LEGENDS FOR HYDROGEOLOGICAL MAPS

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1. INTRODUCTION

Increasingly, hydrogeological data and their interpretation are being presented in map form, and several hydrogeological maps have recently been produced in Australia. The interest in hydrogeological mapping is due to growing public needs for water resources information. The dissemination of hydrogeological information has been facilitated by the increasing availability of groundwater data and of computer graphics systems for processing them. Map presentation permits a rapid evaluation of the hydrogeology and groundwater resources of particular regions. There is a considerable variation in the amount of information depicted upon a given map, depending on the scale and the purpose of the map.

This guide has been prepared to provide the basis for preliminary hydrogeological mapping in the Northern Territory and as a contribution to the work of the Hydrogeological Mapping Sub-committee of the Australian Water Resources Council (AWRC) Groundwater Committee. It is based on guidelines developed by the Research Council of Alberta, the Bureau of Mineral Resources, (BMR), UNESCO, International Association of the Hydrogeologists (IAH) and a number of Australian groundwater practitioners. It is an interim publication based on local cartographic limitations and computer-aided map preparation has not been considered at this stage.

A problem in cartography is that, since it is essentially an art, the style of presentation and the content of maps can vary considerably, depending on map scale, parochial interests and personal preferences. If the map is to be clear and immediately meaningful to all hydrologists, it is necessary to combine the art with some degree of standardisation.

This guide contains a general statement on layout, and an appendix containing symbols and ornaments used in the Northern Territory.
2. HYDROGEOLOGICAL MAPS

A hydrogeological map aims at enabling a better understanding of the hydrogeological regime in a particular area. By depicting the state of groundwaters in their geological framework, it facilitates the assessment and management of the groundwater resources of an area (Qureshi 1985). A wide range of users of the map, specialists and non-specialists, needs to be considered.

Universal problems faced by the compiler of hydrogeological maps include:

1. Definition of the scale and purpose of the map;
2. Ensuring cartographic clarity;
3. Representation of multi-aquifer systems.

Scale and purpose

The scale of the map may range from small (1:5 million to 1:1 million) to large (1:100 000 to 1:25 000). The smaller-scale maps tend to be more academic than practical, and are qualitative in terms of groundwater resources potential. The larger-scale maps are more practical and are groundwater resources or problems-orientated. Medium scale maps (1:500 000, 1:250 000) are useful in the regional development context in the Northern Territory, especially as there is complete topographic and geological coverage of the Territory at the 1:250 000 scale. The production of such maps is expected to remedy some of the deficiencies in the analysis and dissemination of groundwater resources information in Australia that were identified by the WATER 2000 study (DRE, 1983).

Cartographic clarity

Many previously published hydrogeological maps have suffered from undue complexity, some being unreadable even by specialists. There is a limit to the amount of information that can profitably be shown on a single map sheet. Supplementary inset maps generally must be used to show some parameters.
Representation of multi-aquifer systems

The concept of 'principal aquifer' or 'principal groundwater resources' has been used in most published Australian hydrogeological maps. The definitions have varied but in general 'principal aquifer' has been defined as that which produces the best quality water at highest yield from shallowest depth. The concept is useful for showing the best available groundwater resources. It does not represent multi-layered groundwater systems well because principal aquifer boundaries are by definition arbitrary and often cut across groundwater systems.

Background information

This comprises largely geographical detail such as major roads, railways, the larger conurbations, and so forth. Relief is generally not shown on the map since it tends to obscure hydrogeological detail, but inset maps can be used for the purpose. The Australian Map Grid, a national grid, or lines of latitude and longitude, should be shown.

Background information is generally printed in grey with the grid or latitude-longitude lines in black. Regional and town names may also be printed in black, but the type faces should be clearly different from those used for the stratigraphic symbols.

Aquifers and non-aquifers

All strata that appear on the map, whether aquifers or non-aquifers, are shown in plain colour. Intergranular aquifers are coloured blue and fissure aquifers are coloured green, in each case a dark colour indicating an extensive and highly productive aquifer while a lighter tone indicates other aquifers.

Formations giving only limited or local yields are coloured a light tone of brown, while strata with essentially no groundwater resources are coloured dark brown.

Where it is considered to be particularly important to show the continuation of an aquifer beneath a thin but persistent cover of surficial deposits, the appropriate aquifer colour (blue or green) may be continued over the relevant area, but should be crossed by vertical bands of the appropriate colour of brown. The legend normally printed in the margin of the map sheet should state the order of maximum thickness of the surficial cover.
Lithology

Ornament indicating the lithology is printed in grey.

The orientation of the ornament indicates the type of bedding is shown in appendix. If necessary, more detailed lithology may be included in the map legend.

