over two years.

6.3 Isolated Rock Holes

Isolated rockholes are water holding depressions in outcropping rock and are not part of a watercourse (channel). A single wetland type encompasses the variation in landform, rock type, size and shape:

B1222 Isolated Rock Holes.

It includes elevated rockholes in hills and ranges and low outcrops that are hardly elevated above the surrounding plain. They are filled totally from local rain runoff, and water can remain for several months, supporting a distinctive aquatic fauna. Even shallow rockholes such as on Uluru (Ayers Rock) can have a surprisingly high number of aquatic species, including shield shrimps (*Triops australis*) and the amphibious fern *Isoetes muelleri* (with grass like fronds).

The locations of isolated rock holes are well known to traditional Aborigines for whom they were an important water source. Some rock holes are traditionally maintained by cleaning out wind blown sediments and covering them with rocks or bushes to reduce evaporation and consumption by animals.

One particular type of isolated rockhole, called gnamma holes, occurs in hard and typically granitic rocks. They typically have round openings and are in the order of 1 metre in diameter and similar depth. According to Bayly (1999) they are formed by chemical weathering of initially smaller depressions. The word 'gnamma' is based on Western Desert Aboriginal languages for rockhole but the term is now consistently used for circular depressions in slabs and domes (Bayly 1999). The Macquarie Dictionary (1981) gives 'namma' as an alternative spelling and 'melon-hole' as a synonym. One of the authors of this report observed holes in the Murchison area of West Australia that were conical, being wider at the base than at the neck. He was told by pastoralists that these gnamma holes were significantly enlarged by Aborigines, using fire, water quenching and hammering. Gnamma holes observed in the arid NT are typically more cylindrical. Bayly (1999) notes that there are various reports of Aborigines protecting and prolonging water storage in gnammas by covering them with branches or flat rocks and cites observations by Tindale and Lindsay (1963) of channels carved in surrounding rock to divert water into gnammas.

Relatively large, but typically shallower rock basins occur on the plateau on top of the George Gill Range (north western end). They are roughly circular depressions in the bed rock which predominates the land surface, and are typically 20 – 30 m in diameter and 30 – 50 cm deep, with a silt bottom, and hold water for one to two months (D.Schunke, pers. comm.). In some ways they are similar to claypans, but as the water is confined by rock, they are included under isolated rockholes. The single arid NT record of a small sedge - *Eleocharis pusilla* - is known from this wetland type.

Glen Maggie Springs (Mutujulu Waterhole) at the base of Uluru (Ayers Rock) is also included as an isolated rockhole, even though it is at the base of Uluru with soil on some sides. It is a good example of the difficulty in assigning a wetland type for some wetlands. The waterhole is not in a well defined watercourse so it cannot be included under riverine waterholes.

Our 'isolated rockhole' wetland type also includes small caves such as are listed in Toyne (1995) for the Western Desert.

6.4 Wooded Swamps (freshwater)

Eucalypt wooded swamps are a widespread wetland type which have a distinctive groundcover flora following inundation. They can provide important habitat for wetland birds, particularly those that need to roost. There is considerable variation in landform, overstorey vegetation (species and structure), understorey vegetation and hydrology, and it is possible that in the future some additional wetland types will be recognised. Currently only two types are recognised:

B2211 Wooded Swamps (Non-linear)

B2212 Wooded Swamps (Linear/Riverine).

Most wooded swamps are dominated by Coolabah trees: either *Eucalyptus coolabah subsp. arida* in the south or *Eucalyptus victrix* in the north, or intermediate forms (possibly hybrids). Some wetland areas are dominated by River Red Gums (*Eucalyptus camaldulensis*) but these are typically indistinct basins in floodouts or floodplains adjacent to continuing channels. Accordingly, some may be better classified as wooded flood prone flats. *Corymbia flavescens* (similar to Ghost Gums and sometimes called cabbage gums) occur in a few floodout areas with relatively short lasting inundation. The Palm Valley Palm trees (*Livistona mariae subsp. mariae*) form a linear woodland in places such as the Glen of Palms on Palm Creek. This area could be classified as a wooded watercourse or wooded swamp (linear/riverine). The ecological character of the area is more influenced by groundwater springs than by in-channel flow and so it is treated as a wooded swamp.

Non-linear wooded swamps include those that are terminal basins of channels and side channels, depressions within the floodplains and floodouts of major rivers and other landforms. There is considerable variation in the density of the trees from relatively dense woodland to very sparse open woodland. Even where the total cover of trees is less than 30% an area is still classified as a wooded swamp, as long as the trees are somewhat regularly spaced across the wetland, such that they strongly influence its ecological character. If the wooded areas are very patchy or are restricted to a fringe on the basin edge, then some other wetland type will best describe the wetland. It is very common for wetlands of other types to have wooded swamp listed as a secondary type.

Important examples of non-linear wooded swamps include Lake Surprise (Yinapaka), Mudhut Swamp, Woodduck Swamp, the Elkedra floodout swamps, and the Frew Floodout Wooded Swamp.

An example of swamp with emergent Coolabah trees that is not classified as wooded swamp is Indemina Swamp. It consists of three connected basins, of which one has a very sparse Coolabah woodland. It could marginally qualify as a wooded swamp, but overall, the three basins are better classified as freshwater lakes that dry back to herbaceous swamp.

The term gilgai has a quite well defined usage in soil science but also a broader use in central Australia to refer to heavy clay swamps, some of which have Coolabah woodland.

Linear or riverine wooded swamps are those that occur adjacent to major rivers, often on benches that are below the level of the main floodplain but are above the main channel or separated from it by a levee bank. They would appear to function in some ways as swamps, filled with still or relatively slow moving water from over-bank flow from the main channel. However, they are also distinctly linear landforms, which presumably have linear flows of water along them at times when they become part of a broad flowing watercourse. This wetland type also includes some swamp areas in interim floodouts. They are linear in shape and typically carry a linear flow of water, into channels that reform on the downstream side of the swamp.

A major part of the Finke floodout is dominated by Coolabah (*Eucalyptus coolabah subsp. arida*) and Cooba (*Acacia salicina*) the latter being either a large shrub or a single trunked tree. In many parts, the density of trees is such that the term forest is more applicable than woodland. Accordingly it is distinguished here, from other parts of the Finke Floodout, by the name ‘Finke Floodout Forest’. This area has a very distinctive character and in some ways is more of a flat than a basin. It could potentially be given its own wetland type. Because of presumed linear flow through the floodout, which reforms as two significant channels at the eastern and south-eastern edges, the Finke Floodout Forest is included in B2212 Wooded Swamps (Linear/Riverine). Other wetland types in or adjacent to the floodout forest are waterholes, minor channels with Lignum (*Muehlenbeckia florulenta*), and distinct basins between dunes with Coolabah trees of varying density (B2211 Wooded Swamps (Non-linear)), some with dense tall verbine (*Cullen cinereum*) following the recession of waters. There is anecdotal evidence that the Finke Floodout Forest has become considerably more densely vegetated in recent decades, following major river flows in 1974. This may be due to long term recovery from a previous fire. The Finke Floodout Forest may also be influenced by increases in siltation from higher in the catchment.

