Appendix B

Soil Landscape Groupings

Summary of Soil Landscape Groupings:

Profile Abbreviation	Topography	Substrate Lithology	Vegetation	Land Use	Typical Soil Profile / Occurrence	Landscape Limitations	Soil Limitations
Colluvial Landscapes							
Suicide - su	Steep hills and dissected valleys	Late Carboniferous Metasediments	Partially cleared tall closed-forest & tall open-forest	Banana plantation	su1: 40cm dark brown friable (silty) loam; su2: 50cm brown clay loam; su3:100cm orange peda,l silty clay; su4: 100cm+ of well drained, stony, structured Red Earths & occasional Yellow Earths. Soil depth generally >100cm, may be >300cm.	Steep slopes, massmovement hazard High run-on High water erosion hazard Foundation hazard	Low - very low wet bearing strength, high organic matter, high permeability, slow - rapid permeability, and low fertility
Erosional Landscapes							
Megan - me	Rolling low hills to hills with broad crests	Late Carboniferous metasediments	Tall open forest & tall closed forest	Banana plantations, urban development, and grazing	me1: 15-35cm brownish black earthy loam; me2: 5-40cm dark reddish brown pedal clay loam; me3: 60-75cm reddish brown pedal light clay; me4: moderately deep, well drained Red, Brown, and Yellow Podzolic Soils. Soil depth generally >120cm.	Steep slopes (localised) Mass movement hazard (localised) High water erosion hazard (localised) Foundation hazard (localised)	Low wet bearing strength, high organic matter (localised),strong to very strong acidity, stoniness (localised), high to extreme erodibility, low fertility and permeability, high aluminium potential, hardsetting surface (localised), high plasticity.

Summary of Soil Landscape Groupings:

Profile Abbreviation	Topography	Substrate Lithology	Vegetation	Land Use	Typical Soil Profile / Occurrence	Landscape Limitations	Soil Limitations
Ulong - ul	Undulating to rolling low hills	Late Carboniferous metasediments	Tall closed-forest to tall open-forest	Urban development	ul1: 30cm dark brown crumbly loam; ul2: 80cm reddish brown, pedal loam; ul3: 100cm reddish brown clay to silty clay; ul4: 100cm+ reddish brown, pedal, mottled, light to medium silty clay (Red, Brown and Yellow Earths. Soil depth ranges 100cm-250cm.	Foundation Hazard Water erosion Hazard (localised) Steep Slopes (localised) High run-on (localised)	Low to very low wet bearing strength, high organic matter, slow to rapid permeability, strong to very strong acidity, low fertility, aluminium toxicity potential (localised), high erodibility, hardsetting soil.
<u>Transferral Landscapes</u>							
Moonee - mo	Undulating rises, footslopes and drainage plains	Late Carboniferous metasediments	Extensively cleared tall closed-forest & tall open-forest	Beef cattle grazing and improved pastures	mo1: 32cm brownish grey, silty clay loam to silty clay; mo2: 15-75cm light brown, mottled, silty light clay; mo3: >50cm light grey, mottled, gravelly light clay (moderately deep to deep , poorly drained Humic Gleys). Soil depth generally >100cm.	Seasonal waterlogging Foundation hazard Water erosion hazard (localised) Permanently high water tables (localised)	Very low wet bearing strength, high to very high erodibility, slow permeability, strong to very strong acidity, high aluminium toxicity potential, low fertility, strong sodicity.

Summary of Soil Landscape Groupings:

Profile Abbreviation	Topography	Substrate Lithology	Vegetation	Land Use	Typical Soil Profile / Occurrence	Landscape Limitations	Soil Limitations
<u>Alluvial Landscapes</u>							
Coffs Creek - cc	Level to gently undulating floodplains, inset floodplains and terraces	Quaternary Alluvium	Extensively to completely cleared , tall open-forest and open-forest	Urban or industrial development, grazing. Poorly drained areas remain unchanged.	Soils patterns are complex due to alluvial nature cc1: 20cm dark brown, loamy sand; cc2: 60cm brownish black, weakly pedal loam; cc3: 25cm brownish black clay loam; cc4: 20cm brown , weakly pedal, silty clay loam to light clay; cc5-cc7: >50cm yellowish brown, massive light clay (moderately deep to deep, moderately to well drained, Yellow Podzolic soils and Red Podzolic Soils) cc8: >100cm greyish, yellow brown, weakly pedal sandy loam (deep, moderately well drained alluvial soils). Soil depth may exceed 300cm.	Flood hazard Foundation hazard (localised) Seasonal waterlogging (localised) Permanently high watertables (drainage plains and lower reaches of floodplains)	Low wet bearing strength, high organic matter, very slow to rapid permeability (localised), low fertility, strong acidity, aluminium toxicity potential (localised).
Dairyville - da	Level to undulating alluvial terraces and floodplains	Quaternary Alluvium	Completely cleared closed-forest	Cattle grazing on improved pastures	Soils patterns are complex due to alluvial nature da1: 80cm dark brown, friable, silty loam (overlying stones, cobbles and gravels); da2: brown, moderately pedal, silty clay loam; da3: 30cm brown, moderately pedal, fine, sandy clay loam; da4: 40cm brown, moderately pedal clay loam; da5: >50cm brown, silty light clay; da6: >43cm dark brown, weakly pedal, sandy light clay. Soil depth generally >150cm.	Water erosion hazard (localised) Foundation hazard (localised) High run on hazard (localised) Flood hazard (localised) Seasonal waterlogging (localised) High watertables (localised)	Very low wet bearing strength, high erodibility, high organic matter, strong to very strong acidity, aluminum toxicity potential, low fertility,

