GWYDIR RIVER BASIN GROUNDWATER VULNERABILITY MAP

Within the Gwydir River Basin, the features which were deemed important in the development of the groundwater vulnerability map include; Depth to Water Table, Recharge, Aquifer Media, Soil Media, Impact of Vadose Zone, and Hydraulic Conductivity. Ranges and ratings for the development of these maps are discussed below.

Depth to Water Table

Depth to Water Table (DTWT) is an important feature as it determines the depth of unsaturated material through which a contaminant must travel before reaching the aquifer. In general, attenuation capacity increases as the depth to water increases. This is due to the fact that deeper water levels result in a longer travel time, therefore residence time, for any potential contaminant. The presence of low permeability layers, which confine aquifers, will also limit the travel of contaminants into an aquifer. Where an aquifer is confined, depth to water should be redefined as the depth to the top of the aquifer. For semi-confined aquifers a decision must be made as to whether it is more appropriate to consider the aquifer as unconfined or confined groundwater system.

The Depth to Water Table feature, for the Gwydir River Basin, was calculated by combining actual DTWT data with topographic data obtained from the 1:250 000 scale topographic maps. This was possible as the principle shallow aquifers systems are located in unconsolidated sediments and fractured rock aquifers and are considered to be acting hydraulically as unconfined groundwater systems. Where the dominant groundwater system is confined, the depth to the top of the aquifer is used to replace the piezometric head of the bore. The depth to groundwater data used in the construction of this map was obtained from the Departmental groundwater database system (GDS). A 5 metre contour interval was used to classify depth to water table up to >20m depth and is only a representation of the depth to groundwater at any location. In reality groundwater levels used have been collected over a wide-time scale. Thus the map is designed to represent general water table conditions within the river basin. In reality groundwater levels fluctuate depending on groundwater abstraction and climactic conditions.

Table 1 - Ranges and Ratings for Depth to Water

Depth to Water Table (m)

Range	Rating
< 5	10
5 – 10	9
10 – 15	7
15 – 20	5
20 – 25	3
>25	1
Weight 4	

Aquifer Media

The aquifer media component map governs the route and path length (flow system) within the aquifer. The path length is important in determining the time available for attenuation processes such as sorption, reactivity, and dispersion. The aquifer medium also influences the amount of effective surface area of materials with which the contaminant may come in contact within the aquifer. The route that a contaminant will take can be strongly influenced by fracturing, porosity, or by an interconnected series of openings which may provide pathways for easier flow.

For the Gwydir River Basin, the aquifer media was defined by its geology. Geology is the major component relating to groundwater in terms of both its chemical and physical parameters. Therefore, geology is very important in segregating different hydrogeologic systems and provides a prediction of groundwater conditions. The aquifer media component map has been produced from the following geologic and hydrogeologic maps;

New England digital data set - upper north west 1:250 000,

Walgett, Narrabri, Angledool, Moree, and St George 1:250 000 Geological Map Sheets,

Deep alluvial zones were sourced from the Narrabri and Moree Hydrogeology Maps.

The geology has been grouped into the following broad categories;

- Palaeochannel Alluvium - unconsolidated sediments associated with the major groundwater production channels.
- Plain Alluvium - this is a broad classification for all the lower yield alluvium not associated with the major channel alluvium. This includes alluvial deposits within the hardrock terrain.
- Cretaceous/Jurassic/Triassic sedimentary - these rocks are usually associated with the Great Artesian Basin intake beds. They are considered to be relatively unaffected by past tectonic events and therefore display only primary porosity.
- Permian/Carboniferous/Devonian sedimentary - these rocks represent formations of the New England Fold Belt and have been affected by past tectonic events. As a result, they have a reduced primary porosity and consequently have developed a secondary porosity in the form of fractures, faults and joints from which groundwater is available.
- Volcanic - most of the volcanic rocks within the Basin are Tertiary aged basalts. These rocks convey groundwater through cracks, fractures, and joints formed mainly during the cooling of the volcanic material.
- Plutonic - these rocks are also associated with the New England Fold Belt, however they are relatively young for plutonic rocks being typically Permian in age. As a result of the slow cooling during the formation of plutonic bodies, they typically have a low intensity of fracturing. These rocks include, granite, granodiorite and adamellite.
- Metasediments - these rocks are generally the older rocks of the New England Fold Belt. They consist typically of low grade metamorphosed, usually fine grained sedimentary rocks. They exhibit secondary porosity in the form of fractures, faults and joints.

