SOIL SURVEY AND CAPABILITY ASSESSMENT OF
THE UPPER KATHERINE RIVER AREA FOR
IRRIGATED HORTICULTURE

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1. INTRODUCTION

1.1 AIM

This report provides a detailed inventory and evaluation of the land resources of the immediate catchment surrounding the Katherine River: from the western boundary of the Katherine River National Park Reserve to the King River junction. It is designed as a tool for planners, agriculturalists and landholders, to use in the identification and characterization of both present and potential horticultural land.

The survey was initiated in response to requests from the Department of Primary Industries and Fisheries (formerly the Department of Primary Production) and the Department of Lands and Housing (formerly the Department of Lands), for assistance in identifying land suitable for future horticultural production in the Katherine region. Rapid industry expansion at Katherine during the early 1980’s, created the need for a specific inventory of the resources available for horticultural production. While suitable climatic conditions and the availability of good quality surface water are well documented, (Australian Bureau of Meteorology 1982, 1988; Water Resources Division, DME 1985; Smith 1988), the availability of suitable land was identified as a possible constraint to development.

The aim of this report therefore, has been to provide:

- description of the soils and landforms of the area, at a scale appropriate for horticultural development;
- quantification of the physical characteristics of the most suitable soils, particularly parameters relating to the structural and water characteristics of the soils;
- delineation of possible new areas for industry expansion: as well as existing areas currently being underutilized.

1.2 LOCATION

The study area occurs as a longitudinal strip running the length of the Katherine River from the western boundary of the Katherine River National Park Reserve (10km below the Katherine Gorge outlet) to the King River junction (Fig. 1). It is approximately 6km wide and 53km in length, and covers an area of 320km².

It has been targeted specifically to the requirements outlined above, and was selected on the basis of the following criteria:

- economic pumping distance for irrigation supply from 'run of the river' surface flow;
- the confined distribution of levee areas previously identified by Aldrick and Robinson (1972) as suitable for irrigated cropping.

Generally, a pumping distance of 1km or less is considered the economic limit for supplies coming directly from the river. The distribution and extent of alluvial landforms identified in previous mapping however, particularly that of Aldrick and Robinson (1972), indicates that areas with potential for horticultural development often extend further inland (away from the river). To ensure such areas were adequately identified and characterized, the survey boundary was extended to 3km either side of the river.

1.3 LAND USE

Insert attached text.

1.4 PREVIOUS MAPPING

The study area is covered by previous land resource appraisals at three scales. The broadscale resource inventories of Christian et al (1952) and Speck et al (1965), mapped land systems at scales of 1:1 000 000 and 1:250 000 respectively. These studies provide limited detail of the current study area, but present a useful overview, albeit at a regional level, of the history and formation of the current landscape.

More recently, Aldrick and Robinson (1972) mapped land units at a scale of 1:50 000 across much of the Daly Basin. Land units are defined as areas which exhibit a uniform photo pattern and contain similar soil, vegetation and topographic elements wherever mapped (Aldrick and Robinson 1972). Whilst this mapping is particularly useful in identifying broad areas with agricultural potential (for example dryland cropping areas), scale limits its applicability for detailed horticultural/irrigation assessments.

A soil survey conducted by Litchfield (1952) gives a detailed account of the soils of the former CSIRO Levee Farm. This farm was located in the vicinity of the old Katherine powerhouse, and covered an area of approximately 50ha.
Figure 1: Survey area location showing reference areas and 1:25 000 base map layout
The soil descriptions within this report, while specific to the farm area, are relevant to the scope of the current study.

1.5 USE OF THE REPORT

Specifically the report provides:

(i) detailed descriptions of the soils and associated landforms within the study area; including characterization of soil morphology, fertility, structure and water characteristics of the major soils; as well as descriptions of the topographic features, processes, and formation of the current landforms.

(ii) accurate mapping delineating both the extent and distribution of these soils/landforms.

(iii) definition and quantification of the physical characteristics which are or may be limitations to irrigated horticultural development: including features such as slope, soil depth, rock outcrop, susceptibility to inundation, surface and sub-surface soil texture, site drainage, permeability and infiltration.

(iv) an assessment of the potential or capability of the soils to support sustained, irrigated horticultural development: assessed in terms of the degree of limitations a particular soil possesses.

In most cases, this report will be used in the evaluation of specific areas in the light of proposed development. The following steps represent the simplest approach to an evaluation:

- accurately locate the area of interest on the accompanying soil/landform map;
- identify the map unit(s) covering the area; the map unit code represents a combined soil/landform description; soils are numbered by a two number system, the first indicating major soil group (great soil group) and the second a particular soil type (soil family or soil profile class), while landform is listed by abbreviated lettered codes;
- the map legend provides a summary of the important features of the soil types and landforms making up the map units; detailed descriptions are given in the appropriate chapters;
- an assessment of the capability of the identified soil type/landform combination is provided as part of the soil description in Chapter 7; examination of the capability rating will highlight any limitations that may represent constraints to development;
- with the exception of irrigation pumping distance, no economic assessment of the suitability of the mapped lands for development is provided;
- while a glossary has not been presented in this report, the terms of reference used throughout are standard, and conform to the Australian Soil and Land Survey Field Handbook (McDonald et al 1984).
2. METHODOLOGY

A free survey technique was adopted as the most practical methodology for the purposes of this investigation. It has involved four distinct phases.

2.1 INITIAL INTERPRETATION

Initial stereoscopic interpretation delineated areas of uniform photo pattern using 1984 black and white photography at a scale of 1:10,000. Unit boundaries were identified by differences in photopattern associated with changes in landform, vegetation pattern and background tone. The delineation of soil types using this methodology assumes a reasonable correlation between photographic features, particularly vegetation pattern and background tone, and the underlying soils.

The lack of clearing or development over much of the study area, was significant in validating this basic assumption. By comparison, landform was distinguished directly through stereoscopic interpretation.

Each mapping unit represents a combination of an individual soil type and a unique landform element. While these often occur in distinct associations, it is important to emphasize that both entities were delineated separately, and are independent of each other.

Site selection for field study was carried out after initial interpretation was finalized. Sites were selected to ensure all map units and unit boundaries were adequately assessed and characterized. Previous resource mapping, as well as 1:250,000 geologic and 1:50,000 topographic mapping were consulted in detail throughout this phase.

2.2 REFERENCE AREA FIELD STUDIES

Three distinct reference areas were identified for detailed study: Phillips, Manbulloo and Ballongilly Reference areas (Fig. 1.). Each was selected on the basis of the following criteria:

- representing one of three geologic areas;
- representing a large alluvial plain or other suitable area close to the Katherine River;
- representing an area of intensive rural development, particularly irrigated horticulture.

Fieldwork within each reference area was structured to allow detailed description of the soil and landform resources, as well as an assessment of the variation within and between each area. Preliminary soil profile classes delineated on the basis of the described variation, were used for characterizing soil types during later reconnaissance studies. Landform classes were similarly identified.

All sites were described according to the methodology of McDonald et al. (1984). Descriptions included soil morphological features, site location, site topography, site drainage and local geologic features. Descriptions were based on auger borings to 1.5m, with limited deep holes to 5.0m. Pits were restricted to representative sites within the major alluvial soils, and were used mainly for detailed soil characterization. Vegetation data, where recorded, included structure, dominance and species.

Sites considered representative of the variation within each reference area were sampled every 0.1m to 0.3m and every 0.3m to 1.5m for later analysis. Physical analyses included determination of particle size fractions and moisture retention ranges, while limited soil fertility analyses were carried out on selected profiles. In all, 121 field sites were described, the details of which are presented in Table 1.