Summary of Soil Landscape Groupings:							
Profile Abbreviation	Topography	Substrate Lithology	Vegetation	Land Use	Typical Soil Profile / Occurrence	Landscape Limitations	Soil Limitations
Swamp Landscapes							
Newports Creek - np	Low, level to gently undulating coastal back barrier floodplains	Pleistocene estuarine sediments	Extensively cleared closed-forest	Residential and Industrial subdivisions	np1: 50cm dark brown, weakly pedal clay loam; np2: 50cm greyish yellow brown whole coloured light clay; np3: 80cm yellowish brown, mottled Pleistocene clay; np4: >90cm grey, mottled Pleistocene clay (deep imperfectly to poorly drained Yellow Podzolic Soils); np5: 40cm dull, yellow, massive silty clay (deep imperfectly to poorly drained Yellow Podzolic Soils). Soil depth generally >150cm.	Flood hazard Foundation hazard Seasonal waterlogging Water erosion hazard (localised)	Low to very low wet bearing strength, very high organic matter, strong to very strong acidity, strong sodicity, high erodibility, slow permeability, high aluminium toxicity potential, low fertility.

Appendix C

DIPNR Groundwater Status Report

DOC 3

Coffs Harbour
Local Government Area
Groundwater Status Report
&
Map Notes

LAND & WATER
CONSERVATION

COFFS BYPASS
1093.65.CG
RECIEVED
18/4/02
DDC

Technical Report No. NC3/98
Prepared by John Williams
Regional Hydrogeologist
North Coast Region
September, 1997

Executive Summary Coffs Harbour Local Government Area Technical Report and Map Notes.

Background

Groundwater is an important resource in NSW. It makes a substantial contribution as a source of water for the maintenance of aquatic environments, and is an integral component in the long-term management of water resources on both regional and State levels. Groundwater is an important commodity, and a vital component of both urban and rural industries, and our economic and social framework.

The need to properly manage groundwater is, therefore, directly related to the value of this resource and the risk of devaluation or destruction of the resource or related environments through over exploitation or contamination. The risks of groundwater resource degradation are real and significant, and in some areas of the State the effects of degradation are beginning to translate into economic and environmental losses.

Where there is concentrated human activity there is usually contaminated groundwater. Contamination can reach the watertable directly through constructions, such as pits, bores, trenches and tanks; or indirectly through the soil. Once in the watertable groundwater moves laterally and shallow aquifers generally discharge into adjacent streams and springs.

Policies/Programs/Regulations

The NSW Government and the community recognise the need for a coordinated approach to the improved management of groundwater. This is best achieved through implementation of the State Groundwater Policy Framework Document and its Component Policies. Together these documents make up the NSW State Groundwater Policy. The policy is consistent with NSW Government directions for natural resource management.

Why was it developed?

The preservation of groundwater quality and yield is of paramount concern. Under statewide natural resource policies currently being introduced, the DLWC, Environment Protection Authority, other agencies and local government will ensure that groundwater contamination and pollution is minimised. Integral to this regulatory process is that the beneficial use of aquifer systems as well as their vulnerability to pollution and protection measures need recognition.

At the request of Coffs Harbour Council, the DLWC has produced this groundwater status report in conjunction with a groundwater availability map and groundwater vulnerability map to aid council in making informative decisions in town planning.

Proper groundwater management guidelines need to be developed at an early stage if preservation of sensitive ecosystems and groundwater quality & quantity are to be maintained.

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TABLE OF FIGURES

1. INTRODUCTION

With the Coffs Harbour local government area (CHLGA) experiencing a rapidly increasing population, the increasing value of groundwater and the connection with surface water leads to concerns of best management practices. The community's attitude toward groundwater management has changed considerably during the past decade with both the DLWC, Council and the community now recognising the need to sustain the resource in the long term. The Department of Land and Water Conservation (DLWC) is responsible for the preservation of the State's water resources and at the request of Coffs Harbour Council, have investigated the various attributes of the physical and chemical environment in the CHLGA to develop both a groundwater vulnerability map and a groundwater availability map as well as a number of special purpose soil landscape derivative maps. It is envisaged that these maps will provide a useful management tool in the planning of future developments within the CHLGA and help to provide long-term sustainability of the groundwater resource. This is achieved by directing potentially polluting industries towards areas where natural barriers exist thus reducing the potential for groundwater contamination. The location, boundary and bore distribution for the CHLGA is shown in Figure 1.

2. PHYSIOGRAPHIC FEATURES

2.1 Stream Network

The boundaries of CHLGA lie within two catchments; i) Clarence River Valley, and ii) Bellinger River Valley. There are also a number of minor coastal streams extending from Coffs Harbour to Arrawarra that drain the coastal strip.

The Nymboida, Orara and Mitchell Rivers are the predominant tributaries that drain the southern section of the Clarence Valley and the eastern section of the Coffs Harbour tectonic block. These tributaries flow in a generally north - north west direction and have carved steep valleys out of the mountains and occasionally there exist small pockets of flat to undulating country. Rugged terrain and steep slopes separate these rivers from each other. East of Orara River the country tends to be more subdued and less rugged.

2.2 Climatic Features

2.2.1 Rainfall & Evaporation

In the CHLGA, the distribution of rainfall is seasonal and largely controlled by the topography. The highest precipitation of about 220 mm/month occurs in late summer-early autumn and the lowest values of about 45 mm a month occur in the winter months. Coffs Harbour has a median annual rainfall of around 1565 mm (Atkinson & Veness, 1981). Evaporation is highest during the months of September to March with December averaging 6.7 mm/day (Mackie Martin & Associates, 1993).