6.5 Bluebush Swamps

The most abundant wetland shrub is Northern Bluebush (*Chenopodium auricomum*) which can form moderately dense shrub cover of around one metre in height over large areas and dominate whole basins. It is often the structural dominant in swamps, sometimes with scattered Coolabahs (*Eucalyptus coolabah subsp. arida* or *Eucalyptus victrix*) and frequently with annual herbs and grasses as an understorey following the recession of inundation waters. Although there is some variation in the vegetation structure and associated species in swamps dominated by Northern Bluebush, a single and relatively uniform wetland type is recognised:

B2221 Bluebush Swamps.

Another shrub species with a similar common name, Southern Bluebush (*Maireana astrotricha*), occurs in the NT but is not characteristic of swamps. Accordingly the prefix ‘northern’ is not used in referring to bluebush swamps.

Most bluebush swamps do not fill every year and inundation seldom lasts more than about six months.

Northern Bluebush (*Chenopodium auricomum*) also occurs as an occasional element in some other types of swamp. It is palatable to cattle and consequently provides important pasture. It is reputed to be prone to eradication at sites if grazing is too intense.

Bluebush swamps may provide important shelter and nesting sites for wetland birds but this is unconfirmed in the study area.

6.6 Lignum Swamps

Lignum (*Muehlenbeckia florulenta*) is a highly characteristic wetland shrub that is common in the arid NT but rarely dominates large areas. Even so, a distinct wetland type is recognised:

B2222 Lignum Swamps.

This is to accommodate those basins that are dominated by Lignum and because it is an important secondary type at many wetlands, including some Coolabah Swamps and open freshwater basins.

The largest expanse of Lignum swamp is probably that part of Stirling Swamp which is adjacent to the Hanson River; an area that has not been adequately surveyed. Lignum is more often found as a fringe element of some riverine waterholes and in parts of some wooded (Coolabah) swamps.

Areas of Lignum swamp may provide important shelter and nesting sites for wetland birds but this is unconfirmed in the study area.

Gibson and Cole (1988) report patches of Lignum occurring in the Simpson Desert swales of the sand dune system fringing the ‘Plenty River Salt Lakes’. Some of these patches were apparently a relatively rare understorey associated with a more widespread Gidgea (*Acacia georginae*) overstorey.

6.7 Other Freshwater Shrubby Swamps

Occasionally swamps are dominated by Acacia species but typically only where inundation is rare and short lasting. Examples of Acacia dominated swamps occur in river floodouts to the north of the Davenport Ranges. Several of these have an emergent overstorey of scattered gum trees (*Corymbia flavescens*) and there is at least one area in which *Melaleuca viridiflora* is a co-dominant shrub.

One example is known of a floodout swamp dominated by Mulga (*Acacia aneura*).

Melaleuca glomerata is a frequent and characteristic element of the fringe of claypans, semi-saline swamps and rivers but is rarely extensive enough to be the dominant species across a basin.

Melaleuca uncinata dominates some swamps in the south-west of the arid NT.

In the south west of the NT Nitre Goosefoot (*Chenopodium nitrariaceum*) dominants some swamps in a similar fashion to Northern Bluebush (*Chenopodium auricomum*) which it somewhat resembles.

Various semi-woody sub-shrubs are common in swamps and may dominate areas including *Pluchea spp.*.

All the above variations are included in a single wetland type called:

B223 Other Shrubby Freshwater Swamps

6.8 Grassy and Other Herbaceous Freshwater Swamps

There are various freshwater swamps that are dominated by herbaceous plants, with only scattered or no trees and shrubs. Two types are recognised; those that are dominated by grasses and those dominated by other herbs:

B2231 Grassy Swamps

B2232 Herbaceous Swamps (non-grassy)

Grass dominated swamps are relatively uncommon in the arid NT. The largest examples are on the Barkly Tableland, with perennial tussock grasses including Silky Browntop (*Eulalia aurea*), Silky Bluegrass (*Dichanthium sericeum*) and Mitchell Grass species (*Astrebla spp.*). A large grassy swamp occurs at the junction of Manners Creek and a tributary running north from the Toko Ranges, in which the dominant grass species are Silky Browntop and Shedda Grass (*Dichanthium annulatum*), which is introduced (a weed). Several examples of small swamps dominated by Swamp Wanderrie grass (*Eriachne benthamii*) occur adjacent to tributaries of the Finke River and are typically just a few hectares in size. One of these was surveyed while inundated and had apparently held water for over 7 months, without degeneration or death of the emergent grass tussocks.

Small and large sedges and forbs (dictyledonous herbs) occasionally occur as the dominant vegetation in areas of large swamps as well as forming groundcover below some shrubby and wooded swamps. There is some difficulty in determining whether to classify such areas as swamps or open freshwater basins. Many plant species germinate in shallow water or wet mud and do most of their growing after surface water has gone. Even so, it is useful to describe herbaceous swamps as a separate wetland type since this state may characterise the wetland for a substantial period and possibly longer than the duration of free surface water (i.e. for longer than it functions as a lake or pond).

The ecological character of some wetlands is more strongly influenced by waterlogged soil than by free surface water. Some are included in the category of herbaceous swamps. These include areas of long-term groundwater discharge as well as some basins in which inundation is typically shallow and short lasting, but with longer lasting water-logging of soils, due to generally elevated watertables in the surrounding landscape.

Nardoo species (*Marsilea spp.*) are aquatic or amphibious ferns that often form dense mats in some swamps and claypans. When water is present, cloverleaf shaped fronds float on the surface. In some cases Nardoo may be the dominant vegetation cover during and following inundation, but as these species are non-perennial, they will not be evident during prolonged dry times. Thus, some areas may vary from bare clay to dense lush Nardoo meadows.

Budda Pea (*Aeschynomene indica*) is a fast growing annual that is widespread in swamps and can form tall dense stands following inundation, typically between one and two metres high. It can temporarily dominate the character of a wetland but is short lived and is often encountered as standing dead sticks. Verbine (*Cullen cinereum and C. australasicum*) are other annuals that can form dense stands over a two metres high. All three species can also occur as mixtures with other herbs and shrubs. Although they may not have the same abundance after every inundation, they can have a strong influence on ecological character.

Some distinctive small wetlands occur on red earth plains dominated by Mulga (*Acacia aneura*) shrubland. There are two main forms: small claypans and heaving clay depressions or gilgais. Both forms may support dense cover of Nardoo (*Marsilea spp.*), as well as other characteristic wetland plants including Bluebush (*Chenopodium auricomum*).

It should be noted that the distinction between freshwater and saline swamps is not always clear-cut and some wetlands contain saline and relatively freshwater sections. Stirling Swamp is an example of this.