<table>
<thead>
<tr>
<th>Reference area</th>
<th>No. of sites to 1.5 m</th>
<th>No. of deep sites</th>
<th>No. of pits</th>
<th>No. of sites sampled for analysis</th>
<th>Area (km²)</th>
<th>Site intensity (ha/site)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phillips</td>
<td>44</td>
<td>0</td>
<td>0</td>
<td>12</td>
<td>16</td>
<td>35</td>
</tr>
<tr>
<td>Manbulloo</td>
<td>45</td>
<td>0</td>
<td>3</td>
<td>10</td>
<td>23</td>
<td>50</td>
</tr>
<tr>
<td>Ballongilly</td>
<td>32</td>
<td>3</td>
<td>0</td>
<td>10</td>
<td>11</td>
<td>35</td>
</tr>
</tbody>
</table>
2.3 RECONNAISSANCE FIELD STUDIES

Fieldwork during this phase, was aimed at verifying the mapping units and boundaries over the entire study area. Little emphasis was placed on detailed resource descriptions. Full sites were described in each new or unknown unit, while check sites were used to verify boundaries. Check sites used surface observations only, to describe the site features (location, topography, geology, drainage and dominant vegetation) and soil type in each area. Where surface observations were inadequate to reliably establish the soil type, a full site was described.

Preliminary soil profile and landform classes delineated during the reference phase, formed the basis for these assessments. As new variation was encountered, these groups were revised accordingly. Changes to the mapping were adjusted in the field, and notes on the correlation between soils, topography and mapping units were recorded.

In all, 131 full field sites and 234 check sites were described, covering an area of 270km², with a site intensity of 75ha/site. Limited sampling was undertaken to characterize soils not represented in reference areas, and to correlate particle size fractions across the whole study area. No pits or deep borings (to 5.0m) were put down.

2.4 FINAL INTERPRETATION AND MAPPING

Site data and analytical results were entered on the CSIRONET VAX 11/780, and collated using the WARIS package. Sorting routines were used to manipulate the data and verify the soil profile and landform classes tentatively delineated during fieldwork, while listing routines provided data output in a form suitable for summary descriptions and publication purposes. Comparison of computer outputs and field notes formed the basis upon which final soil profile classes and associated landform classes were described.

Final photographic interpretation included mapping changes to accommodate the final system of map units, and any changes noted in the field. Map drafting involved the reduction of linework from a photo scale of 1:10 000 to a final map scale of 1:25 000. Base maps at this scale were produced as quarter sections blown up photographically from standard 1:50 000 topographic sheets. Base map layout for the study area is shown in Figure I. Final map production involved the overlaying of thematic information, including linework and map unit designations, over half tone versions of the bases, prior to publication.

Fieldwork during this final phase was restricted to characterizing the infiltration, permeability and bulk density of the major irrigable soils. Limited sampling of soils for which analytical data was incomplete was also undertaken. A complete summary of the analytical procedures, sites and depths sampled is outlined in Appendix II.

2.5 LAND EVALUATION

Evaluation of the land resources within the study area for irrigated horticultural development was undertaken using the following steps:

- determination of the physical limitations to horticultural development and sustained production;
- quantification of the limitations into a 5 class system (Table 7);
- assessment of the limitations and capability of each mapping unit (soil/landform combination).
3. CLIMATE

The Katherine region lies within the Australian climatic zone designated Summer Rainfall–Tropical (Australian Bureau of Meteorology 1982). The climate within this zone is characterized by periodic heavy rains, with generally hot and humid conditions during the summer (wet season), and mild to warm and generally rainless conditions during the winter (dry season) (Kinhill Stearns 1983).

During the summer half of the year (November to April), the region comes under the influence of meteorological disturbances associated with the southward intrusion of warm, moist, monsoonal air, resulting in a hot, rainy season. In the winter half of the year (May to October), high pressure systems pass slowly across the continent from the west to the east. This produces mild, dry, south–east trade winds, which affect the Katherine region throughout most of the dry (Kinhill Stearns 1983).

The available climatic data for the Katherine region is discussed below and summarized in Figure 2 (Australian Bureau of Meteorology 1988).

3.1 RAINFALL AND EVAPORATION

The mean annual rainfall for Katherine is 1,040 mm, 95% of which occurs during the period from November to April (the wet season). The highest recorded annual rainfall was 1,497 mm in 1898, while the lowest rainfall on record was 437 mm in 1952. The average number of days with rainfall of 0.2 mm or more is 74, and the highest 24-hour rainfall recorded in Katherine was 234 mm in January 1910.

Convectional processes during the wet season cause a high incidence of thunderstorms, and there is an average of approximately 16 days per year on which thunder is heard at least once. The average annual evaporation (Class A pan) for the Katherine region is 2,563 mm, far exceeding mean annual precipitation (Kinhill Stearns 1983; Australian Bureau of Meteorology 1988).

While analysis of the rainfall data indicates that, by Australian standards, rainfall to the Katherine region is relatively reliable, wet season variability is recognized as a major problem limiting dryland agriculture (Mollah 1986). This is of little consequence with regard to irrigated horticulture however, which is limited more by factors such as evaporation and humidity.

3.2 TEMPERATURE AND HUMIDITY

The average annual temperature in the Katherine region is approximately 27°C. The highest temperatures are recorded in October and November, at the start of the wet season. The lowest temperatures are recorded during the dry season months of June and July. In November, the average daily maximum is 38°C, while the average daily minimum is 25°C. In July, the average daily maximum is 30°C and the average daily minimum 13°C. The highest temperature on record in Katherine was 45.6°C in November 1962, while the lowest recorded temperature was 2.8°C in July 1965. Frosts have not been recorded in the Katherine region (Kinhill Stearns 1983; Australian Bureau of Meteorology 1988).

The influence of monsoonal air upon the climate of the Katherine region is evident from an examination of the available humidity data. Average relative humidity rises from a minimum of 52% at 9 a.m. and 25% at 3 p.m. in the dry season, to a maximum of 81% at 9 a.m. and 55% at 3 p.m. during the wet season (Kinhill Stearns 1983; Australian Bureau of Meteorology 1988).

3.3 WINDS

In general, wind roses for Katherine indicate low wind speeds and a high percentage of calms. The morning wind roses for the wet season (October to January) indicate a dominant north-westerly component, which is probably a consequence of the southward movement of monsoonal air. In contrast, wind roses for the dry season (April to August) indicate a dominant south-easterly to north-easterly component due to the influence of high pressure systems to the south of the continent. Extreme wind gusts occur only occasionally; 115 km/h (32 m/s), being the highest gust on record. Annual maximum gusts are usually from the north-eastern or south-eastern quadrants, and are generally associated with thunderstorm downdrafts (Kinhill Stearns 1983; Australian Bureau of Meteorology 1983).

3.4 SUNSHINE, CLOUD AND FOG

The sunniest period is generally from June to August, during the dry season, while the least sunshine occurs during the wet season months of December to March. There is a particularly strong seasonal variability of cloud cover, ranging from an average of 20 clear days during the dry season months of June to August to an average of 1 or 2 in the wet season months from December to March. There is no available data on the occurrence of fogs or temperature inversions (Kinhill Stearns 1983; Australian Bureau of Meteorology 1988).
Figure 2: Climatic data for the Katherine region (after Australian Bureau of Meteorology 1988)
4. GEOLOGY

Within the surveyed region three geologically distinct areas were identified (after Randal 1963):

(i) Maude Creek to McAddens Creek junctions:
   - alluvium, residual sand, soil and colluvium, siltstone and greywacke, basalt and tuffaceous sandstone.
(ii) McAddens Creek to Chinaman Creek junctions:
   - alluvium, residual sand, soil and colluvium, limestone.
(iii) Chinaman Creek to King River junctions:
   - alluvium, residual sand, soil and colluvium, sandstone and siltstone.