Table 2 - Ranges and Ratings for Aquifer Media

Aquifer Media

Range (Geology Type)	Rating
Palaeochannel Alluvium	10
Plain Alluvium	9
Volcanic	7
Jurassic/Triassic Sedimentary	6
Permian/Carboniferous/Devonian Sedimentary	5
Metasediments	3
Plutonic	1
Weight 5	

Soil Media

Soil has a significant impact on the amount of recharge which can infiltrate into the ground and hence on the ability of a contaminant to enter into the ground. The presence of fine-textured materials, such as silts and clays, can decrease relative soil permeability and restrict contaminant migration. Moreover, where the soil zone is fairly thick, the attenuation processes of filtration, biodegradation, sorption, and volatilisation may be quite significant. Soil media can be described in terms of its textural classification and ranked in order of pollution potential.

For the Gwydir River Basin groundwater vulnerability map a soil attenuation map was produced from previously published soils data obtained from the Central Mapping Authority (CMA), 1988. This data has been published at a scale of 1:2 000 000 and as a result is considered to be the main limitation of the resulting groundwater vulnerability map. As soil attenuation properties are related to the amount of clay present within the soils, the soil attenuation map can be directly inferred from the soil permeability map which is also directly related to the amount of clay within the soil units. It is the ionic charge of clay particles causing adsorption and absorption processes which enables a rating to be given to soil units based on their capacity to retard the progression of a potential contaminant through the soil profile. The soil units present have been rated based on attenuation after permeability ratings from Piscopo et al, 1997. This soil attenuation map has been used to produce the soil media component map, as well as for the development of the impact of vadose zone component map.

The soils media component map attempts to classify the soils of the study area into areas based on the soils media's ability to allow any potential contaminant to move through this it towards the aquifer.

The ranges and ratings for soils have been classified as outlined in Table 3.

Table 3 - Ranges and Ratings for Soil Media

Soil Attenuation

Range	Rating
Stony Sandy Loams	10
Shallow Loams	9
Red Brown Earths	7
Deep Structured Red Clay Loams	6
Shallow Black Self Mulching Clays	5
Deep Black Cracking Clays	4
Coarsely Cracking Grey and Brown Clays	3
Yellow and Red Texture Contrast Soils	2
Scalded Red Texture Contrast Soils	1
Weight 2	

Hydraulic Conductivity

Surficial Hydraulic conductivity of the aquifer media is related to the hydraulic conductivity of the local geology. Hydraulic conductivity controls the rate at which a potential contaminant will enter an aquifer system and consequently, how fast the contaminant will travel through the aquifer system.

The surficial hydraulic conductivity ranges for the Gwydir River Basin were devised using hydrogeolgic experience within the Department and related back to conductivities of the differing geological rock types.

The ranges and ratings for Hydraulic Conductivity of the aquifer media have been classified as outlined in Table 4.

Table 4 - Ranges and Ratings for Surficial Hydraulic Conductivity

Surficial Hydraulic Conductivity

Range (Relative Hydraulic Conductivity of Aquifer Media)	Rating
High Conductivity Surficial Alluvial	10
Volcanic	9
Colluvium	8
Cretaceous/Jurassic/Triassic Sedimentary	6
Permian/Carboniferous/Devonian Sedimentary	4
Metasediments	3
Low Conductivity Surficial Alluvium	2
Plutonic	1
Weight 1	

Recharge

Net Recharge represents the amount of water per unit area of land that penetrates the ground surface and reaches the water table. This recharge water is available to transport a contaminant vertically to the watertable and horizontally within the aquifer. In addition it controls the volume of water available for dispersion and dilution of the contaminant in the vadose and saturated zones. In general, the greater the recharge, the greater the potential for groundwater pollution.

The components incorporated in the recharge feature for the Gwydir River Basin were; Slope, Rainfall and Surficial Hydraulic Conductivity.

This feature was specifically generated for the study area. It incorporates available features that are believed to be important to the recharge component of the study area. The equation used classifies an area based on its ability to act as a recharge zone. The factors used to generate the Recharge map for the Gwydir River Basin include; slope, surfical hydraulic conductivity and rainfall. DTWT and aquifer media are considered to be minor contributors, however, as they are used as other component maps, they have not been used in the recharge map to reduce data bias.

Rainfall information was obtained from the Atlas of NSW, CMA, 1998.

Slope percentages were calculated using the Digital Elevation Model (DEM) data.