One example of a herbaceous swamp (about 30m wide) on top of a rock range is known from Watarrka National Park (George Gill Range). Some swamps are also known from some flat topped (table top) hills in the south of the arid NT (P.Latz pers. comm.). There are probably other examples too, but swamps located on the tops of ranges are rare in the arid NT.

6.9 Flood Prone Flats

Flood prone flats are a marginal and poorly defined group of wetland types, associated with floodplains and floodouts. It approximates the term 'land subject to inundation' with the implication that inundation is not sufficient to result in swamp vegetation. The distinction from basins is not easily made. The main difference is that flats do not hold water on the surface for long. When water is present it is generally flowing, even if slowly. Flood prone flats often form the general landscape of floodplains and floodouts, with basins within them forming swamps and lakes. Various subdivisions of flats are possible but current information only justifies a very basic breakdown:

F0001 Bare flood-prone flat

F0002 Wooded flood-prone flat

F0003 Shrubby flood-prone flat

F0004 Grassy flood-prone flat

Areas marked as swamp on 1:250,000 topographic maps may be flood prone flats under the arid NT wetlands classification. A fairly large area marked as Thring Swamp on the western side of the Davenport Ranges is a floodplain of Wycliffe Creek and not a swamp in our classification system. A brief inspection during our survey found a mixture of types of flood prone flats, including substantial areas of predominantly bare, hard set clay.

Several examples of wooded flood prone flats were encountered, such as the flood plain of Mt Benstead Creek in the East MacDonnell Ranges. It is densely wooded with River Red Gum trees from a flood event several decades ago.

6.10 Watercourses

Most watercourses in the arid NT are considered to be wetlands. Even though some only carry or hold water briefly, most of them have riparian vegetation that depends on the intermittent flows. A possible exception is some small steep watercourses in bedrock which only ever carry water during and immediately after rain, and due to the bedrock do not support wetland plants. However, small residual pools within such watercourses do count as wetlands.

In the classification of arid NT wetlands, watercourses are primarily divided on landform, into upland and lowland. They are also divided at an upper level in the classification, into waterholes and channels. Waterholes are effectively basins within the watercourse and hold still water after most of the watercourse has ceased flowing and has no surface water. The channels are the rest of the watercourse. Waterholes which are predominantly bounded by bedrock are broadly referred to as rockholes. They typically have less fringing or emergent vegetation. They are not recognised as a distinct wetland type due to the many variations in amount of exposed bedrock.

Another important attribute used to distinguish separate wetland types is the longevity of surface water. Drainage channels only hold water when flowing (as defined here) and most do so only temporarily, with the exception being a few spring fed reaches, typically of only a few hundred metres length. Four broad categories of longevity are used in distinguishing wetland types: permanent; non-permanent but long-term (generally wet); near-seasonal; and temporary (generally dry). Near-seasonal applies to large waterholes in the north of the arid NT, where river flows are strongly associated with summer monsoon rains although these are not reliable, varying greatly between years.

Most of the water in watercourse wetlands comes from higher in the catchment as in channel flow. Other sources include local runoff, sheet flow across flats, water flow below the surface of the channel (in the hyporheic zone), and ground water discharge into the hyporheic zone or directly into permanent pools. All the large rivers in the arid NT are temporary, only flowing after rain. Rivers can be dry for years at a time and large flows are infrequent but can occur very rapidly. Water may only flow for short periods of days and weeks, however, following widespread heavy rains, some rivers, notably the Finke, can flow along substantial parts for months or even one to two years. Even when there is no surface flow, water continues to move along many rivers under the surface, including water from groundwater discharge.

Long-term Upland Streams and Waterholes

There are a few upland streams and waterholes in the arid NT that are permanent or only dry up occasionally. Most are spring fed. Because of the importance of permanent waters for the survival of fish and some other species, two types of longevity are recognised, distinguishing those that have never been known to dry out (permanent) from others that are non-permanent but nevertheless flow for long periods. The running channels and associated waterholes are separated, as part of the hierarchical approach to classification. This separation also reflects real differences in vegetation and use by aquatic fauna. Also, some of the long-term upland waterholes are not dependent on long-term running streams. Instead, their longevity is due to some combination of shading from the surrounding terrain and ground water discharge directly into the waterhole or from an adjacent seepage spring.

WU1111 Permanent Upland Waterholes

WU1121 Non-Permanent but Long-term Upland Waterholes

WU2101 Permanent Spring-fed Upland Streams

WU2102 Non-Permanent but Long-term Spring-fed Upland Streams

There is a distinct flora and fauna associated with permanent freshwater pools and springs. For example, Tassel Sedge (*Carex fascicularis*) is only known in central Australia from a single spring-fed wetland in the Chewings Range, where it grows on the edges of small pools. Another aquatic plant which is restricted in central Australia to permanent upland pools, is Swamp Lily (*Ottelia ovalifolia*), which is only known from pools in the catchment of Palm Creek and Bagot Creek.

There are several long-term waterholes in the Palm Valley area of which at least two have not been known to go dry and are treated as permanent. They are typically shallow and confined by bedrock and owe their longevity to aquifer discharge. They are classed as upland due to the surrounding terrain and an evident but shallow gradient, even though they are only a few metres in elevation above the main channel of the Finke River through Finke Gorge.

Yarribilong Rockhole on Newhaven Station is an example of a long-term upland waterhole that is near the bottom of a hill but not on the surrounding plains. The creek feeding out of it is very minor, rocky and has a low but obvious gradient following the gentle lower slopes of the range. A similar example is John Hayes Rockhole; a non-permanent but long-term waterhole in the East MacDonnell Ranges. The creek below John Hayes Rockhole is quite substantial, with moderately large River Red Gums, and the rockhole is really intermediate between upland and lowland. In this case, it is treated as lowland.

There are numerous small long-term upland waterholes in the George Gill Range in Watarrka National Park. It is possible that some are semi-permanent or permanent.

There are some relatively small but presumably permanent or semi-permanent upland waterholes that allow fish (*Leiopotherapon unicolor*) to survive in several creeks and rivers and are listed in the review of fishes in the arid NT (chapter 10).

Other examples of long-term upland wetlands and associated biota are discussed under the section on springs as there is some overlap between them. The running channels and associated pools are not springs but wetlands created by springs. However, in general usage, the term spring is often used as inclusive of the associated wetlands. There is often insufficient information to classify non-permanent springs as either generally wet or long-lasting but generally dry. Some springs are known to run for months to years following periods of prolonged high rainfall, but may also be dry for many years.

Temporary Upland Waterholes

The great majority of upland waterholes are temporary. They typically dry out between rainfall events and are more often dry than wet. A single wetland type incorporates a range of longevity, substrate, depth and vegetation:

WU1201 Temporary Upland Waterholes.