Surface hydrology

Surface hydrological features are shown in blue. A list of standard symbols is given (Appendix). Perennial streams are defined as those which register flow nine years out of ten.
3. LEGEND FOR HYDROGEOLOGICAL MAPS

The lithological patterns shown are intended as 'basic' patterns for particular rock types, to be used in text figures, black and white maps, coloured maps, and graphic logs and sections. With full-colour maps on which rocks are shown by age colours, the lithological patterns may be used as screens in the appropriate age colour or as overprints (in black and white or some other appropriate colour).

The BMR Screens and Patterns booklet (BMR, 1978) has patterns suitable for most of the proposed lithological patterns, and can provide several alternatives for many of the rock types. The use of the standard patterns renders hand-drawing unnecessary. The patterns listed are regarded only as 'basic' patterns to provide a guide to what should be used. For geological reasons (e.g. clarity or balance of information presented) it may be desirable to vary the style of the symbol. Various devices may be used to achieve this; they include, as applicable: elements (e.g. dots) may be used, in a random or regular pattern; size, spacing, boldness, of elements may be varied; where colour is used, reverse patterns may be employed (e.g. white crosses on red background for granite, instead of red crosses on white background).

Rock type names are generally terms which are meant to cover a range of similar rock types - e.g. granite symbols are also used for granodiorite and adamellite, and may be used for textural variants - e.g. granite porphyry.

Where the rock type to be portrayed is intermediate between those listed it may be appropriate to use combination patterns (e.g. dot-dash for shaly sandstone) or adaptations (e.g. for dolomitic limestone). Additional elements may also be added to standard symbols to portray special features of rocks (e.g. random oblique dashes - for feldspar - may be added to a sandstone pattern to indicate feldspathic sandstone or arkose, and randomly orientated triangles to indicate greywacke.

The patterns for sedimentary rocks may also be used for the corresponding un lithified sediment. Where both sediment and sedimentary rocks of the same, or similar, lithology appear on a map and it is not practicable to use colour to distinguish between the two, it is generally preferable to use a subdued pattern for the sediment and a bolder pattern for the rock.
Special types of rocks, e.g. alkaline igneous rock may be portrayed by the pattern for the nearest broad igneous rock type, or by an adaption of such a pattern, depending on the complexity of the map.

Those patterns having a linear element in them may be used, if drawn freehand, to indicate bedding trends. If a purely geometric pattern is used, care should be taken to ensure that the pattern does not inadvertently appear to indicate a geological trend of any kind.

Patterns for dolerite, pegmatite and other dyke rocks should only be used where the scale of the map and area of outcrop warrants doing so. Symbols for dykes and veins, and abbreviations for minerals (and some rocks) are given in 'Symbols Used on Geological Maps' (EMR, 1978). Other abbreviations appear in the SMR List of Standard Abbreviations (SMR, 1981).

**Aquifer type-yield maps**

In the UNESCO (1983) legend, strata that appear on the map, whether aquifers or non-aquifers, are shown in plain colour (see Appendix). Intergranular aquifers are coloured blue and fissured aquifers are coloured green. In each case a dark colour indicates an extensive and highly productive aquifer whilst a lighter tone indicates local and less productive aquifers. Formations giving only limited or local yields are coloured light brown, whilst strata with essentially no groundwater resources are coloured dark brown. Where it is important to show the continuation of an aquifer beneath a thin but persistent cover of surficial, the appropriate aquifer colour (blue or green) may be continued over the relevant area, but is crossed by vertical bands of the appropriate colour of brown.

On these maps, salinity is indicated by orange lines (Appendix) and lithology is indicated by ornament.
4. SALINITY / BORE YIELD MAPS

Maps with a salinity-yield colour matrix have traditionally been used in Australia and reflect the historic concern of hydrogeologists with finding fresh water in an arid land. This style of map has been used for national reviews of Australia's groundwater resources (AWRC, 1978).

Colour contrast is used for salinity variations; fresh water is shown in blue, brackish water in green and yellow, and saline water in brown. Tonal contrast is used for yield variations: lower yielding aquifers are indicated by lighter tones, and higher-yielding aquifers by darker tones. The Appendix shows a proposed classification, with selected salinity and yield categories. Tonal contrast is indicated by percentage high absorption of positive and can be enhanced by use of different patterns to achieve the required tones. The salinity categories are related to possible water use as follows:

**Groundwater salinity**

(mg/L Total dissolved solids)

<table>
<thead>
<tr>
<th>Salinity Range</th>
<th>Water Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 500</td>
<td>All purposes including domestic and irrigations</td>
</tr>
<tr>
<td>500 - 1500</td>
<td>Most purpose (1500 mg/L is limit for drinking water)</td>
</tr>
<tr>
<td>1500 - 3000</td>
<td>Some irrigation, all livestock</td>
</tr>
<tr>
<td>3000 - 7000</td>
<td>Most livestock</td>
</tr>
<tr>
<td>7000 - 14000</td>
<td>Some livestock, industrial use</td>
</tr>
<tr>
<td>14000 - 100000</td>
<td>Limited industrial use</td>
</tr>
</tbody>
</table>

Information common to both types of map

Information common to both types of map comprises:

- Background information, printed in grey or black;
- Geological features in black, with lithology shown as ornament;
Surface hydrology in blue;
Potentiometry and groundwater flow in violet;
Man-made features and alterations of the groundwater regime in red;
Structure contours, isopachs, and subsidiary aquifer boundaries in dark green;
Cross-sections;
Subsidiary maps and insets.