In each of the three areas, significant portions are dominated by geologically recent Quaternary alluvium. This has led to the formation of distinct soils and landforms common throughout the region. Where Quaternary alluvium is not present, variation within the landscape is closely related to the underlying bedrock geology. Soil and landform development in these areas is characterized by varying degrees of lithologic control depending on the age, structure and alteration of the parent material.

The geology within each area is presented in Figure 3.

The exact relationship between geology, soil type and landform is discussed below.

4.1 QUATERNARY ALLUVIUM

Landforms immediately adjacent to the river in all three areas have been mapped as Quaternary alluvium (Qa). These sediments consist predominantly of fine sand, and represent material deposited as levees during river incision and development. For the purposes of this report such sediments are referred to as river alluvium. Changes during Quaternary times saw widespread flooding and alluvial deposition decline, probably as a result of deepening and enlargement of the Katherine stream channel. Flooding over levee areas effectively ceased, leaving terraces, which are now inactive or only barely active (> 1:100 year AEP flood event).

Soil development on river alluvium is characteristic of the fine, sandy nature of the floodplain sediments. Soils are generally mature and include deep, well drained, fine earthy sands and sandy earths on the alluvial terraces, and poorly drained earths and clay soils in back terrace drainage areas.

Quaternary alluvium has also been mapped in many upland areas, as residual sand, soil and colluvium (Czs). For the purposes of this report these sediments are referred to as upland colluvium. They are neither spatially nor genetically associated with the river system and represent unconsolidated deposits which have formed as a consequence of geologic erosion and weathering. They derive primarily from the Mullaman Beds (Lower Cretaceous sediments) which once blanketed much of the area, but are now often present as remnants only. Formation and deposition occurred as a result of post-Tertiary warping, which tilted the Daly Basin, and initiated the current erosion cycle (Randal 1963).

Soil development is variable and depends on sediment depth, nature of the parent material and position in the landscape. Deep earth soils, earthy sands and gravelly and rocky lithosols all occur.

4.2 AREA I

Area I lies wedged between the Daly River Basin to the west, and the southern end of the Arnhem Land Plateau to the north and east. Five geologic rock units occur within the area, and provide evidence of significant, geologic activity in the past:

(1) Quaternary alluvium (Qa).
(2) Residual sand, soil and colluvium (Czs).
(3) Burrell Creek Formation (Elb).
(4) Edith River Volcanics (Ew).
(5) Antrim Plateau Volcanics (Ea).

The oldest rocks in the area are contained in the folded and sheared Burrell Creek Formation*, which is extensively exposed both north and south of the river. These sediments were originally laid down in the trough which constituted the early beginning of the Pine Creek Geosyncline. They consist of greywacke and siltstone with subordinate sandstone, conglomerate and shale (Randal 1963).
Figure 3: Geology of the survey area (after Randal 1963)
Volcanic formations were subsequently extruded and now overlie the Burrell Creek Formation sediments to the east and south. The Edith River Volcanics are acid to intermediate lavas dominated by ashstone, tuff and tuffaceous sandstone. The Antrim Plateau Volcanics by comparison, comprise basic lavas and tuffaceous sediments, primarily basalt and some tuffaceous sandstone (Randal 1963).

The influence of each of these rock types on soil and landform development is pronounced. Burrell Creek Formation sediments form a distinctive complex of skeletal rises and colluvial infill valleys. Rock outcrop is extensive, often showing vertical beds, of shale and siltstones. Soils occur as shallow, stony lithosols on the rises, or fine textured, silty soils in the colluvial valleys. In contrast, shallow, fine textured red earths and lithosols form on the acid Edith River volcaniclastic rocks, while grey and brown cracking clays dominate areas occupied by Antrim Plateau Volcanics. Both volcanic groups have formed gently undulating plains and rises.

- Recent detailed mapping has identified the upper part of the Burrell Creek Formation as a separate formation: the Tollis Formation (unconformably overlying the Burrell Creek Formation) (Mulder and Whitehead 1988).

### 4.3 AREA II

The geology of Area II is dominated by sediments of the Daly River Group. Geologic mapping identified the following units:

1. **Quaternary Alluvium (Qa).**
2. **Residual sand and soil, colluvium (Czs).**
3. **Jinduckin Formation (cemj, emu).**
4. **Tindall Limestone (emt).**

The Jinduckin and Tindall Formations are calcareous and arenitic sediments of marine origin. They were laid down as a result of gentle down warping within the southern Daly Basin, which formed a shallow epicontinental sea during Cambrian times. Sedimentation was followed by uplift and a period of high stability. Low relief and the absence of folding in the Cambrian formations are evidence of this (Randal 1963).

The Jinduckin Formation (including the Manbulloo Limestone Member) is made up of sandstone, siltstone and silicified flaggy limestone (Randal 1963). This formation dominates most of Area II. Landforms developed on Jinduckin sediments are often undulating, with abundant limestone outcrop, usually as distinct contoured terraces. Soils are predominantly lithosols and shallow, fine textured red earths. Jinduckin sediments also occur as subordinate quartz sandstones and siltstones (Randal 1963). There are associated with undulating topography and gravelly lithosols.

The Tindall Limestone Formation only occurs surficially in small areas to the east and west of the township. It forms the basal unit of much of the southern Daly Basin however, and underlies the Jinduckin Formation. It usually occurs as lutitic or crystalline limestone and chert (Randal 1963), and has associated with it relatively flat topography and hardset, loamy red earths.

### 4.4 AREA III

Area III is dominated by sediments of the Cretaceous Mullaman Beds, occurring as remnants of a previously extensive sheet. Geologic mapping identified the following units:

1. **Quaternary Alluvium (Qa).**
2. **Residual sand, soil and colluvium (Czs).**
3. **Mullaman Beds Formation (Klm).**
4. **Ooloo Limestone Member (Olo).**

The Mullaman Beds were laid down after the stable Cambrian Period. Marine transgressions and subsequent uplifting resulted in the deposition of fine-grained sediments over much of the Daly Basin. During Tertiary times, climatic conditions favoured the formation of a laterite profile which developed readily on the soft, Lower Cretaceous sediments. Post-Tertiary warping produced present elevations and initiated the current cycle of erosion (Randal 1963).

The Mullaman Beds include sandstone, siltstone, grit conglomerate and porcellanite (Randal 1963). Landform is characterized by relict plateaux and scarps, isolated mesas, eroded, hilly terrain, footslopes and lower lying, undulating plains. Soils are generally shallow and coarse textured, and include lithosols and gravelly earths and sands.

The Ooloo Limestone Member is limited to isolated surficial deposits in the west. It is probable however, that Ooloo sediments underlie much of the area mapped as Mullaman Beds (Water Resources Division, DME 1985).
It includes calcareous and arenitic sediments and silicified limestone, with some chert and stromatolitic limestone (Randal 1963). It represents the uppermost of the Cambrian formations and constitutes an aquifer with good potential for supply of irrigation quality groundwater (Water Resources Division, DME 1985).