Generally Dry (Temporary) Upland Channels

Upland watercourses are those descending from hills and mountains and typically have relatively steep gradients, narrow channels and tend to have rocky substrates but also include sandy creek beds. They typically only run for days to weeks following rain. They tend to have fewer and smaller fringing trees than lowland watercourses, and where there is a significant amount of woody vegetation it is often dominated by *Melaleuca* species. All these variations are combined in a single wetland type:

WU2201 Generally Dry (Temporary) Upland Channels.

Permanent Lowland Waterholes

Lowland waterholes are those in watercourses with predominantly low gradients. Some are in small lowland watercourses but the long-term waterholes are mostly in medium to large watercourses. Waterholes in large watercourses in gorges and relatively open valleys passing between ranges are all counted as lowland, even though they may be flanked by rocky uplands. Waterholes at the base of ranges, such as plunge-pools, may be hard to classify as either upland or lowland. The size of the channel, gradient, substrate and surrounding terrain should be considered when determining the most useful category.

Permanent waterholes are defined as those which are not known to dry out in recorded or oral history. The permanent waterholes in the MacDonnell Ranges bioregion are quite well identified. Permanent lowland waterholes also occur in the Toko Ranges, Dulcie Ranges, the Davenport Ranges and in the Murchison Ranges, but there is generally less information for distinguishing permanent from other long-term but non-permanent ones. There are also some long-term and possibly permanent rockholes at the base of isolated ranges in the Great Sandy Desert Bioregion. Most of the permanent waterholes are at least moderately deep and large, but some are quite shallow, owing their longevity to aquifer discharge.

Three distinct types of permanent lowland waterholes in watercourses are recognised, based on surrounding landform:

WL1111 Permanent Lowland Waterholes at the Base of Ranges

WL1112 Permanent Lowland Waterholes in Gaps & Gorges

WL1113 Other Permanent Lowland Waterholes

Permanent Lowland Waterholes at the Base of Ranges occur at the base of hill/mountain ranges where drainage channels emerge from gullies, including plunge pools below waterfalls and cascades. The waterholes are typically confined by bedrock. On average, these waterholes are smaller than other permanent lowland waterholes. There are two such waterholes in the Finke River system (Upper Serpentine Gorge and Puka). Some of the permanent pools in the Davenport Ranges and the Murchison Ranges probably fit in this category, although the ranges are generally low and dissected. Similarly, some waterholes in the Dulcie Ranges may fit in this category but may not be permanent.

Permanent Lowland Waterholes in Gaps & Gorges are confined and shaded by hill/mountain ranges on either side, where a major channel cuts a gap or gorge in the range. The waterholes are confined by bedrock but may be flanked by alluvial sediments. Ellery Creek Bighole and Glen Helen Gorge Waterhole are the only examples in the Finke River system. There are long-term waterholes of this type in the Dulcie Ranges but more information is required to confirm which, if any, are permanent. There are several examples in the Davenport Ranges and probably in the Murchison Ranges, including: Old Policemans Waterhole, Kangaroo Rockhole and others in the Frew River system, and probably some in the upper Whistleduck Creek system. There are two permanent waterholes in the Elkedra River (R.Driver pers. comm.) that are presumed to best fit this wetland type.

Other Permanent Lowland Waterholes includes waterholes confined by hill/mountain ranges or smaller rock outcrops, and presumably by bedrock below the waterhole. This wetland type also includes some waterholes that are more distant from ranges and which are spring fed. Those in the Finke River system are: 2 Mile Waterhole (upstream of Glen Helen Gorge); Boggy Hole, Running Waters and Illara Waterhole. There are some near-permanent waterholes located away from the ranges in the Elkedra

River, but have been known to dry out at least once. Nora Waterhole in the Toko Ranges is believed to be permanent and best fit this wetland type. It is adjacent to low rocky ranges with a low cliff on one side but is not in a gorge or gap. It is likely that there are examples in the Davenport and Murchison Ranges.

Long-term but Non-permanent Lowland Waterholes

Long-term waterholes are any that are non-permanent but more often hold surface water than not. The term 'generally wet' is used here interchangeably with 'long-term' in describing the persistence of waterholes. Several categories of longevity can be used to describe individual waterholes but are not used to define extra wetland types:

Semi-Permanent - only dries out in the most severe droughts – in the order of once in 50 years or less frequently;

Rarely Dry - usually inundated but dries more frequently than semi-permanent - in the order of once in 10 to 40 years;

Occasionally Dry - usually inundated but dries out several times a decade - more frequently than once in 10 years.

As for permanent waterholes, separate wetland types are defined on the basis of landform.

WL1121 Generally Wet Non-permanent Lowland Waterholes at the Base of Ranges

WL1122 Generally Wet Non-permanent Lowland Waterholes in Gaps and Gorges

WL1123 Other Generally Wet Non-permanent Waterholes

WL1124 Large Turbid Near-Seasonal Lowland Waterholes

WL1202 Temporary (Generally Dry) Lowland Waterholes

Generally Wet Non-permanent Lowland Waterholes at the Base of Ranges includes Redbank Gorge Waterhole in the Finke River system. It is semi-permanent, having only been known to 'dry' once in recorded history, when it was filled with sand, thus displacing surface water. John Hayes Rockhole in the East MacDonnell Ranges is known to dry up more regularly, in droughts. It is treated as lowland and as discussed for upland waterholes, is a good example of a watercourse that is somewhat intermediate between hills (uplands) and plains (lowlands). Muranji Rockhole in the Cleland Hills is sometimes regarded as permanent but was encountered dry in May 1996 (Wischusen 1998) and should be regarded as 'rarely dry' with minimal or no groundwater input. It is a deep waterhole completely bounded by bedrock. There are several waterholes at the base of the George Gill Range which are often assumed to be permanent but are probably not. Brian Bowman was manager of the pastoral lease that included the Watarrka area for several decades from about the 1930s. He stated that in droughts there was no water that was accessible to cattle, including Reedy Rockhole which dried back to a seepage (P.Latz pers. comm.).

Generally Wet Non-permanent Lowland Waterholes in Gaps and Gorges includes Simpsons Gap and Bond Gap waterholes in the Todd River system, and Fringe Lilly Gorge waterhole in the Hugh River section of the Finke system.

Large Turbid Near-Seasonal Lowland Waterholes is a wetland type based on long waterholes in the Mitchell Grass Downs bioregion in the north-east of the arid NT, including the Barkly Tablelands. Virtually all rainfall occurs in summe,r and the bulk is associated with monsoonal clouds originating to the north. Annual rain is unreliable but is more reliable than further south in the arid NT. Large river channels traverse the black (or grey) clay plains, with numerous waterholes. Some of the deeper and longer lasting ones are associated with minor rock outcrop, however there are none that are known to be spring-fed. The waterholes which best fit this pattern are in the Georgina River system, with catchments extending north of the arid NT where the monsoon influence is even stronger. The drainage systems associated with the Davenport Ranges, also mainly flow following summer rains, but may be less reliable than in the Barkly tableland. Further collation of stream flow and rainfall records and oral history would allow more detailed hydrological description.