2.2.2 Temperature

The entire valley experiences warm to hot conditions during the period from November to April with an average summer maximum temperature of 26.3^{0}C, however temperatures will vary with elevation and proximity to the coast.. Mild to warm days occur for the remainder of the year with minimum winter temperatures of 7.8^{0}C (Atkinson & Veness, 1981). Frost occurs everywhere in winter except along the coastal strip.

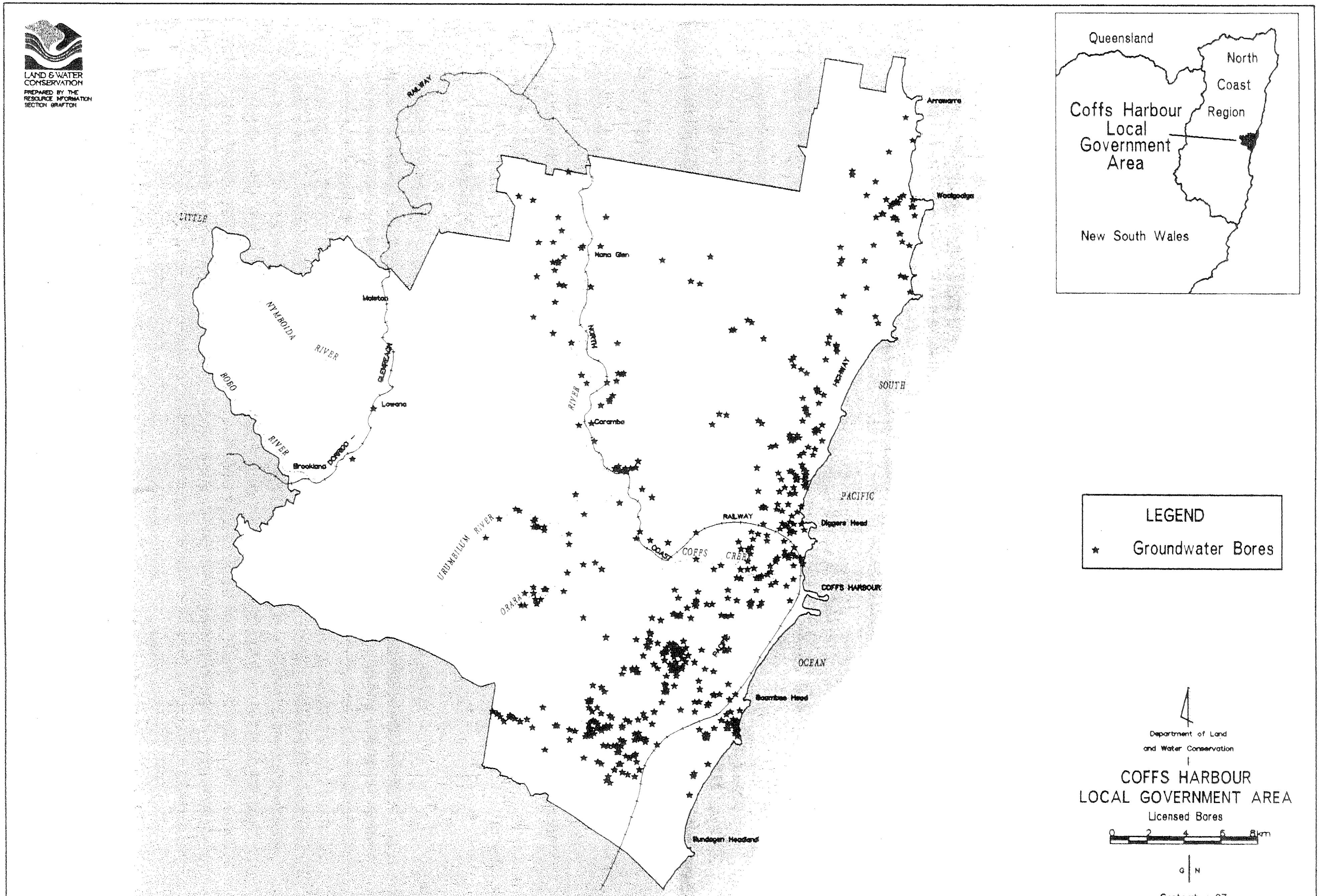
LAND & WATER CONSERVATION
PREPARED BY THE RESOURCE INFORMATION SECTION GRAFTON
Queensland
North
Coast
Region
Coffs Harbour
Local
Government
Area
New South Wales
LEGEND
Groundwater Bores
Department of Land
and Water Conservation
COFFS HARBOUR
LOCAL GOVERNMENT AREA
Licensed Bores
0 2 4 6 8km
September 97
Arrawarra
Woolgoolga
Nana Glen
Coramba
Lowanna
Brooklana
Diggers Head
COFFS HARBOUR
Boambee Head
Bundagen Headland
SOUTH
PACIFIC
OCEAN
HIGHWAY
RAILWAY
NORTH
RIVER
COFFS
CREEK
COAST
URUMBILUM RIVER
ORARA
NYMBOIDA
RIVER
BOBO
RIVER
LITTLE
GLENREAGH
DORRIGO

Figure 1.

2.3 Soils

Three distinctly different soil/geomorphic associations can be recognised in the CHLGA and are frequently identifiable by their relationship to terrain features; i) Coastal Sands, ii) Alluvial Soils, and iii)Bedrock Soils (Atkinson & Veness, 1981). Milford H (in prep) Soil landscapes of the Coffs harbour 1:100 000 Sheet, DLWC Sydney.and separate it into Aeolian landscapes, alluvial landscapes and the rest

2.3.1 Aeolian Landscapes

These soils have sandy textured profiles, low nutrient status, highly erodible and have high permeability. The Holocene dunes, beaches and estuarine flats have little or no soil profile development and drainage depends on local relief.