### 4.5 SUMMARY AND DESCRIPTION OF THE GEOLOGIC ROCK UNITS

*(after Randal 1963)*

<table>
<thead>
<tr>
<th>Code</th>
<th>Rock Unit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Qa</td>
<td>River Alluvium (Quaternary Alluvium)</td>
<td>Alluvium, sand, silt and gravel.</td>
</tr>
<tr>
<td>Czs</td>
<td>Upland Colluvium (Quaternary Residual Material)</td>
<td>Residual sand and soil, colluvium, minor travertine.</td>
</tr>
<tr>
<td>Klm</td>
<td>Mullaman Beds</td>
<td>Sandstone, siltstone and porcellanite.</td>
</tr>
<tr>
<td>Cmo</td>
<td>Ooloo Limestone</td>
<td>Partly silicified limestone: stromatolites.</td>
</tr>
<tr>
<td>Gj</td>
<td>Jinduckin Formation</td>
<td>Ferruginous sandstone and siltstone; minor marl, dolomite and chert.</td>
</tr>
<tr>
<td>Guu</td>
<td>Manbulloo Limestone (member)</td>
<td>Partly silicified, flaggy, limestone.</td>
</tr>
<tr>
<td>Gt</td>
<td>Tindall Limestone</td>
<td>Crystalline limestone with minor calcilutite and chert nodules.</td>
</tr>
<tr>
<td>G</td>
<td>Antrim Plateau Volcanics</td>
<td>Massive and vesicular basalt, minor agglomerate and feldspathic sandstone.</td>
</tr>
<tr>
<td>He</td>
<td>Edith River Volcanics</td>
<td>Toscante and dacite flows, phorphyritic intrusives.</td>
</tr>
<tr>
<td>B</td>
<td>Burrell Creek Formation</td>
<td>Siltstone, shale, greywacke and greywacke - siltstone.</td>
</tr>
</tbody>
</table>

This listing provides a detailed reference for use in conjunction with Figure 3.
5. HYDROLOGY

The water resources of the Katherine area (Katherine Gorge to King River junction) were identified during a study to determine future options for the Katherine town supply. Significant surface and groundwater supplies were described (Fig. 5.1.1.). A summary of the sources and yields of these supplies is presented in Table 5.1.1 (Smith 1980; Britten 1985; Macqueen 1985; Water Resources Division, DME 1985; Barlow 1986; Smith, pers. Comm., 1988).

5.1 SURFACE WATER

Surface water availability for the area is wholly dependent upon the Katherine River system, but differs in terms of the resources upstream and downstream of the town.

Upstream of Katherine, dry season flow is relatively minor, and is limited to baseflow from the Seventeen Mile Creek catchment. Surface water use is currently restricted to Katherine town water supply, using 'run of the river' surface flow from the Donkey Camp Pool. Future supply options are dam sites on either McAdden's or Dorothy Creeks, to supplement the present source. As a result, land use within the catchment feeding Donkey Camp Pool, and especially adjacent to the river, is restricted to minimize potential effects on the town supply. This presents a major limitation to horticultural development within the catchment upstream of Donkey Camp Pool. (Water Resources Division, DME 1985).

Downstream from the town, significant groundwater discharge from the Daly Basin aquifers, means dry season flow is both larger and more consistent (Water Resources Division, DME 1985). Current use of this resource is restricted to supply for irrigated horticulture and rural living purposes. Its potential for use as town supply is unlikely, due to potential problems with water quality, (especially hardness and pollutants), recreational pressures and resource allocation considerations (Water Resources Division, DME 1985).

The quality of surface water in both sectors is variable, and depends on the season and input or loss associated with connecting aquifers. Non-carbonate hardness increases between Katherine Gorge and the township, but is insignificant in comparison with the carbonate hardness that develops downstream. This occurs as the river intersects the Tindall Limestone Formation, where rapid changes in water quality occur, due to the influx of bicarbonate dominated waters from its aquifer. (Kinhill Stearns 1983).

Peak river flows are characterized by decreases in hardness and salinity and increases in turbidity, water colour, and biological loading. (Kinhill Stearns 1983).

5.2 GROUNDWATER RESOURCES

Three significant groundwater resources were identified in the Katherine area (Water Resources Division, DME 1985):

- aquifers associated with the Tindall Limestone Formation;
- aquifers associated with the Jinduckin Formation;
- aquifers associated with the Ooloolo Limestone Formation.

The Tindall Limestone aquifer underlies Katherine to the north-west and south-east. Recharge is by rainfall, and subsequent groundwater movement is towards the Katherine River (below McAdden's Creek junction); where dry season baseflows are sustained through groundwater discharge. When considering the potential yield of the Tindall Limestone aquifer to provide town, rural living or agricultural supply, both groundwater and surface extraction between the McAdden's Creek and the King River Junctions must be considered. The interdependence between aquifer supply and river baseflows is such that for most purposes both resources are considered part of the same system.

Unlike the Tindall Limestone, the Jinduckin Formation (including the Manbulloo limestone) does not discharge significantly into the Katherine River. While reasonable bore yields can be obtained (2011s), a combination of poor groundwater circulation and an apparent low rate of recharge to the aquifer, means that continuity of supply is unpredictable. Potential problems with water quality are also suspected due to high groundwater solute levels, particularly calcium sulphate.

The Ooloolo Limestone Formation occurs some 30km south-west of Katherine. Although little investigation has been undertaken in the Katherine area, studies elsewhere have shown that in comparison with the Tindall Limestone:

- recharge to the Ooloolo Limestone aquifer is often greater;
- water quality is similar for both formations;
- Ooloolo Limestone is generally more widespread and has a greater potential for development.

Significant areas of Ooloolo Limestone occur below the King River junction and may show promise for future development. (Water Resources Division, DME, 1985).
Figure 5.1.1 Surface and groundwater resources of the Katherine region (after Water Resources Division, DME 1985)
5.1.1 Summary of the sources and yields of present and future water supplies in the Katherine area
(Smith, pers. comm., 1988)

<table>
<thead>
<tr>
<th>Source</th>
<th>Yield September–November (ML/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Donkey Camp Pool</td>
<td>5</td>
</tr>
<tr>
<td>2. Town Bores</td>
<td>13</td>
</tr>
<tr>
<td>3. Donkey Camp Pool Expanded</td>
<td>10</td>
</tr>
<tr>
<td>4. Town Bores Upgraded</td>
<td>15</td>
</tr>
<tr>
<td>5. Tindall Limestone Aquifer: Katherine to King River</td>
<td>18</td>
</tr>
<tr>
<td>6. Tindall Limestone Aquifer: Katherine to Edith River</td>
<td>52</td>
</tr>
<tr>
<td>7. Ooloo Limestone Aquifer: King River area</td>
<td>Unquantified</td>
</tr>
<tr>
<td>8. Keckwick Damsite</td>
<td>75+</td>
</tr>
<tr>
<td>9. 17 Mile Creek Damsite</td>
<td>60</td>
</tr>
<tr>
<td>10. McAddens Creek Damsite</td>
<td>10</td>
</tr>
<tr>
<td>11. McAddens Creek Damsite</td>
<td>14</td>
</tr>
<tr>
<td>12. McAddens Creek Damsite</td>
<td>40</td>
</tr>
<tr>
<td>13. McAddens Creek Damsite</td>
<td>30</td>
</tr>
<tr>
<td>14. Dorothy Creek Damsite</td>
<td>25</td>
</tr>
<tr>
<td>15. Dorothy Creek Damsite</td>
<td>15</td>
</tr>
</tbody>
</table>

5.3 WATER DEMAND

Water demand for the purposes of this report includes all water use other than for town supply. As both present and future town supply will come from surface water sources upstream of Katherine, priority for use of the water resources available below Donkey Camp Pool takes on a different perspective. Only the aquifers of the Tindall and Ooloo Limestones are considered to have significant potential in terms of groundwater extraction or discharge to the river. The Tindall system currently provides all supplies for rural living and irrigated agricultural production in the Katherine area (Smith, pers. comm., 1988). By comparison, the Ooloo limestone aquifer is as yet unquantified, and intensive use of this resource is not foreseen for some years. Water demand for the Katherine area therefore, will rest primarily with the Tindall system in the foreseeable future.