The waterholes in this type are typically highly turbid with a milky grey colour from the 'black soil' of the plains. There are several waterholes that typically hold water through the dry season to the next wet and a few that hold water through droughts, for two or more years of low rainfall. Several may be semi-permanent, such as One Mile Waterhole at Souden, Big Ranken, and Junction Waterholes. Lake Nash Waterhole, although the largest, is not the longest lasting and dries out in many years, possibly due to relatively pervious soils (K.Schwartzkopff pers. comm.)

The majority of the waterholes of this wetland type are heavily grazed at some stage in the dry season. The gentle banks of the waterholes typically support a dense cover of low herbaceous plants, when not disturbed by stock. Two types of floating aquatic plants occur and may be more abundant in waterholes that are fenced from stock: Water Lilies (*Nymphaea sp.*) and the lily-like Marshworts (*Nymphoides spp.*) which have much smaller leaves (or pads) than the lilies. There is anecdotal evidence that the abundance of lilies is decreased by cattle. The waterhole at Avon Downs homestead is fenced from stock and has an abundant cover of lilies (P.Latz pers. comm.). The waterholes are tree lined, predominantly by *Eucalyptus barklyensis* (Barkly Coolabah) with occasional Bauhinia trees (*Lysiphyllum gilvum*). Shrubs, predominantly *Acacia farnesiana* are mixed in with the trees. In some places the noxious weed *Parkinsonia aculeata* is an element of the shrub layer, with the potential to form dense thickets. Another noxious weed, Noogoora Burr (*Xanthium strumarium s.lat.*) has apparently greatly increased in 2000-2001, and is widespread, with dense thickets in many places.

Temporary (Generally Dry) Lowland Waterholes includes a broad range of sizes and topographies of waterholes. Various subdivisions could be made based on the basis of size, depth, substrate and fringing vegetation and further analysis of survey data from the inventory could assist with this. This category includes some large waterholes in the mid-lower Finke River that can last well over a year, such as Snake Hole. It is possible that some may be 'long-term' rather than temporary, if they are often refilled by river flow without totally drying out. In which case, an additional wetland type could be defined to accommodate them. Some waterholes periodically get filled with sediments, only to be scoured out in subsequent floods. The intensity and duration of rain and the vegetation cover in the catchments both influence in-filling and re-formation of these waterholes, that are temporary not only in the sense of inundation (G. Ride pers. comm. and Unmack 2001a). Good examples are the waterhole in Trephina Gorge, Long Waterhole near the homestead of Conniston Station and a waterhole recorded by Strehlow near Idracowra homestead. The latter two have been relatively shallow due to sediments for decades but were previously recorded as significant waterholes.

Temporary Lowland Channels

Watercourses in lowlands tend to be wide, sometimes with deep channels, and typically have sandy beds, but substrates may also be clay, loam, gravel, pebbles or bedrock. Some lowland watercourses have coarse gravel or pebble substrates where they travel between or emerge from rocky uplands. In general, lowland water courses are lined by relatively tall trees dominated by *Eucalyptus* species; however, there are also some minor lowland channels, and some with no fringing woody vegetation. Seven separate types of lowland channels are recognised:

WL2001 Major Wooded Watercourses

WL2002 Minor Lowland Wooded Watercourses

WL2003 Melaleuca Dominated Lowland Watercourses

WL2004 Acacia Dominated Lowland Watercourses

WL2005 Unwooded Lowland Watercourses

WL2006 Braided Channels

WL2007 Highly Saline Channels

Major Wooded Watercourses: in most of the arid NT, River Red Gums (*Eucalyptus camaldulensis*) dominate most major drainage lines and many minor ones. Some drainage lines are fringed by Coolabah (*E. coolabah subsp. arida*) and occasionally by Bastard Coolabah (*E. intertexta*). Bean Trees (*Erythrina vespertilio*) are also common on river banks northwards from the MacDonnell Ranges, but never as dominants. Rivers in the Mitchell Grass Downs and Channel Country bioregions generally have clay or loamy clay soils. Major rivers in the Davenport Ranges have long reaches between rocky ranges, but not in gorges, and the river beds are pebbled. Water courses in the Mitchell Grass Downs Bioregion are predominantly fringed by *Eucalyptus barklyensis* (Barkly Coolabah) with occasional Bauhinia trees (*Lysiphyllum gilvum*). A small proportion of the minor creeks are dominated by *Acacia stenophylla* (River Cooba). Small side or annabranch channels occur but are generally not extensive and are not described as a separate type. Also, it is quite common for major river channels to divide for several hundred metres or more and then rejoin.

Minor Lowland Wooded Watercourses: are distinguished from major wooded watercourses on size and have smaller trees, narrower and shallower channels.

Melaleuca Dominated Lowland Watercourses: are channels in which Melaleuca species dominate, without an overstorey of trees. The main examples of this type are in watercourses flowing out from the Davenport and Murchison, where *Melaleuca dissitiflora* dominates many minor lowland channels and some sections of major watercourses, including at either end of wooded waterholes.

Acacia Dominated Lowland Watercourses: in the east of the arid NT there are extensive areas dominated by low woodland/shrubland of Gidgea (*Acacia georginae*), particularly in the Channel Country Bioregion. Minor drainage lines in these landscapes are typically lined with Gidgea. In the Barkly Tableland there are a few minor lowland creeks in which River Cooba (*Acacia stenophylla*) is the dominant overstorey. A small number of minor lowland creeks in the Toko Ranges are dominated by Mineritchie (*Acacia cyperophylla*). This species also dominates a few minor upland creeks in the small part of the Stony Plains bioregion that occurs in the arid NT.

Unwooded Lowland Watercourses: there are various areas where lowland channels have no fringing trees or shrubs. These are typically relatively minor channels though grassy or stony plains and have relatively minimal biological values as wetlands.

Braided Channels: there are very few examples of braided channels in the arid NT but there is one area of sufficient extent to warrant inclusion as a wetland type. The Lander River floods out between the end of its major channel at about Curlew waterhole and the large basin of Lake Surprise. The floodout consists of numerous minor and interconnected channels across a fairly narrow floodplain of about 1 to 1.5km wide and extends for about 15km (D.Langford pers. comm.). Larger channels reform and dissipate along the route to Lake Surprise.

6.11 Springs

Springs occur in many parts of the arid NT, and though not common, they play an important role in wetland creation and longevity of inundation. Most permanent waterholes are spring fed. Many salt lakes have temporary springs on their edges and some also have groundwater discharge under the lakebed. Indeed much of the surface salt can be from this source. ‘Springs’ is used in a broad sense to include any groundwater discharge that reaches the surface. It includes those that produce flowing water, only a trickle or only saturated soils. Those that are not flowing are often called soakages or seepages and Bayly (1999) discusses their traditional importance as drinking water for desert Aborigines. Some springs are permanent, with relatively constant output flow. Others vary dramatically in volume, at times producing flowing streams and at other times dwindling to a seepage or drying up completely.