2.3.2 Alluvial Landscapes

These soils are found on fluvial and estuarine sediments derived from the nearby uplands. Yellow Earths comprise the major part of the geomorphic floodplain, Alluvial Loams and Gravels are typically found on the modern inset floodplain, Red Brown Loams on a terrace and Humic Gleyed Silts in the swamps.

2.3.3 Bedrock Landscape

The soils have a commonly weakly structured loamy A horizon, a moderately structured light B horizon, red colour, moderate to free drainage, good soil depth, moderate to high natural fertility, low shrink-swell potential and low erodibility. Soils that overlie the Clarence Valley Sedimentary Rocks are typically Grey-Brown Podsolic Soils and Yellow Podsolic.

2.4 Regional Geology and Geography

The geology of CHLGA comprises rocks of both the most southern portion of the Clarence-Moreton Basin, the eastern section of the Coffs Harbour tectonic block, and a small portion of the Nambucca Block in the south eastern corner. Quaternary alluvium deposits occur along the major streams of the area and along the coastline.

2.4.1 Coffs Harbour Tectonic Block

The Coffs Harbour Block (CHB) underlies the majority of the study area and comprises Late Carboniferous metasediments and is overlain by the Mesozoic Clarence - Moreton Basin to the north. As indicated on the Dorrigo-Coffs Harbour 1:250 000 Metallogenic Series, the CHB is separated from the Dyamberin Block to the west by the Demon Fault and the east west trending Bellingen Fault system marks the southern boundary with the Nambucca Block. Within the CHB, the Late Carboniferous metasediments comprise the Coramba Beds to the north, the Brooklana Beds in the middle and the Moombil Beds to the south.

The Coramba Beds comprise a thick extensive sequence of turbidites as well as minor pelagic rocks and ocean floor basalt. The turbidite rocks are predominantly massive greywacke, laminated siltstone and mudstone with minor conglomerate derived from a felsic to intermediate volcanic chain. These beds are distinguished from the Brooklana Beds, which they conformably overlie, by a predominance of sandstone over siltstone and mudstone. These beds extend northward from Coffs Harbour and typical exposures can be observed along most of the headlands north to Arrawarra.

The Brooklana Beds consist of thinly bedded siliceous mudstone and siltstone with rarer sandstones. Bedding thickness can vary from one centimetre to several metres thick and are commonly interbedded with lighter coloured, more siliceous rocks which may be finely laminated. They extend from the Bellinger Fault to a line drawn from Coffs Harbour to Lowana (Atkinson &

Veness, 1981). The Moombil Beds are interpreted to be the oldest rocks of the CHB and comprise black massive siltstone with minor greywacke and granule conglomerate.

The origin of the CHB is interpreted as an accretionary complex associated with a subduction zone once active on the eastern margin of Australia. A series of accretionary prisms developed when the trench fill sediments (turbidites), and some pelagic sediments (chert and jasper) and underlying oceanic crust (meta-basalt) were scraped off from the descending oceanic plate and subsequently deformed.

In all there have been three periods of structural deformation affecting the Coffs Harbour Block resulting in tight folding of rock layers, steeply dipping bedding planes and cleavage planes (Dept. of Mineral Resources, 1992). The stress exerted on the rocks during structural deformation have caused the rocks to undergo dyanothermal metamorphism with the degree varying from prehnite-pumpellyite to lower greenschist facies. The regional strike of both bedding and cleavage in the CHB is predominantly west-northwest, however changes to a northerly direction near Red Rock (Dept. of Mineral Resources, 1992).

2.4.2 Clarence-Moreton Basin

The basin is a north-south-trending structure containing mostly unfolded Middle Triassic to Early Cretaceous sediments and minor volcanics. The drainage pattern of the main tributaries of the Clarence flow in a northwest direction. Haworth and Ollier (1992) provide evidence to suggest that the Clarence once flowed in a northwest direction connecting onto the Condamine River just across the Continental Divide. In Late Triassic times, terrestrial sediments began to fill the subsiding Clarence-Moreton Basin and continued through the Jurassic and probably Cretaceous era. Eroded material from the CHB provided a source of sediment to fill ancient valleys in the southern part of the basin. With time, thick sequences of sedimentary material accumulated covering and unconformably overlying rocks of the CHB. Large scale sedimentation in the Basin ended about 80 My ago. At about this point in time, seafloor spreading of the Tasman Sea commenced and continued until about 60 My ago. Haworth and Ollier (1992) state that an axis of uplift associated with the opening of the Tasman Sea developed parallel to and inland of the continental margin. Eastern Australia consequently had a new continental edge and coastline with the initiation of coastward drainage. Table 1 presents a summary of the stratigraphic subdivisions of the Clarence-Moreton Basin. The Department. of Mineral Resources (1992) provides a more detailed description of the stratigraphic units.

Table 1. Stratigraphic subdivision of Clarence-Moreton Basin (source: Dept. of Mineral Resources, 1992).