Macqueen (1985) assessed the maximum long term potential yield of the Tindall System to be in the order of 120ML/d. Realistically however, the safe yield of the system is 52ML/d, which corresponds to the calculated historical minimum groundwater discharge from the aquifer to the river.

The safe yield is set at a level that ensures there is baseflow in the Katherine River throughout the year. This is necessary to maintain supply to rural consumers using surface flow, satisfy public recreation needs and protect the riverine ecology.

Demands for water in the Katherine area peak in the period from September to November. This period also represents the time when both surface water resources and groundwater are least capable of yielding supplies, due to low streamflow and maximum drawdown of watertables (Smith, pers. comm., 1988).
From September to November each year, practically all river flow at Katherine is baseflow provided by the Tindall Limestone Aquifer lying to the north-west and south-east. In extremely dry years the limiting baseflow rate equals the safe yield (52ML/d), all of which enters from the south-east (Fig. 5.1.1.) (Smith, pers. comm., 1988).

This limiting flow closely matches the irrigation needs for horticulture projected in the Katherine area to the year 2015 (Table 5.3.1). Similarly, Sturtz (1985) estimated that under conditions of normal development (low projection) the Tindall system would be capable of supplying water demands (other than for town supply) until the year 2015 (Table 5.3.2). Ultimately however, the projected long-term growth in horticulture between Katherine and the King River is expected to use 95ML/d, which will exceed the safe yield.

**TABLE 5.3.1 Demand projections (ML/D) for Katherine irrigation supply (Smith, pers. comm., 1988)**

<table>
<thead>
<tr>
<th>Year</th>
<th>Irrigation Supply (ML/D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>21</td>
</tr>
<tr>
<td>2000</td>
<td>32</td>
</tr>
<tr>
<td>2010</td>
<td>45</td>
</tr>
<tr>
<td>2015</td>
<td>56</td>
</tr>
<tr>
<td>2020</td>
<td>56-116</td>
</tr>
<tr>
<td>2030</td>
<td>56-116</td>
</tr>
<tr>
<td>2040</td>
<td>56-116</td>
</tr>
</tbody>
</table>

The Tindall Limestone Aquifer also extends north-east of Katherine township, to the Edith River, and drains to the Katherine River with a median outflow rate in the September to November period, of 18ML/d (Fig. 4.). In the extremely drier years, however, there is negligible contribution to river baseflow. The Tindall Limestone Aquifer can, therefore, provide a safe yield of 18ML/d for agriculture in the area between Katherine and Edith River. This yield and land area should support all projected long-term field cropping (excluding horticulture) and animal industries (Smith, pers. comm. 1988).

It is clear from Table 4 that agricultural water use is by far the major demand placed on the Tindall system. Current agricultural consumption (1983-84) is estimated at 12 ML/d, and is expected to increase significantly as irrigated land area increases. Table 5.3.2, present and predicted dry season water use from the Tindall system, other than for public supply (ML/d) (after Water Resources Division, DME 1985).

**TABLE 5.3.2 Present and predicted dry season water use from the Tindall system; other than for public supply (ML/d)**

<table>
<thead>
<tr>
<th>Year</th>
<th>Katherine Council (1)</th>
<th>Agriculture (1)</th>
<th>Total (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tindall</td>
<td>CSIRO</td>
<td>Rural</td>
</tr>
<tr>
<td>1984</td>
<td>0.4</td>
<td>0.2</td>
<td>0.2</td>
</tr>
</tbody>
</table>
agricultural development, particularly horticulture, continues to expand. In the three years prior to 1985, horticultural production in the Katherine area increased at an annual rate of 60% (Sturtz 1985). While development at this rate is obviously not sustainable, long term increases in horticultural production appear inevitable. As development proceeds, planning and control mechanisms governing water use will be necessary to ensure the allowable yield of the system is not exceeded. Water licensing provisions already in place should provide the necessary safeguards.

Predicted water demand on an industry basis, under three rates of development, is presented in Table 5. These predictions reflect the current situation at Katherine, where approximately 75% of all water extracted from the Tindall system, is used for horticultural production (Sturtz 1985; Water Resources Division, DME 1985). At present, the majority of this production occurs on properties along the Katherine River downstream from the town.

Industry expansion will mean not only increases in the number of horticultural enterprises and the total area under production, but also possible changes in crop preference and production technology; for example, dripper irrigation versus broadacre, overhead sprinkler irrigation. Future increases in horticultural water use will most likely come from:

- Increased development of horticultural areas downstream of Katherine; including underutilized areas on existing farms and possible new areas on Manbulloo Pastoral Lease;
- Increased development of the horticultural blocks in the Venn/Mataranka area;
- Increased production of broad acre vegetable crops, such as potatoes, onions, beans, and carrots.

In addition, increases in the production of irrigated or supplementary irrigated forage and field crops, and expansion within the intensive animal industry, will contribute significantly to rising water demand. Predicted water use for development within these areas is presented in Table 6 (Sturtz 1985).

Smith (pers. comm., 1988) suggests the following strategic approach for maximizing efficient water use in the Katherine area:

(a) concentrate horticulture development to the south–east of Katherine, utilizing the Tindall Limestone Aquifer. Expansion beyond year 2015 may require conjunctive use of sources developed for potable water supply at that time. Horticulture should expand towards the town from the existing farms at Venn Airstrip and along the Katherine River downstream from the Low Level Crossing;

(b) concentrate field cropping and animal industries to the north–west of Katherine, utilizing the Tindall Limestone Aquifer between the town and Edith River. Siting agriculture in this area will maximize utilisation of Tindall Limestone Aquifer groundwater.
6. LANDFORM

Two broad landform categories occur within the survey area; alluvial and upland. The development and formation of these landscapes, as well as detailed descriptions of the landform elements they comprise are discussed below.

6.1 ALLUVIAL LANDFORMS

6.1.1(a) Definition and development

Alluvial landforms owe their formation to processes associated with river development and alluviation. They are associated with sediments deposited by the river and show no lithologic control from surrounding geologies. Lateral distribution is limited to a 2-3km strip, which runs parallel to the river and effectively represents the area affected by > 1:100 AEP (annual exceedence probability) flood events.

Included in this group are the stream channel, alluvial terraces and associated drainage areas that lie behind. Together these landforms comprise the alluvial floodplain of the Katherine River. Fairbridge (1968) defined an alluvial floodplain in the following ways:
- topographically as a relatively flat landform lying adjacent to a stream;
- geomorphically as a landform composed of unconsolidated depositional material derived from sediments transported by the stream;
- and hydrologically as a landform subject to periodic flooding by the parent stream.

In assessing the Katherine floodplain, all three definitions were considered. Topographic and geomorphic assessments detailing the nature and extent of the floodplain, are documented within this report, while hydrologic assessment has used the flood mapping of Watson et al (1970) and Abbey (1988).