The following equation is used to generate a **Recharge Value**. This Recharge Value is then grouped into a range of values that are given a rating for use in the final DRASTIC calculation.
Recharge Value = Slope % + Rainfall + Surficial Hydraulic Conductivity
Where:

Slope %

Range	Factor
< 2%	4
2-10%	3
10 - 33%	2
>33%	1

Rainfall (mm)

Range	Factor
400-500mm	1
500-600mm	2
600-700mm	3
700-800mm	4
800-900mm	5

Surficial Hydraulic Conductivity

Range (Relative Hydraulic Conductivity of Surficial Media)	Factor
High Conductivity Surficial Alluvial	8
Volcanic	7
Colluvium	6
Cretaceous/Jurassic/Triassic Sedimentary	5
Permian/Carboniferous/Devonian Sedimentary	4
Metasediments	3
Low Conductivity Surficial Alluvium	2
Plutonic	1

The maximum Recharge Value is: 17

The minimum Recharge Value is: 3

The rating table for Recharge is shown in Table 5.

Table 5 - Ranges and Ratings for Recharge

Recharge

Range	Rating
14-17	10
12-14	8
10-12	7
8-10	5
6-8	3
3-6	1
Weight 4	

Impact of Vadose Zone

This feature attempts to classify that zone of soil and regolith (saprolite) found above the water table, known as the vadose zone, with regard to its ability to allow any potential contaminant to move through this zone towards the aquifer. It refers to the zone above the watertable which is unsaturated or discontinuously saturated. The type of vadose zone media determines the attenuation characteristics of the material including the typical soil horizon and rock above the water table. The media also controls the path length and routing, thus affecting the time available for attenuation and the quantity of material encountered. The routing is strongly influenced by any fracturing or cracking present, which may reduce the travel time considerably.

The factors available and considered important in defining the impact of vadose zone in the Gwydir River Basin include; Soil Attenuation and Depth to Water Table. A more detailed breakdown of the factors employed, as well as the resulting equation and ratings, are discussed in the range and rating tables devised for the Basin.

The equation used incorporates these factors believed to be important to the vadose zone component map of the study area. The equation provides a **Vadose Zone Value** for areas defined by these factors relative to other areas within the study area. This **Vadose Zone Value** is then grouped into ranges that are given a rating for use in the final DRASTIC calculation.

Impact of Vadose Zone = Soil Attenuation Type + DTWT

Where;

Soil attenuation type has been developed from the differing soil units and Depth to Water Table (DTWT) which are factored for their contribution to the vadose zone impact.

Soil Attenuation

Range	Factor
Stony Sandy Loams	9
Shallow Loams	8
Red Brown Earths	7
Deep Structured Red Clay Loams	6
Shallow Black Self Mulching Clays	5
Deep Black Cracking Clays	4
Coarsely Cracking Grey and Brown Clays	3
Yellow and Red Texture Contrast Soils	2
Scalded Red Texture Contrast Soils	1

Depth to Water Table (m)

Range	Factor
< 5	5
5 – 10	4
10 – 15	3
15 – 20	2
20 – 25	2
>25	1

The resulting maximum **Vadose Zone Impact** range is 14

The minimum **Vadose Zone Impact** range is 2

The ratings for **Vadose Zone Impact** are displayed in Table 6.

Table 6 - Ranges and Ratings for Vadose Zone Impact

Vadose Zone Impact

Range	Rating
12-14	10
10-12	9
8-10	7
6-8	5
4-6	3
2-4	1
Weight 4	

AQUIFER VULNERABILITY CLASSIFICATION IN THE GWYDIR RIVER BASIN

Five classes of vulnerability have been chosen to describe the relative assessment of the probability of a groundwater resource to contamination; "*low*", "*moderately low*", "*moderate*", "*moderately high*" and "*high*". These classes are shown as distinct colours on the vulnerability map.

"*High*" vulnerability ranked groundwater resources are located primarily along stream and river drainage lines predominantly associated with unconsolidated sediments in the hard rock terrain. This includes the Gwydir River from east of Bingara through to Biniguy at the start of the alluvial plain, the upper Horton River, the unconsolidated alluvium associated with Weah Waa Creek within the hard rock terrain, and the unconsolidated alluvium associated with Moredun Creek west of Ben Lomond in the east of the catchment.

There are also minor areas of high vulnerability located within the volcanic terrain around Uralla in the southeast of the catchment. Aquifers within this class require a high level of protection due to their capacity to transmit groundwater.