Age	Stratigraphic Unit	Lithology	Depositional Environment	Thickness
Middle - Late Jurassic	Kangaroo Creek Sandstone	Quartz arenite, conglomerate	Terrestrial	150m
Middle Jurassic	Walloon Coal Measures	Claystone, lithic sandstone, coal, minor ironstone	Terrestrial	600m
Early Jurassic to Late Triassic	Bundamba Group	Conglomerate, quartz-lithic sandstone and minor siltstone	Terrestrial	?600m
Middle Triassic	Nymboida Coal Measures	Quartz-lithic sandstone, siltstone, conglomerate, coal rhyolitic tuff, basalt	Terrestrial	100m

2.4.3 Upper Nambucca Block

The south eastern corner of the CHLGA is underlain by the Bellingen Slate, a stratigraphic unit of the Nambucca Block. The Bellingen Slate, as indicated on the Dorrigo-Coffs Harbour 1:250 000 Metallogenic Series, is dominated by Early Permian age dark micaceous slate, lithofeldspathic sandstone and minor conglomerate. The provenance of these rocks are principally a quartz-rich volcanic terrain which has subsequently undergone low-grade regional metamorphism (Dept. of Mineral Resources, 1992).

3. STATUS OF THE GROUNDWATER RESOURCE

3.1 The Occurrence of Groundwater

In recent years many bores and excavations have been constructed in the CHLGA and groundwater is becoming a more widely used water resource. It is however often overlooked that the surface water and groundwater resources are closely related. Due to the delay time between recharge from precipitation and discharge, groundwater often sustains flow in streams and creeks during extended dry periods until the drought is broken. Thus during dry periods, considerable recharge to the Nymboida, Orara, Mitchell and Bellingen Rivers occurs from the enveloping Carboniferous and Jurassic rocks.

As rain falls on to the land surface, a percentage of rainfall infiltrates the ground surface, depending largely on the climatic features such as annual rainfall, air temperature and evaporation. The percentage of rainfall that infiltrates to the water table will vary with the rainfall event. During low intensity rainfall events, most rainfall infiltrates or is lost to evapotranspiration and there is little runoff. In high intensity events, direct runoff occurs after the soil profile has become fully saturated. Secondary recharge results from topography, surface water, soil and geological characteristics.

Infiltrating water passes through the soil profile to the watertable or seeps along an impermeable interface to discharge down gradient, contributing to the base flow of streams. Some of the water that reaches the water table percolates further to the deeper aquifers within the consolidated rocks. However, the deeper aquifers are likely to have a slower rate of recharge and caution should be taken as yields and water levels can drop significantly after sustained pumping. Close monitoring of water levels should be undertaken and groundwater users may need to rely on more than one bore (with bores spread well apart) to obtain long term sustainable supplies.

In the CHLGA, groundwater occurs in all the rock formations to varying degrees with the greatest supplies being encountered in the more highly fractured and structurally deformed Carboniferous rocks. Generally the deeper a bore is drilled the more water bearing zones are intersected, thus slight increase in yields are likely to be obtained by deeper bores. At present, most groundwater pumpage in the fractured rocks and alluvium is from shallow aquifer zones less than 30m from the surface.

Individual property groundwater assessments can be obtained from the Department's Regional Hydrogeologist at Grafton or from the Hydrogeology Unit in Parramatta. Arrangements to obtain Departmental advice should be made through the North Coast Regional Office at Grafton.

3.2 Previous Groundwater Work

In April 1987, at the request of the NSW Public Works Department, the Dept. of Water Resources (DWR) conducted a groundwater survey of the unconsolidated sediments south of Sawtell to investigate the potential for an emergency groundwater supply. Subsequent investigations followed in 1991. In February 1993, the DWR undertook a detailed investigation of the Bonville sand dune aquifer. The investigation involved a mini wellfield consisting of 8 spearpoints and one bore. Using geophysical, geochemical and groundwater modelling, the estimated annual recharge, aquifer storage, transmissivity and drawdown levels were calculated. The results indicated that the sand dune aquifer at Bonville is capable of yielding the required 1000 ML over a six month period.

Mitchell McCotter & Associates Pty Ltd (November, 1992) developed an Environmental Impact Statement for the proposed borefield. Overall it was concluded that the development of the borefield will have a minimal effect on the overall catchment management objectives and initiatives.

Mackie Martin & Associates Pty Ltd (June, 1993) completed a pump test analysis on a fractured rock aquifer in the Moonee area. The water was observed to be of marginal quality (<1500 mg/L) but increased after sustained pumping to 1700 mg/L and contained elevated iron and manganese levels. The report concluded that in order to achieve a supply of 5 ML/day, 7 to 10 bores spaced well apart would be required. It was also observed that the groundwater quality was unsuitable for drinking purposes and the aquifer was in an area susceptible to pollution from surface activities, ie. septic tanks.

Mackie Martin & Associates (MM&A) Pty Ltd (August, 1993) carried out an analysis of the regional groundwater resources for Coffs Harbour Shire Council. The investigation utilised 149 bore records stored on the DLWC groundwater database to determine aquifer hydraulic properties and define prospective areas for an additional water supply scheme. The report identified several areas containing significant bore yields however, elevated iron levels were common at the majority of sites due to the nature of the bedrock.

In November 1993, the DWR raised a number of concerns over the accuracy of the MM&A assessment of the Moonee Area. The DWR indicated that the Moonee Area could not satisfy council requirements and that further investigations were not justified.

3.3 Groundwater Chemistry

The quality of natural groundwater within these aquifers may be influenced by many factors including the chemical composition of rain water, aquifer media and pollution associated with human activity. Soluble minerals from the sediments accumulate with in the groundwater as it flows through a particular aquifer zone. Aquifers that mostly consist of mineral quartz, such as sands, gravels, sandstones and quartzite, do not add much salt to the water (McKibbin, 1995). The metamorphosed clay and shale sedimentary sequences of the CHB were originally deposited in a marine environment, thus a high level of residual salt (NaCl) has been incorporated within the sediment during the time of consolidation.