The Katherine floodplain is indicative of a modern, apparently active landform, characterized by the development of natural levees adjacent to the stream channel: a wide, relatively flat alluvial plain; and low lying backswamp and drainage areas bordering the upland slopes behind. Such features are typical of the structure and form of many active floodplains (Fairbridge 1968).

The river's course is direct and uncompromising, with, weakly developed channel meanders and a narrow floodplain. Wright (1965), in characterizing the drainage systems of the Daly Basin, described the Katherine as a perennial river, with an angular form, characterized by lengthy straights (> 4-5km) and sharp inflexions. Aldrick (1984) further suggested channel form and floodplain size are closely related, and dependent upon the geology and terrain being traversed. Similarly, restrictions imposed by the structure of surrounding lithologies have limited lateral channel movement and precluded further widening and development of the floodplain.

In contrast, hydrologic evidence indicates that the river's floodplain under current conditions, is only barely active, and possibly relict. Wolman and Leopold (1959) defined an active floodplain as an alluvial plain subject to inundation by the annual flood (highest discharge in each year or a 1/2 AEP flood event). Fairbridge (1968) reviewed this definition on the basis that it was not indicative of many larger river systems, and suggested that areas affected by inundation with a flood frequency of 1:10 years, would better represent active floodplains.

Within the Katherine System, Barlow (1986) estimates that a 1:50 AEP flood event or larger is required before substantial overbank flow and direct floodplain inundation occurs. Similarly, Wright (1965) states that the upper sections of the Daly and Katherine Rivers represent mature, stable floodplains. He suggests the position of debris lines and the well developed morphology of levee and backplain soils indicate both overbank inundation and deposition are now rare (> 1:100 years). There is significant inconsistency, therefore, between the current flood regime within the Katherine system and past floodplain development.

Evidence of significant prior floodplain activity can be inferred from features left 'relict' within the current floodplain. Most obvious is the presence of distinct, raised, natural 'levees' immediately adjacent to the stream channel. Fairbridge (1968) suggests such features form only as a result of direct overbank sedimentation. As floodwaters move from the channel onto the floodplain, flow becomes shallow and widespread, increasing resistance and precipitating deposition. Where overbank deposition is recent, surface microrelief is often irregular and variable, especially within 1-2 widths of the stream channel. Fairbridge (1968) states that deposited sediments often occur as elongated bars and intermittent depressions striking at right angles to the bank. The absence of any such irregular depositional features within the stable landforms of the Katherine floodplain, suggests such processes have not occurred for sometime.

Hydrologic evidence reinforces this conclusion. Watson (1970) suggests that for the floodplain to be at its present level, the river must have once exceeded the highest raised levees by up to 1m or more on a regular basis (for
example: flood events of the size of 500,000 cusecs). Structural parent materials within the Katherine system, particularly highly silicified limestones, may have imposed previous, temporary base levels, which lead to the development of such conditions. The absence of direct overbank flow over much of the floodplain, even with relatively large, current, flood events (> 1:100 AEP), suggests active levee deposition has effectively ceased.

It is possible, therefore, that the landform elements making up the Katherine floodplain represent young river terraces and not active river levees. Aldrick (1984) suggests terraces within the Daly Basin have formed as a result of climatic change, changes in structural control or normal evolutionary processes of stream development. Deepening and enlargement of the river's stream channel as a result of river rejuvenation during the Pleistocene Epoch, appears the most likely cause within the Katherine system.

Wright (1965) described three stages of river rejuvenation within the Daly Basin. The first was probably due to geological uplift and a change from a humid to a drier climate. This caused hillside instability and erosion, and led to the deposition of alluvial banks and plains along the major rivers. The second stage followed a moderate climate change back to a wetter regime. River rejuvenation occurred and resulted in shallow channel entrenchment, and widespread flooding. Alluvial deposition covered the older levees, and formed extensive younger levees and river backplains. A much larger climatic change followed in the third stage, causing increased run off and renewed river rejuvenation. The major rivers became deeply entrenched, and began cutting through the alluvium deposited during Stage 2. To date, the major rivers have cut down to bedrock, and are still actively incising. It is this last stage that appears largely responsible for the relict nature of the present Katherine River floodplain.

Irrespective of this evidence, minor flooding still commonly occurs (1:10–1:20 AEP), particularly inundation of lower lying backplain areas. Such flooding is best termed backwater flooding. Its causes, in the general absence of widespread direct overbank flow, relate to:
- the influence of local upland drainage;
- the complicated and congested drainage patterns at most tributary river junctions;
- and direct overbank flow from isolated sections of river where bank and terrace development is inadequate; for example: sharp river bends, tributary river junctions.

Backwater flooding initiates from the fact that bank heights at many junctions and some sharp bends, are often at levels lower than or similar to that of floodplain backslope areas. Where flooded tributaries are retarded at swollen junctions, direct overbank flow to backslope areas offers a convenient release for converging floodwaters. The height to which water rises within the floodplain is a function of the level and size of backslope areas, and the quantity of local drainage feeding the system (Watson 1970).

Evidence of this mechanism is provided by the broad clay plains that occur in association with the river and its tributaries. Aldrick (1972) suggests their formation has occurred through the deposition of fine sediments where local runoff is retarded and ponded during peak flood events. Sediment loads from local tributary catchments and not river floodwaters represent the most likely source. As such, the back-plains are still actively aggrading and represent young features formed since the final entrenchment of the main rivers; from sediment sources within local tributary catchments.

Watson (1970) and the Department of Lands and Housing (1988) both suggest inundation in the vicinity of the Katherine Township occurs as a result of backwater flooding. Flooding occurs initially by overflow from Leigh Creek to the right bank floodplain (1:5 AEP), followed by back flooding on the left bank floodplain in the vicinity of the Low Level bridge (1:10 AEP). At higher levels (1:30–40 AEP) overflow at the river bank near the hospital occurs and general flooding of the left bank floodplain commences.

For a level having 1:100 AEP, both left and right bank floodplains are extensively flooded and the Stuart and Victoria Highways are cut. Floodwaters also cut the Gorge Road upstream of the township. Much of the higher river bank land near the river, however, remains dry at this level of flooding. Flood depths in the built up area vary from nil along the high river banks to about 1.4m along Katherine Terrace; while depths of > 4.0m inundate the floodplain proper.

In the worst possible case (i.e. the maximum probable flood), floodwaters are estimated to exceed the level of the 1:100 AEP flood by about 1m. The whole of the floodplain, including the higher river banks and terraces, would be inundated under these conditions. (Department of Lands and Housing 1988)

Abbey (1988) has completed accurate flood mapping from the township area downstream to Vampire Creek. Flood contours are based on a 1:100 AEP designated flood, which is estimated to all intents as equivalent of the large 1957 event. The maps provide detailed information on location and expected flood heights across the floodplain, but do not detail the type of flooding (i.e. direct overbank or backwater flooding).
Topographic position within the floodplain usually clarifies this. Flood surface contours (1:100 AEP) for the Manbulloo Homestead area (Reference Area 2) are presented in Figure 5 as an example (after Abbey 1988).

6.1(b) Landform element descriptions

Topographic assessment of the Katherine River floodplain identified three broad landforms: stream channels, alluvial terraces and back terrace drainage depressions. These recur throughout the floodplain system and comprise a number of distinct landform elements. A series of cross-sections taken through the Katherine River is presented in Figure 6. These illustrate the topographic relationships between the river system, the alluvial plain and the surrounding lithologies.