"*Moderately High*" groundwater vulnerability includes areas represented by volcanic and relatively young sedimentary rocks as well as the confluences of the unconsolidated sediments. These areas also have characteristically high surficial hydraulic conductivity as well as low soil attenuation properties. These attributes along with relatively shallow watertables play an important role in their vulnerability classification.

"Moderate" groundwater vulnerability covers much of the central and western zone including both unconsolidated and hard rock terrain. This class covers numerous differing aquifer media primarily including unconsolidated sediments around and west of Moree, both the older and younger sedimentary rocks, as well as some metamorphic and igneous rocks. These areas typically have a depth to water table of around 10 to 20m in the unconsolidated sediments and <15m in the hard rock terrain with recharge in these areas is being moderate. No one combination of vulnerability factors is responsible for this class, but it is observed that moderately vulnerable aquifers are consistent with moderate classes in the component maps.

"*Moderately Low*" groundwater vulnerability is primarily located in 2 areas.

Firstly, a large portion of the unconsolidated colluvial sediments overlying the Palaeochannel material. These areas are also characterised by a deep depth to water table and relatively low recharge. The soils and impact of vadose zone components also exhibit low ranges due to the presence of thick clay sequences therefore resulting in a greater potential for attenuation.

Secondly, many of the areas covered by yellow and red texture contrast soils are classed as moderately low groundwater vulnerability due to their high attenuation properties as well as a low surficial hydraulic conductivity.

"*Low*" groundwater vulnerability is associated with the unconsolidated sediments where the depth to water table is greater than 25m, low surficial hydraulic conductivity and areas of low rainfall producing low recharge rates. Other low vulnerability areas are situated in areas where there is a combination of fractured rocks along with yellow and red texture contrast soils. These areas offer better groundwater protection due the presence of overlying weathered material acting as a barrier as well as deep watertables thus allowing a greater opportunity for contaminants to attenuate.

Level of Assessment Required

Groundwater vulnerability maps do not directly consider the chemical nature of the pollutant in assessing vulnerability. They are concerned only with the hydrogeologic setting, which makes the groundwater susceptible to contamination from a surface source.

When a development application is being prepared or considered, it is important that the impact of the development on both surface water as well as and groundwater is assessed. It is important to know who uses these resources (beneficial use) and what the current quality of the water is. Potentially polluting developments should not be allowed within highly vulnerable areas. Where such activities are proposed, significant engineering measures would be necessary to minimise the risks of pollution to the groundwater system.

The following Table, modified after the Australian Water Resources Council (AWRC), Draft Guidelines for Groundwater Protection, 1992, is a guide to the amount of groundwater assessment required for a development that requires consent in the five aquifer vulnerability classes.

Vulnerability Classification	Groundwater Assessment Requirements
Low	**Groundwater Contamination Assessment Report** A desk study is required to identify the concerns and potential risk to groundwater or the environment and the need for any further action to be presented in the development application. A standard format hydrogeological report would most likely result.
Moderately Low	**Site Investigation With Monitoring** A potential risk is indicated by the vulnerability map requiring site investigation and groundwater monitoring. The extent of work should involve a limited amount of site investigation, soil and water sampling and testing, definition of flow systems and reporting, in addition to a desk study.
Moderate	**Detailed Site Investigation and Monitoring** For moderate vulnerability areas, or where the previous levels of investigation indicate a demonstrated risk to groundwater, a detailed groundwater site investigation is required. The work should include an ongoing monitoring program, details on the protection design factors, (natural attenuation, physical barriers, etc) in addition to the previous levels of investigation.
Moderately High	**Demonstrated Groundwater Protection System** The risk to groundwater, as demonstrated by the vulnerability map, is an area in which contamination to groundwater cannot be tolerated. The work should include a desk study, detailed site investigation, and implementation of an on-going monitoring program, as indicated above. In addition, the protection design system incorporating natural attenuation, hydraulic barriers, physical barriers etc, needs to be demonstrated, to be effective. The proposal will need to include a feasibility plan for a clean-up, in addition to a detailed monitoring and ongoing assessment program.
High	**Demonstrated Remedial Action Plan/Prohibition** This classification identifies the area as having a potential risk so great as to warrant a demonstrated remedial action plan. The work should include a desk study, site investigations, ongoing monitoring, plus a demonstrated remedial action plan for clean-up, which analyses the effectiveness of the remediation approach in achieving designated water quality criteria. The financial capacity of the responsible party to enact the plan should also be evaluated. In the event that the risk to groundwater is unacceptable, an activity may be banned by the responsible authority.

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