Spring waters are produced from a wide variety of rocks and sediments including elevated mountain ranges and relatively shallow surface rocks such as calcrete. Water may be stored in pores in the rock (e.g. sandstones) or in cracks and joints in otherwise impervious rocks (e.g. quartzites). Cracks in calcareous rocks such as limestone, dolomite and calcrete are widened as groundwater dissolves $CaCO_3$ out of the rock. Calcrete groundwater is typically saline and calcareous but is sometime fresh. Some springs rise from deeper pervious rock that is confined by overlaying impervious rock. Natural springs can occur where there are cracks in the overlaying formations and are called artesian springs. The associated water bearing rocks are called confined aquifers. The largest and best known confined aquifer in Australia is the Great Artesian Basin (GAB), which has areas of both discharge and recharge in the arid NT (south east corner). However, it is quite certain that there are no GAB springs on the scale of the magnificent Dalhousie Springs in northern South Australia, where vast volumes of hot water pour out through various springs and have produced mounds metres high. The water pools at Dalhousie support endemic fishes as well as a great diversity and abundance of wetland plants and birds. Among the other Great Artesian Basin Springs, most of which are towards the basin edge, are some on the northern fringe of the Simpson Desert in Queensland. Most of these are relatively minor and do not produce a surface flow of water and have not produced mounds (R.Fairfax pers. comm.). It is possible that there are also minor springs that form seepages in the NT portion of the Simpson Desert.

Those springs that yield flowing water for great lengths of time are of great biological importance and clearly warrant inclusion in this inventory of wetlands. Those that only produce seepage or only flow for a few weeks or months following rain have less certain status as wetlands, and do not often support populations of water dependent plants or animals. However, some seepage areas do have a unique dependent flora, such as *Hydrocotyle D62620 Harts Range* and some of the ferns found only in seepage areas in moist gorges.

There are various ways of categorising springs. In the classification of arid NT wetlands they are divided into upland and lowland, flowing versus non-flowing, saline and semi-saline versus fresh and also into categories of longevity and other aspects of landform: degree of shading and whether or not in a drainage line. This results in a relatively large number of spring types, however, despite relatively little documentation of individual springs in some types, each type is felt to have an identifiably different ecological character as described below. Details of aquifer type are not included in the definitions of wetland type, although they may be important for detailed understanding of the hydrology of associated wetlands. There is some overlap between some spring wetland types and other wetland types, however, springs need to be treated separately because of their relative longevity in an arid landscape. Springs that discharge directly into waterholes are not included.

There are numerous anecdotal reports of daily variations in the flow rate of natural springs; sometimes with suggestions that this is due to effects of the moon's gravity on ground water. The very slow rates of water movement through most aquifers make this explanation unlikely to be correct. The influence of changing atmospheric pressure and changes in evapotranspiration are more likely explanations (*R.Read* pers. comm.)

Upland Springs

The following types of springs in upland terrain have been defined as wetland types:

SU1101 Permanent Running Upland Freshwater Springs
SU1102 Generally Wet Running Upland Springs (non-permanent)
SU1211 Temporarily Running (generally dry) Freshwater Upland Springs
SU2111 Permanent Sheltered Freshwater Minor Springs and Seepages
SU2112 Non-permanent Sheltered Freshwater Minor Springs and Seepages
SU2201 Generally Wet Minor Springs and Seepages in Exposed Upland Terrain
SU2202 Temporary Minor Springs and Seepages in Exposed Upland Terrain (generally dry)

Permanent Running Upland Freshwater Springs: a small number of springs produce a permanent running spring fed stream. There is at least one in the Chewings Range of the West MacDonnell Ranges, one in the Mount Palmer Ranges in the far west of the MacDonnell Ranges and possibly two in the Treuer Range in the north east of the Burt Plain Bioregion. Those in the greater West MacDonnells support rare and relictual plants. An aquatic invertebrate, the Water Penny (*Sclerocyphon fuscus*) also occurs in these wetlands. It is considered relictual in inland Australia, where it is only known from a few very low salinity spring-fed pools and streams in the arid NT.

Generally Wet Running Upland Springs (non-permanent): there are a number of upland springs which produce creek flow that are not permanent but may be more often flowing than not. Most occur in or adjacent to creeks. A range of water chemistry (salinity and calcareousness) is included since there is insufficient data about the associated wetland values to define separate wetland types on water chemistry. There are a few long-term springs in the Dulcie Ranges that produce flowing water, such as at Old Huckitta Homestead.

Temporarily Running (generally dry) Freshwater Upland Springs: includes a range in water chemistry. Most examples are in or adjacent to creeks. Many other upland springs exist, but for most there is insufficient information about the strength and reliability of flow to allocate them to specific wetland types. There are several springs that may run for many years, but there is insufficient data to determine if they are 'generally wet' or temporary (generally dry); for example some in the Anmatjirra Range and Yundurbulu Range. Many are grouped in the broad wetland type 'SF1.1 Running Upland Freshwater Springs'.

Permanent Sheltered Freshwater Minor Springs and Seepages: minor springs and seepages are those which typically do not flow at a sufficient rate to create 'running water'. Those that are permanent and emerge in shaded gorges and canyons in sandstone and quartzite ranges are very significant for regional biodiversity. They support various relictual ferns that require relatively mesic environments. These ferns are rare in arid Australia, being restricted to these environments, but most species are common in wetter coastal areas. Different species and groups of species are found in each moist gorge, and it is not known the extent to which this a result of random survival and dispersal histories as opposed to habitat differences between gorges. The terms gorge and canyon are used quite loosely and interchangeably in central Australia.

There are several species of ferns, which in central Australia are restricted to mesic environments (about 11 species). Most are only known from relatively deep shaded gorges, but a few occur in association with running streams in moderately shaded gullies. Some grow in areas of saturated soil, while others are only known from seepage areas on rock walls with typically just a few plants. These latter are at the smallest end of the size spectrum of wetlands, but the dependence of the ferns on free water justifies their inclusion as wetlands. A few species may not require seepage, only deep shade, and so are not considered to be wetland plants nor indicators of micro-wetlands.

Most of the examples of this wetland type are in the MacDonnell Ranges Bioregion (West MacDonnells and George Gill Range), with one example known in the north east of the Great Sandy Desert Bioregion (one species only) and several examples in the Burt Plain Bioregion (Dulcie Ranges – one species only). There are none in the Davenport Murchison Ranges Bioregion despite suitable shaded gorges and relatively high rainfall and humidity. This is an indication that groundwater discharge in the gorges there is not sufficiently reliable to sustain any relictual fern species. By far the greatest concentration of wet gorges is in the George Gill Range; however, the greater west MacDonnell Ranges area has a higher diversity of mesic fern species (10 compared to 7 in the George Gill Range).

Non-permanent Sheltered Freshwater Minor Springs and Seepages: after rains there are many more seepage areas and minor springs in gorges as well as other parts of the landscapes. These may be important contributors to the longevity of some pools, but they do not have a particular suite of characteristic plants.