- **Stream channels (Sc)**
  A complex unit representing the active elements of the Katherine River system; including stream beds, stream banks, stream bars and active levees. It is subject to extreme erosion and aggradation as a result of frequent, channelled stream flows (>1.2 AEP) during wet season floods. It is generally 300-400m in width, and flanked by distinct alluvial terraces which clearly delineate its boundary.

- **Alluvial terraces (At)**
  A major proportion of the Katherine River floodplain occurs as distinct alluvial terraces. Comparison of terrace dimensions and topographic cross-sections through a number of areas identified three distinct elements within the terrace system.

  - **Raised terraces (Rt)**
    Distinct low ridges (3.0-5.0% slope) immediately adjacent to the streambank of the Katherine River; generally 1.0-2.0m above the remainder of the terrace, and 50-100m in width, (occasionally 200m or more). They occur as linear to sinuous scrolls that closely follow the shape of the river. Raised terraces are rarely susceptible (>1.100 AEP) to overbank or backwater flooding.

  - **Flat terraces (Ft)**
    Level to gently undulating plains (<1.0-3.0% slope), immediately behind and 1.0-2.0m below adjacent raised terraces; commonly 200-400m in width (occasionally 600m or more); and <1.0-1.5m above the level of back terrace drainage depressions. Flat terraces represent the broadest elements within an alluvial terrace. Overbank flooding is uncommon (1:50-100 AEP) but occasional backwater flooding (1:10-50 AEP) may occur.

  - **Back terrace (Bt)**
    Gently undulating plains (>1.0-3.0% slope), immediately behind and <1.0-1.5m below the level of flat terrace elements; commonly 100-200m in width (occasionally 300m or more). Back terraces are similar in many respects to flat terrace elements, except for low lying position and susceptibility to common (1:1-10 AEP) (sometimes frequent) (>1.2 AEP) backwater flooding. These elements often occur as a transitional zone between the alluvial terrace proper (raised and flat terrace elements) and the drainage line behind.

Although terrace dimensions vary considerably, the position and shape of terraces within the landscape is consistent. Most alluvial terraces follow the shape of the river, are elongate and have a constant width throughout their length.

Terrace length is determined by the entry of river tributaries, or where rugged terrain lies immediately adjacent to the river. It varies considerably, ranging from short terraces of less than 1.0km, through to extensive areas greater than 6.0km in length. Within this broad range three common terrace lengths were recognized: short terraces <1.0-1.5km, moderately long terraces 3.0-4.0km, and long terraces >5.0-6.0km. Most terraces were identified as either short or moderate. Long terraces occur only occasionally and are usually characterized by intensive development (for example: the terrace upon which the township of Katherine is located).

Terrace width represents the distance between the stream channel and back terrace drainage line. It varies between 100-1000m, and is dependent both on the length of terrace and the combination of terrace elements present. Three common terrace widths were identified: narrow terraces <100-200m, moderately broad terraces 300-600m, and broad terraces >800-1000m. Narrow terraces usually occur as isolated raised terraces or in combination with minor flat terrace components. Drainage areas lying behind are usually well defined and narrow (Fig. 7). In comparison, moderately broad terraces comprise well developed raised and flat terrace components. Small back terrace elements are common, and are transitional to the drainage area behind. The back terrace depression is wider and less defined (Fig. 7). Broad terraces are often complex and combine all three terrace elements. The flat terrace is dominant and combines with a well developed back terrace to produce a wide alluvial plain. Back terrace depressions occur as broad, ill-defined drainage floors (Fig. 7).
Figure 5: Flood surface contours (1:100 AEP) over the Manbulloo Homestead area (Reference Area 2), showing flood depths, floodplain extent and flood free terrace areas (after Abbey 1988)
Figure 6: Topographic cross-sections showing changes in soil type and landform associated with the river system, alluvial plain and the surrounding upland lithologies
Figure 7: Typical landform elements and configurations making up narrow, moderately broad and broad alluvial terraces
While three distinct terrace elements were identified during interpretation and fieldwork, a combined topographic unit has been used to standardize and simplify final mapping. Topographic differences within the terrace system generally occur in association with changes in soil type. As such, mapping units identifying different soil types within a terrace usually delineate terrace elements, as a consequence.

**Back Terrace Drainage Depressions (Td)**
This unit defines the inland extent of the alluvial terraces and forms a natural division between the alluvial sediments associated with the river system, and the lithologically controlled sediments of the surrounding upland areas. They occur as level to gently inclined, shallow, open drainage depressions; generally concave in cross-section with gently inclined sideslopes. The depressions run parallel to the river and drain water laterally from the surrounding terrace and upland slopes, until intercepted by tributaries joining the Katherine River stream channel. Channel incision is usually absent or weakly defined, and is indicative of low velocity, short duration flows, consistent with the limited catchments that surround these depressions. Occasionally, closed depressions occur within or adjacent to back terrace depressions. These are usually shallow, elongate, semi-permanent billabongs which are inundated annually.

Inundation most commonly occurs as a result of floodwaters backing up river tributaries and retarding local drainage. In extreme flood events (for example: > 1:100 AEP flood) some back terrace depressions may act as spillways for the Katherine River and carry excess flows directly from the river's stream channel. In general, however, back terrace drainage depressions carry local drainage and undergo annual inundation only as a result of backwater flooding.

**6.2 UPLAND LANDFORMS**

**6.2.(a) Definition and development**
Upland landforms represent erosional landscapes characterized by lithologic control from underlying geological materials. Geomorphic processes such as geologic erosion, weathering and laterization have also been important in shaping the present landforms. These processes have masked much of the structural control of the parent-lithologies, and resulted in the formation of a gently undulating to undulating landscape.

**6.2.(b) Landform element descriptions**
Topographic assessment of the upland areas surrounding the Katherine River identified five broad landforms: plains, rises, low hills, drainage depressions and associated floodplains. These recur throughout the survey area and include a number of distinct landform elements. The basic framework used in describing the elements comes from the classification of McDonald et al (1984). Erosional elements are characterized by unique combinations of relief and modal slope, while drainage elements occur as open, fixed, erosional stream channels, associated local floodplains or closed depressions.

**Upland plains (Lp, Gp, Up)**
McDonald et al (1984) defined plains as a level to undulating landform pattern, characterized by extremely low relief of < 9m (usually about 5m).

Three distinct plain elements were identified:

<table>
<thead>
<tr>
<th>Elements</th>
<th>Modal slope</th>
</tr>
</thead>
<tbody>
<tr>
<td>(i) Level plains (Lp)</td>
<td>&lt; 1.0%; about 0.3%</td>
</tr>
<tr>
<td>(ii) Gently undulating plains (Gp)</td>
<td>1.0-3.0%; about 2.0%</td>
</tr>
<tr>
<td>(iii) Undulating plains (Up)</td>
<td>3.0-10.0%; about 6.0%</td>
</tr>
</tbody>
</table>

Upland plains occur where the structural influence of the underlying geology no longer dominates the landscape; usually as a result of in situ weathering and geologic erosion. They are common in areas of residual sand, soil
and colluvium: weathered clays developed on Antrim Plateau Volcanics: colluvial pediplains below Mullaman Bed scarps; and in lower lying areas of the Jinduckin and Manbulloo formations. Drainage occurs as overland flow along dips and ill defined depressions, until intercepted by upland drainage depressions.

Upland rises (Gr, Ur, Rr)
McDonald et al (1984) defined rises as a landform pattern of variable modal slope, fixed erosional stream channels and very low relief; from 9-30m (usually about 15m).