Plotting the hydrogeochemical results on a trilinear diagram indicates a strong sodium cation trend. The sodium adsorption ratio (SAR) was calculated to assess the suitability of the water for irrigation. Excessive sodium in irrigation water can adversely affect soil structure. The magnitude of this effect can be related to the relative proportions of sodium ions to calcium and magnesium ions in irrigation water. If water used for irrigation is high in sodium and low in calcium, the cation-exchange complex may become saturated with sodium. This can destroy the soil structure owing to dispersion of the clay particles. A low SAR (2 to 10) indicates little danger from sodium; medium hazards are between 7 and 18, high hazards between 11 and 26, and very high hazards above that (Fetter, 1994). SAR values for samples collected from the CHB ranged from 0.9 to 9.3.

The groundwater quality can also vary with respect to the overlying soil composition. The soil has the capability to generate relatively large amounts of acid and to consume much of the dissolved oxygen in the infiltrating water. Through the decay of organic matter via oxidation, carbon dioxide gas generated can then react with water to produce carbonic acid (H_2CO_3). Carbonic acid can dissociate by transferring hydrogen ions to produce bicarbonate (HCO_3^-), which is the dominant carbonate species over the normal pH range of groundwater. Groundwater chemical analysis carried out on bores within the Carboniferous age Brooklana and Coramba Beds indicate that the major anion with in the upper zone of the shale rocks is bicarbonate. This indicates that the upper zone is characterised by active flushing through relatively well leached rocks that result in low total dissolved salt concentrations. Chemical analysis of the major ions from deeper aquifers identify chloride as the dominant anion. The source of the chloride is from the residual salt and indicates there has been a lower level of flushing as compared to the shallower aquifers.

The groundwater quality in all basalt layers is very good although only sparse information is available on the deeper aquifer zones. Groundwaters are typically of fresh quality. However, the basalts contribute calcium and magnesium salts to the groundwater. Water that contains high levels of dissolved calcium or magnesium salts are described as being hard. In domestic use, the calcium and magnesium will react with soap and form insoluble scales that clog pipes. Groundwaters with a high hardness are still very good quality for stock, domestic, horticulture and general farming purposes. For further information on hardness, the DLWC has a Water Environmental Laboratory at Arncliffe, NSW. It is recommended for groundwater users that rely on this resource for domestic or irrigation purposes to have the water tested for the major ions to assess the suitability of the water for the desired purpose.

3.4 Groundwater Availability

As of 01/09/96 there are 581 licensed bores within the CHLGA. There are also likely to be a large number of bores which are unlicensed and therefore not recorded. Groundwater within the CHLGA can be categorised into three broad geological features. These include 1) the unconsolidated sediments (beach and sand dunes plus the Quaternary alluvium), 2) the Carboniferous age fractured rocks of the Coffs Harbour Block (Coramba Beds, Brooklana Beds and Moombil Beds) together with Permian age Nambucca Block (Bellingen Slate), and 3) porous Mesozoic age sedimentary rocks (Kangaroo Creek Sandstone, Walloon Coal Measures, and Bundamba Group).

3.4.1 Unconsolidated Sediments

The unconsolidated sediments in the CHLGA are generally quite shallow and discontinuous, offering little potential for large supplies of groundwater. The coastal streams along this section of the coastline do not extend into the highlands forming the New England Plateau, and they do not have the physiographic features of the larger valleys. The unconsolidated material along this section of the coastline is interpreted as having been predominantly deposited under estuarine conditions with scattered beach and dune deposits.

Between Mullaway and Moonee Beach, the sediments consist mainly of brown and grey sands, silts, and clays underlain by siltstone followed by basalt. Private bore yields are low (<0.3 L/s) and are of good to marginal quality, however most bores are drilled in excess of 10 metres to intersect shallow aquifers within the bedrock where greater yields are achieved. Further south, around the town of Coffs Harbour, lithological bore logs indicate the sediments comprise more clays and muds with occasional shelly bands, reducing the overall permeability.

To date the only prospective areas identified include a sand and gravel aquifer south of Bonville, situated between Pine Creek and the coast. This aquifer was identified by the Department of Water Resources during exploration drilling in 1992. The bore yields 13 L/s of good quality water from an aquifer of fine yellow sand with some minor interbeded clays before grading into marine clays at a depth of 10 metres. Other exploration bores nearby intersected similar lithological horizons however only yielded 2.5 L/s and 6.6 L/s.

Around the township of Aurania, the DLWC records show two private bores that yield 10 L/s and 16.5 L/s from a shallow gravel aquifer. These bores and others are located within close proximity to the Orara River which is most likely to be acting as a recharge source. Historical records of the groundwater chemistry show typically the water has very low salinity values, is slightly acidic (pH = 6) and typically has very low ion concentrations. The major cation within this area is sodium whilst the dominant anion is bicarbonate. Calculated SAR values are typically low (less than 10) and of low hazard.

3.4.2 Fractured Rocks

The metamorphic rocks of Coffs Harbour Block are typically thought to have a low porosity as they are principally composed of fine grained sedimentary material that that have undergone low grade metamorphism forming interlocking crystals. The tectonic stresses exerted on the CHB during structural deformation have caused folding and faulting increasing the porosity of the rocks. Physical and chemical weathering can also increase the rock porosity and the weathering is often more intense along the fracture surface where a plane of weakness exists. It can therefore be difficult to definitively class the groundwater potential of these rocks as the recorded bore yields can change considerably over short distances.

The best potential for high bore yields occur in regions where the bedrock is deeply weathered and fractured. Areas that exhibit deep weathering profiles tend to have increased bore yields as a result of an increased permeability. It is the ability of the weathered zone to transmit water and its ability to store water that constitutes the most significant hydrologic properties. A large proportion of the bores drilled in the CHB intercept water bearing zones in the weathered portion of the rock.