Generally Wet Minor Springs and Seepages in Exposed Upland Terrain: these are areas of reliable groundwater discharge in upland areas, but not in sheltered gorges and typically do not produce running water. This wetland type includes minor springs and seepages in drainage lines as well as others. It includes very minor soakages in sandy creeks and those that form small pools in rockier areas. Few such wetlands are documented sufficiently to distinguish permanent from other generally wet seepages. A considerable range in salinities is likely. At least one of those recorded has formed a low mound of concreted organic matter adjacent to a creek, with some surface salt crystals. This example, in the Yundurbulu Range, generally has an associate pool, with dense bullrushes (*Typha domingensis*), but in droughts, it is reduced to a soakage. The presence of some minor spring may only be evident in the vegetation, with species such as *Juncus A87739 MacDonnell Ranges* (a water rush), which requires good water supplies but not necessarily saturated surface soils.

Temporary Minor Springs and Seepages in Exposed Upland Terrain (generally dry): many springs and seepage areas appear after heavy regional rains and may last from weeks to months. This wetland type includes temporary minor springs and seepages in drainage lines and on hill sides, the latter typically being on the mid-lower slope above a drainage line. A considerable range in salinities is likely.

Lowland Springs

The following types of springs in lowland terrain have been defined as wetland types:

SL1111 Generally Running Freshwater Springs in Lowland Drainage Lines
SL1112 Temporary (generally dry) Running Freshwater Springs in Lowland Drainage Lines
SL1121 Generally Running Saline/Semi-saline Springs in Lowland Drainage Lines
SL1122 Temporary (generally dry) Running Saline/Semi-saline Springs in Lowland Drainage Lines
SL2111 Freshwater Minor Springs and Seepages in Lowland Drainage Lines
SL2121 Saline/Semi-saline Minor Springs and Seepages in Lowland Drainage Lines
SL2211 Freshwater Lowland Minor Springs and Seepages not in Drainage Lines
SL2221 Long-term Springs on Salt Lake Margins and Lake Beds- Saline/Semi-saline
SL2222 Temporary Springs on Salt Lake Margins and Lake Beds - Saline/Semi-saline (generally dry)
SL2223 Mound Springs - Saline/Semi-saline
SL2224 Other Saline/Semi-saline Lowland Springs

Generally Running Freshwater Springs in Lowland Drainage Lines: there are two permanent examples of this type which produce two of the permanent large waterholes in the Finke River system: Running Waters and Illara Waterhole. Both emerge in broad sandy sections of river that are not in gorges and produce flowing surface water, for up to 2 km at Illara. A much smaller spring in Wallis's Paddock in the East MacDonnell Ranges generally produces running water and is nearly 1 km from the base of a large quartzite range, but it is not associated with a major sandy wooded watercourse, unlike Illara and Running Waters.

Temporary (generally dry) Running Freshwater Springs in Lowland Drainage Lines: there are no well documented examples of this type.

Generally Running Saline/Semi-saline Springs in Lowland Drainage Lines: there is at least one good example of this type, which is in a minor tributary of the Finke River in the Finke bioregion. The spring is long-term and normally, surface water flows for several hundred metres, however, in the early 1970s discharge reduced to the point where there was no surface flow. Despite its unusual character, no rare plants have been recorded there.

Temporary (generally dry) Running Saline/Semi-saline Springs in Lowland Drainage Lines: there are no well documented examples of this type.

Freshwater Minor Springs and Seepages in Lowland Drainage Lines: there are probably various wetlands created by groundwater discharge in this category, some of which may be important for regional biodiversity.

Saline/Semi-saline Minor Springs and Seepages in Lowland Drainage Lines: this type incorporates a range of reliability/longevity. One such spring, in a tributary of the Finke River in the Glen Helen area, has formed a mound of calcified organic matter on the banks of a minor lowland creek. The creek is close to low hills and is arguably upland or intermediate. Another spring, several kilometres south, in the Finke River south of Glen Helen Gorge, has the rare Bladey Grass (*Imperata cylindrica*). Salinity has been recorded as 1350 ppm total dissolved solids, which is semi-saline under the definitions adopted for arid NT wetlands. A third spring (or springs) in the same area emerges in a pool on the edge of 2 Mile Waterhole and so does not qualify as a spring wetland type, only as a characteristic of a permanent waterhole wetland. The salinity of the groundwater at 2 Mile Waterhole has been recorded as 11,000 ppm TDS. A smaller example is Bitter Springs in the East MacDonnell Ranges, which is smaller in volume and less reliable than the one at 2 Mile Waterhole, but was important as a water supply to early gold miners at the Arltunga gold fields.

Various springs in the Palm Valley area are arguably in this category but might alternatively be considered upland or intermediate. They are very important for regional biodiversity, sustaining most of the population of the rare endemic palm *Livistona mariae subsp. mariae*, the only arid NT population of the sedge *Eleocharis geniculata* and one of the main arid NT populations of two grass species *Imperata cylindrica* and *Phragmites australis*.

Freshwater Lowland Minor Springs and Seepages not in Drainage Lines: flow is generally minor and includes isolated soaks in sand country and at the base of granitic ranges, some of which only marginally qualify as wetlands. No subdivision is made on longevity due to very little documented data on occurrence and nature, although these would be well known to traditional Aborigines and to some stockmen.

Long-term Springs on Salt Lake Margins and Lake Beds - Saline/Semi-saline: there are long-term springs on the edge of salt lakes. The only one surveyed for its wetland values is on the edge of one of the Karinga Creek system of saline lakes, in the Finke Bioregion, with water emerging from the edge of the calcrete plateau which fringes the lake. Although semi-saline (2430μS/cm), it is important for stock watering, and unrestricted access by stock is the main impact on natural values. In addition to broad areas of saline ground water discharge, some salt lakes have surface springs in the lake bed, with several recorded for Lake Amadeus (Jacobson 1996), where they are relatively low in salinity (90,000 ppm) compared to the surrounding hypersaline brines (240,000 ppm TDS).

Temporary Springs on Salt Lake Margins and Lake Beds - Saline/Semi-saline (generally dry): following high regional rainfall there are numerous temporary saline springs on the edges of large salt lakes. Some are assumed to be discharge from shallow calcrete aquifers in paleodrainage lines.

Mound Springs - Saline/Semi-saline: there are some springs in the NT that have water with high mineral content and which form low mounds or banks composed of solids deposited by evaporating water and concreted organic matter and wind blown soil. Springs of this nature in the area between Glen Helen Gorge and Ormiston Gorge have been referred to as 'mound springs' (anon 1972, Pitts 1994). These are not on the same scale as many of the Great Artesian Basin mound springs, such as at Dalhousie Springs. One near Glen Helen Gorge emerges from a mound about 2m high. Several other mounds in the same valley are presumed to be extinct springs. Only small volumes of water are produced and the 'mounds' are relatively very small. The water comes from a local aquifer rather than a major sedimentary basin (*R.Read* pers. comm.). One has formed a distinct mound, rising some 2 metres above a surrounding plain. The other active spring is adjacent to a creek and has a much less pronounced mound; possibly due to erosion during creek floods. A similar spring was observed, during this inventory, at Spring Creek on Conniston Station. This produces flowing water in most years and even when not running still forms a seepage, according to local Aborigines (M.Lines pers. comm.).