Three distinct types of rise were identified:

<table>
<thead>
<tr>
<th>Elements</th>
<th>Modal slope</th>
</tr>
</thead>
<tbody>
<tr>
<td>(i) Gently undulating rises (Gr)</td>
<td>1.0-3.0%; about 2.0%</td>
</tr>
<tr>
<td>(ii) Undulating rises (Ur)</td>
<td>3.0-10.0%; about 6.0%</td>
</tr>
<tr>
<td>(iii) Rolling rises (Rr)</td>
<td>10.0-32.0%; about 20.0%</td>
</tr>
</tbody>
</table>

Gently undulating rises are characterized by very long, gentle sideslopes and broad crests. Undulating and rolling rises, by comparison, exhibit respectively shorter, steeper sideslopes and narrower crests. The differences relate directly to changes in modal slope. Upland rises occur throughout the survey area, and are not restricted to particular regions or geologies. Drainage is effected through upland drainage depressions and associated floodplains.

Upland low hills (Ul, Rl, Sl)
McDonald et al (1984) defined low hills as a landform pattern of variable modal slope, fixed erosional stream channels and low relief; from 30-90m (usually about 50m).

Three distinct types of low hill were identified:

<table>
<thead>
<tr>
<th>Elements</th>
<th>Modal slope</th>
</tr>
</thead>
<tbody>
<tr>
<td>(i) Undulating low hills (Ul)</td>
<td>3.0-10.0%; about 6.0%</td>
</tr>
<tr>
<td>(ii) Rolling low hills (Rl)</td>
<td>10.0-32.0%; about 20.0%</td>
</tr>
<tr>
<td>(iii) Steep low hills (Sl)</td>
<td>≤ 32.0-56.0%; about 40.0%</td>
</tr>
</tbody>
</table>

Trends in landform shape and structure resemble those of upland rises, although generally exaggerated due to greater changes in relief. Upland low hills occur throughout the survey area, but are often restricted to areas where the structure of the underlying geology is still evident. Mullaman Bed scarps and rough terrain associated with Manbulloo and Burrells Creek sediments are good examples. Drainage is similar to that for upland rises, although floodplain development is usually limited and stream channels strongly incised.

Upland drainage depressions (Ud)
Upland drainage depressions occur as fixed erosional stream channels within the plains, rises and low hills that surround the Katherine River. Most represent part of the tributary network feeding the river system, and occur as strongly incised, open drainage depressions commonly concave in cross section with moderately inclined sideslopes. Stream channel (streambed and banks) incision is well defined and characteristic of these drainage lines. It is indicative of high velocity, high volume flows consistent with intense rainfall and large upland catchments. Generally, active levee development is minor and restricted to the lower reaches of the larger tributaries. Almost all upland drainage depressions are ephemeral and flow only during the wet season. Inundation and flooding are common during this period, and occur primarily as a result of high rainfall events. In the lower reaches of the major tributaries, drainage retardation during times of peak river flow compounds this problem.
Upland floodplains (Uf)

Upland floodplains occur as narrow, alluvial plains characterized by wet season inundation, and subject to active erosion and aggradation by channelled and overbank streamflow. They occur in association with upland drainage depressions, and are characterized by the presence of a strongly, incised stream channel. Inundation is common with a flood frequency of >1/2 AEP (annually flooded). Flooding occurs in conjunction with, and for similar reasons to that described for upland drainage depressions.

6.3 SUMMARY OF TOPOGRAPHIC UNITS

Alluvial landform elements

- Sc Stream channels
- At Alluvial terraces
- Td Open, back terrace drainage depressions
- Cd Closed, back terrace drainage depressions

Upland landform elements

- Lp Level plains
- Gp Gently undulating plains
- Up Undulating plains
- Gr Gently undulating rises
- Ur Undulating rises
- Rr Rolling rises
- Ul Undulating rises
- Rl Rolling low hills
- Sl Steep low hills
- Ud Open, upland drainage depressions
- Uc Closed, upland drainage depressions
- Uf Upland floodplains

This listing represents a summary of the topographic (landform) map reference as used throughout the 1:25 000 mapping.
REFERENCES


TABLE 1: Field work details for reference areas

<table>
<thead>
<tr>
<th>Reference area</th>
<th>No. of sites</th>
<th>No. of deep pits sampled for analysis to 1.5 m</th>
<th>Area (km²)</th>
<th>Site intensity (ha/site)</th>
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</thead>
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<tr>
<td>Phillips</td>
<td>44</td>
<td>0</td>
<td>12</td>
<td>16</td>
</tr>
<tr>
<td>Manbulloo</td>
<td>45</td>
<td>0</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>Ballongilly</td>
<td>32</td>
<td>3</td>
<td>0</td>
<td>10</td>
</tr>
</tbody>
</table>
TABLE 4: Present and predicted dry season water use from the Tindall system; other than for public supply (ML/d) (after Water Resources Division, DME 1985)

<table>
<thead>
<tr>
<th>Year</th>
<th>Tindall</th>
<th>CSIRO Rural</th>
<th>Golf</th>
<th>Low</th>
<th>Med</th>
<th>High</th>
<th>Low</th>
<th>Med</th>
<th>High</th>
<th>Low</th>
<th>Med</th>
<th>High</th>
<th>Low</th>
<th>Med</th>
<th>High</th>
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<td>75.0</td>
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<td>50.0</td>
<td>80.0</td>
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(1) Low, medium and high projections correspond to demands with 85%, 70% and 45% probability respectively, of being equalled or exceeded by supply.

TABLE 5: Predicted agricultural water demand (ML/d) on an industry basis by 1990 (after Sturtz 1985)

<table>
<thead>
<tr>
<th>Industry</th>
<th>Rate of Development</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Minimum</td>
</tr>
<tr>
<td>Horticulture</td>
<td>12</td>
</tr>
<tr>
<td>Field crops</td>
<td>3</td>
</tr>
<tr>
<td>Animals</td>
<td>0.03</td>
</tr>
<tr>
<td>TOTAL</td>
<td>15</td>
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</table>

TABLE 6: Potential increases in water use from the Tindall system (ML/d) by 1990 (after Sturtz 1985)

<table>
<thead>
<tr>
<th>Areas of proposed development</th>
<th>Rate of development</th>
<th>Area of production use (ha)</th>
<th>Predicted water use (ML/d) assuming full irrigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased horticultural areas</td>
<td>min 200</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>downstream from Katherine</td>
<td>av 200</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>max 300</td>
<td></td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Proposed horticultural farms</td>
<td>min 200</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>(Venn/Mataranka area)</td>
<td>av 400</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>max 600</td>
<td></td>
<td>24</td>
<td></td>
</tr>
</tbody>
</table>
Increased production of broadacre, min 200 4+/8 irrigated horticulture, fieldcrops av 400 8+/16 and forage max 600 12+/24

<table>
<thead>
<tr>
<th></th>
<th>min</th>
<th>av</th>
<th>max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intensive animal industries</td>
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<td>1.0</td>
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(+) assumes weighted average water consumption of 0.02 ML/ha/d for supplementary irrigation.
APPENDIX I: Aerial photography used in delineating the soils and landforms within the survey area

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<th>Katherine River Farms</th>
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<tr>
<td>Scale:</td>
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<td>Colour:</td>
<td>Black and White</td>
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<table>
<thead>
<tr>
<th>Date flown</th>
<th>Film (NRc)</th>
<th>Run</th>
<th>Frames</th>
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<tr>
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<tr>
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