The CHB as a groundwater resource is generally used for stock watering and supplementing domestic requirements where suitable. The rock strata exhibits a secondary porosity consisting of tight discontinuous fractures that gives a minimal increase in permeability. Areas that have undergone structural deformation as shear zones create groundwater pathways allowing a greater yield to be obtained. Most common bore yields are around 0.5 to 1.0 L/s with occasional supplies up to 5 L/s. The groundwater is generally slightly acidic with a low salinity value. To better describe the groundwater potential of the CHB, it has been divided into stratigraphic units as defined on the Dorrigo - Coffs Harbour 1: 250 000 Geological Series Sheet.

As mentioned earlier, the south eastern corner of the CHLGA is underlain by the Bellingen Slate, a stratigraphic unit of the Nambucca Block. The Bellingen Slate is a low-grade metamorphic sequence and as such has been grouped within the fractured rock classification.

3.4.2a Coramba Beds

Between Corindi Beach and Woolgoolga there are only a small number of bores which are generally licensed for domestic purposes. Good quality water with bore yields typically less than 1 L/s can be obtained at shallow depths. Most bores in this area are drilled through the shale sequences and into the underlying oceanic basalt to a depth of around 10 - 15 metres.

Between Woolgoolga and Moonee Beach good quality water is obtained at variable depths, however most bores intersect either a basalt or fractured shale aquifer at about 20 to 30 metres depth. Yields are typically around 1 L/s although higher yields can be achieved from deeper bores drilled to intersect two or more aquifers. The water quality is likely to deteriorate with depth from the surface. The DLWC records indicate along the northern part of Sandy Beach individual bores have obtained yields of 6 L/s and 19 L/s from a weathered and fractured shale sequence. Other areas that have obtained small irrigation supplies occur to the north west of Moonee Beach within a fractured basalt aquifer. An analysis of water from a bore north of Sandy Beach shows a slightly elevated electrical conductivity (EC) value of 1160 uS/cm, a pH of 6.65, a total calcium value of 11.62 mg/L and a calculated SAR value of 9.0. Similarly an analysis of water from approximately 2.5 kilometres west of Dammerels Head shows a slightly elevated EC value of 1260 uS/cm, a pH of 7.2, a total calcium value of 44.1 mg/L and a calculated SAR value of 4.82.

To the west around Nana Glenn and Coramba, yields of 0.5 L/s are typical with most bores drilled 15 to 20 m in depth. Yields in excess of 2 L/s have been obtained from the deeper shale aquifers east of the Orara River near the tributaries Kalbury Creek and Poperaperan Creek. Further west there are very few bores however a private bore at Lowanna yields 3 L/s of good quality water.

South of Moonee Beach to Coffs Harbour there is a reasonable distribution of bores providing stock, domestic and garden supplies with yields varying from 0.1 to 7 L/s. Bores drilled to a depth of about 40 m typically intersect two to three aquifers, each aquifer yielding about 1 L/s. To the west of the Pacific Highway within the more elevated areas, there are fewer bores and only domestic supplies of around 0.5 L/s are usually obtained. The water is of good quality but is observed to deteriorate with depth. Measured pH values vary from 5.8 to 6.7 and have sodium concentrations around 45 - 110 mg/L. Calculated SAR values within this areas vary from 1.1 to 4.5.

3.4.2b Brooklana Beds

South of Coffs Harbour, around North Bonville and Boambee there is a dense concentration of private bores with the majority licensed for domestic purposes. Good quality water, similar to the Coramba Beds, occurs at shallow depths, however bore yields are typically low, varying between 0.1 and 1 L/s. Around the township of Boambee there are about 70 licensed bores and during extended dry periods there is likely to be some interference effects between bores when excessive pumping occurs. An analysis from a shallow shale aquifer shows an EC value of 270 uS/cm, a pH of 6.3, a total calcium value of 16.4 mg/L and a calculated SAR value of 1.4.

The highest recorded bore yield within this stratigraphic sequence, as indicated on the DLWC database, is 5 L/s from a private construction near Sawtell. It is expected that the quality of the water would be similar to other areas, although variations are to be expected as a result of differing rock types and other factors. Water analysis from a shallow weathered shale aquifer shows an EC value of 530 uS/cm and a pH of 6.5.

3.4.2c Moombil Siltstone

This stratigraphic unit occupies only a small portion of the CHLGA and there is only a limited number of bores for which information is available. Bores extracting groundwater from this unit occur at Crossmaglen, within the upper reaches of Bonville Creek. The Department's records indicate a number of private bores extract 0.5 L/s of good quality groundwater from a meta-basalt aquifer. The permeability of the meta-basalt is influenced by the degree of fracturing and the inter-connection of vesicular bubbles formed during cooling & crystallisation of the magma.

3.4.2d Bellingen Slate

Where the Bellingen Slate occurs, bore yields are typically low (0.5 L/s) with most bores drilled tapping aquifers between 15 to 25 m. The water is of good quality (TDS: 500 - 1000 mg/L) due to active flushing of the weathered zone but is likely to deteriorate with greater depth of the aquifer. The maximum recorded yield is 2 L/s located approximately 2 km south west of Bonville. The township of North Bonville lies on the CHB and is geologically separated from Bonville by the Crossmaglen Fault. Around Bonville, numerous low yielding domestic bores have been constructed with most bores extracting water from one or more shale/slate aquifers to obtain yields of around 0.5 to 1 L/s. The predominance of bores are drilled 20 to 30 metres in depth.