Another mound spring is recorded at the eastern end of Lake Amadeus: 'several metres high, encrusted with carbonate' (Jacobson 1996, p. 259).

There was information deduced from a very early Queensland grazing cadastral map, which indicated the presence of a spring on the present day Tobermorey Station in the NT. Other springs marked on the map in Queensland are from the Great Artesian Basin, leading to supposition that there may be undiscovered mound springs in the NT. However, consultation with hydro-geologists from the NT Department of Lands Planning and Environment (P.Jolley and R.Read, pers. comm.) and careful cross-referencing of the old map to modern topographic maps, indicates that the springs in question are from the Georgina Basin and now lie beneath stock dams.

Other Saline/Semi-saline Lowland Springs: this wetland type was created to accommodate any saline or semi-saline springs in lowlands that do not fall into the categories of the specific types such as mound forming springs and springs on the edges of salt lakes. There is little information about any such springs or their biological values. It is unlikely that such springs are of great importance for regional biodiversity, but not impossible. One possible example is Emu Spring near Central Mount Wedge, which has salt tolerant plants and is presumed to emanate from a calcrete aquifer in a paleodrainage line (as described by Wischusen 1998). Emu Spring is mapped (1:250,0000 topographic map) as in or near a drainage line, so may be better placed under 'Saline/Semi-saline Minor Springs and Seepages in Lowland Drainage Lines'.

6.12 Subterranean Wetlands

Subterranean wetlands are not explicitly included in our wetland definition for the arid NT but are included in as a wetland type for consistency with the Ramsar classification:

U0001 Underground Waterfilled Spaces in Rock with Macroscopic Invertebrates

Very little is known about these wetlands. What information there is indicates that such environments are widespread even though known limestone caves are small, above the water table, and therefore dry. Sampling of bore waters has confirmed the presence of subterranean macroscopic aquatic invertebrates, typically in calcrete and possibly strongly associated with paleodrainage lines. The presence of large wet caves cannot be ruled out, but it is assumed that small cracks are the main habitat.

6.13 Artificial Wetlands

In the wetlands classification for the arid NT, artificial wetlands are divided according to the source of the water which characterises a place as a wetland. Apart from toxic mine tailings dams, most artificial wetlands increase the availability and reliability of habitats for some species of waterbird and some aquatic plants. Artificial wetlands have been grouped into the following types.

A1001 Dams Across Watercourses

A1002 Excavated Dams/Tanks in Swamps and Pans

A1003 Other excavations: quarries, borrow pits, mine pits

A2001 Excavated Dams Filled from Bores

A2002 Built-up Earth Tanks Filled from Bores

A2003 Minor Overflow from Bores

A2004 Open Metal/Concrete Tanks filled from Bores

A2005 Rogue Bores

A3001 Sewage Ponds

A3002 Swamps Created/Modified By Treated Sewage

A4001 Mining Tailings Ponds

Stored rainfall runoff

Dams Across Watercourses: the majority of dams across watercourses are created to store water for stock. A notable exception is the large dam at Jervois Mine at the base of the Jervois Range. Most are temporary but are deep enough to hold water for months or years between rainfall runoff events. Dams across watercourses are generally located in areas of moderate gradient and on small to medium sized watercourses, where water flows are unlikely to break the dam. In the Barkly tableland, there are examples of dams or tanks on relatively flat ground and there are remains of much older stone wall dams, including some across the Georgina River. These were created by Chinese gold miners in transit between the Northern Territory gold fields and Queensland, probably in the 19th century. A few stock dams are sustained by springs and form permanent or semi-permanent water bodies, for example, Black Stump Dam and Craigie Dam on Tobermorey Station and Tourmaline Dam (aka Recreation Dam) on Conniston Station.

Excavated Dams/Tanks in Swamps and Pans: excavated earth tanks, sometimes referred to as dams, are created to store water for stock and are typically in natural wetland basins (swamps or lakes). By increasing the depth of the waterbody in the excavated area, evaporation losses are reduced, and longevity is increased. Excavated material is typically piled up to form an adjacent wall and on gentle slopes may also function as a dam.

Other excavations: quarries, borrow pits, mine pits: any form of human excavation can form a water storage area. Inundation is generally shallow and brief in unplanned water storage due to a small catchment area.

Bore Water

Excavated Dams Filled from Bores: some excavated tanks and dams store surface runoff but are also used to store bore water. Examples in the Hanson and Lander river catchments contribute to the persistence of translocated fishes.

Built-up Earth Tanks Filled from Bores: in predominantly flat areas, there is little concentration of rainfall run-off, and stock water storages are typically elevated earth tanks called 'turkeys nests' which are filled from bores.

Minor Overflow from Bores: small swamp areas can form as a result of the overflow of bore water at bores, troughs and next to turkeys nest tanks. These are uncommon and are typically unimportant for wetland plants and animals in the arid NT.

Open Metal/Concrete Tanks filled from Bores: metal and concrete tanks have a smaller surface area than earth tanks but never-the-less support wetland plants such as *Typha domingensis*.

Rogue Bores: there have been several rogue bores in the NT portion of the Simpson Desert, releasing uncontrolled flows of water from the Great Artesian Basin. According to Graham Ride, the most notable rogue bore is McDills No.1 Bore which has sustained a large continuous wetland between sand dunes in the Simpson Desert for many decades. Specific values are undocumented, but the wetland is known to be utilised by waterbirds. This artificial oasis will be much reduced in size now that the bore is rehabilitated. Some controlled flow is to be maintained at the wishes of traditional Aboriginal owners. Other lesser examples are Dakota Bore and Anacoora Bore (G. Ride pers. comm.).

Sewage Water

Sewage Ponds: sewage ponds that treat effluent from larger settlements can cover substantial areas. The largest group, and only one well documented for birds, is the Alice Spring Sewage Ponds. These ponds are regularly used by larger numbers of waterbirds of a great many species.

Swamps Created/Modified By Treated Sewage: the largest and only well surveyed example is Illparpa Swamp adjacent to the Alice Springs Sewage Ponds, where an intermittent/semi-permanent Typha Swamp has developed in recent decades. The treated effluent overflows from the treatment ponds into the natural swamp, but is now drained into the outlet creek to reduce mosquito breeding. In natural arid NT wetlands, Bullrushes (*Typha domingensis*) only occur in relatively small areas, generally as fringing vegetation.

Mining Effluent

Mining Tailings Ponds: there are substantial mining effluent storage ponds in the Tanami desert. Details of size of ponds and toxicity levels are unknown, but gold mining effluent ponds at Tennant Creek are reported as causing deaths in waterbirds.