3.4.3 Porous Rocks

Sedimentary rocks are formed from sediments through a process termed diagenesis. This involves compaction from the weight of overlying materials and binding of individual grains by physiochemical reactions. The sedimentary rocks of the Clarence catchment were formed by these processes. The rocks are fractured to some degree from the release of pressure during erosion of the overlying material. There are few bores drilled within the porous sedimentary rocks within the CHLGA. For completeness of the report, a summary of their groundwater potential is provided with the information given having been largely sourced from McKibbin (1995).

3.4.3a Walloon Coal Measures

Groundwater in the Walloon Coal Measures mostly occurs in joints, bedding planes, fractures and porous sequences. The aquifer is mostly confined, with low to medium permeability. Bore yields commonly range from 0.5 to 5 L/s of good quality water.

3.4.3b Bundamba Group

The Bundamba Group is a low yielding and low salinity aquifer system with very few bores tapping the groundwater resource. Bore yields are mostly less than 0.5 L/s but range to 2.5 L/s. The maximum thickness is believed to be approximately 600 m, which indicates the potential for increased yields with greater bore depths.

3.4.3c Kangaroo Creek Sandstone

The Kangaroo Creek Sandstone obtains its name from the prominent sandstone escarpments exposed by Kangaroo Creek in the Nymboida area (Drury, 1982). This unit comprises quartz sandstone with minor conglomerate horizons and offers the best potential of the Clarence River Valley sedimentary rocks for a low salinity groundwater resource. Groundwater can be found in the pores between grains (primary porosity) as well as in fractures (secondary porosity). The water quality is typically good, however most bore yields are about 0.5 L/s. Higher yields can be obtained from weathered and fractured horizons.

4. DLWC Groundwater Availability Mapping

A methodology for preparing groundwater availability maps has been developed by the DLWC Centre for Natural Resources (CNR), Hydrogeology Unit. The method used to produce the GHLGA groundwater availability map has refined the traditional CNR methodology combining this information with special purpose soil landscape derivative maps (Milford, in prep) available for the local area.

Geology was used to define the three aquifer systems; unconsolidated sediments, porous rocks, and fractured rocks, in which groundwater commonly occurs. The major geological units of the regions were defined from published geological maps. The geology was provided in digital format by the Department of Mineral Resources, Armidale and incorporated into the DLWC Geographic Information System (GIS).

To give better definition within the unconsolidated sediments, special purpose soil permeability and soil thickness maps were used to indicate likely changes in groundwater availability.

A search of the existing groundwater information from the Department's groundwater database provided yield and salinity information on individual bores. An assessment of the dominant water quality and yield information for the area was made based on groundwater information from the database and hydrogeologic setting. Where specific bore or groundwater information was not available, interpolation between data points and general hydrogeologic assessment was used to classify particular geological units and areas. Where conflicting TDS data between bores was found, the median value was chosen. Local variations in water salinity can be expected due to isolated hydrogeologic conditions.

4.1 Suitability Classification

Groundwater was classified into one of four definitions based on individual bore TDS and EC water quality information and a general suitability index used in the State of the Environment

Report, Groundwater Sub-Chapter (DWR, 1995). This classification is based on the maximum concentration of salts for the intended purpose. It provides a general guide to the suitability of water for a particular use and may vary according to plant or stock type, soil type, nature and concentration of saline content, climate, duration of use and need.

Total Dissolved Salts (TDS)	Classification	Suitability
<500 mg/L	"fresh"	Suitable for stock domestic and irrigation purposes as well as municipal use.
501-1500 mg/L	"marginal"	Suitable for stock, domestic and some irrigation purposes.
1501-5000 mg/L	"brackish"	Stock water, suitable for dairy cattle, beef, cattle, horses and sheep.
> 5000 mg/L	"saline"	Limited stock use.

Aquifers were further classified according to whether they would yield greater than or less than 1.5 L/s, to a bore or well. A groundwater availability map has been prepared by the DLWC which shows the groundwater potential for the various aquifers (Figure 2).

5. VULNERABILITY MAPS -

5.1 Why Do We Need Them

Groundwater and surface water interact to control river flow. A typical "rule of thumb" for rivers and streams is that approximately 50% of the flow (volume) is groundwater derived (Sinclair Knight Merz, 1995). The DLWC considers that in order to maintain surface water quality, it is very important to limit particular land use activites that are located within close proximity to environmentally sensitive areas. If the groundwater is contaminated, then pollutants can relocate via an aquifer within the the underlying geology and discharge into nearby streams and rivers

With Coffs Harbour experiencing rapid urban expansion, it is imperative that sound environmental planning be implemented to manage the region's resources so that they can sustain their economic, social and environmental uses. Not only will vulnerability maps play an important role in planning, but in the long term can save millions of dollars since remedial works of contaminated aquifers are costly and often irreversible.

Part of understanding the degree to which an aquifer is vulnerable is knowing what activities pose the most serious threat of contamination. By limiting certain industries and their associated activities to areas consistent with the Department's guidelines, effective management policies can be implemented with the empathises on a sustainable groundwater resource.

Potential anthropogenic sources for metals and other contaminants include saw mills, garbage depot's, sewerage disposal sites, cattle dips, petrol stations., fertilised pastures, pesticides and herbicides & runoff from roads & buildings. Other pollutant sources include poultry farms, piggeries and any intensive farming practices. Significant landscape "capacitance" may be buffering adverse impacts that will become apparent only in the future as the buffer zone becomes exhausted. Nutrients and agrochemicals should be retained near the surface for degradation or uptake in the rhizosphere, rather than flushed through to the water table.