Potentiometry and groundwater flow

Potentiometric contours are essential where data are available. With other groundwater and related hydrodynamic features they are shown in the Appendix and are printed in violet.

Man-made features

Man-made features and alterations of the groundwater regime are shown in Appendix and are printed in red. More detailed classification of bores and wells may be necessary for larger scale hydrogeological maps, and a range of additional symbols is available if required (Qureshi, 1985).

Horizon contours

Horizon contours, isopachs, subsidiary aquifers and other concealed geological or hydrogeological features may be shown in dark green (Appendix).

Geological information

Geological information is shown in black. Appendix indicates some standard symbols commonly used on hydrogeological maps. If required a wide range of other geological maps symbols is available (BMR, 1978).
Stratigraphic symbols

Stratigraphic symbols may be printed in black, in order to identify units which are not characterized unequivocally by the combination of area colour and screen. The current BMR standard (BMR, 1974) is recommended with minor modifications, as shown in Appendix.

Cross-sections

It is standard practice to illustrate the geology and hydrogeology at depth by the use of vertical cross-sections. These sections may be printed on the margin of the map, or alternatively within an accompanying explanatory text. Block diagrams may also be used.

The lines along which the sections are drawn should be clearly indicated by lines printed in black on the map. The significance of these lines should be explained in the sheet legend and they should be labelled so as to identify the particular section.

The horizontal scale of the cross-section should generally be the same as that of the map. The vertical scale is commonly exaggerated; however, the vertical exaggeration should be limited to 3:1 since over-exaggeration, especially upon large scales, may present a misleading picture of aquifer geometry and hydrodynamics.

The lines and ornament used in the cross-section should be the same as those used on the map.

The end-points of each section, together with any point of importance along the section, should have their locations specified, preferably by the use of grid reference. A bar-scale of altitude (vertical scale) at each end of the section is necessary.

Lines of individual well sections may also be used, or details of typical or index wells may be given on the map margins.

Subsidiary maps and insets

The map margins may be used for subsidiary maps to show such features as:

- hydrochemistry
- structural geology
- topography
- reliability of data
- groundwater provinces
- groundwater resource parameters
- hydraulic characteristics
- statistical information on bore yields
- recharge
- bore hydrographs
- subsidiary aquifers
- climatic parameters
- surface hydrology and drainage basins

A wide range of options is available for the design of the subsidiary maps. Special legends for hydrochemical maps have been developed (UNESCO, 1975), in general using orange lines for groundwater salinity, and representing anions types by colour - blue for carbonate, yellow and brown for sulphate, and green for chloride.

Inset maps may also be used to provide hydrogeological detail in critical or complex areas at a larger scale than the main map.
5. EXPLANATORY NOTES

Explanatory notes are desirable in order to explain and amplify the map. If space permits, abbreviated explanatory notes can be incorporated in the map margins. Otherwise, a separate booklet is necessary. This allows for the presentation on ancillary data such as water-bore information, hydrochemistry, and a bibliography of groundwater reports pertaining to the mapped region (Qureshi, 1984, 1985).

The explanatory notes may include an outline of the geology, the aquifer types and distribution, the flow systems, the groundwater resources, and the water quality characteristics. Representative hydrographs, rainfall data, and infiltration or recharge characteristics may also be included (Qureshi, 1985).
6. CONCLUSIONS

Different styles of hydrogeological mapping are currently used in Australia. Some standardisation of symbols is desirable, but that the map compiler needs a flexible approach for different scales and purposes, and for the varied hydrogeological situations in this large and complex continent.
7. BIBLIOGRAPHY


BMR (1974) - Australia Standard Colour Scheme and Stratigraphic symbols for geological maps.

BMR (1978) - Symbols used on Geological Maps BMR, Canberra.

BMR (1981) - Preferred abbreviations. BMR, Canberra.


AWRC (1975) - Australia: Principal groundwater resources Scale 1:500 000 - AWRC.

1. **UNESCO aquifer type - yield classification** (after UNESCO 1983)

1. **Intergranular aquifers**
   - **blue** Ia Extensive and highly productive aquifers
   - **Screened** Ib Local or discontinuous productive aquifers or extensive but only moderately productive aquifers

2. **Fissured aquifers, including karst aquifers**
   - **green** IIa Extensive and highly productive aquifer
   - **screened green** IIb Local or discontinuous productive aquifers, or extensive but only moderately productive aquifers

3. **Strata (intergranular or fissured rocks) with local and limited groundwater resources or strata with essentially no groundwater resources**
   - **Screened brown** IIIa Strata with local and limited groundwater resources
   - **brown** IIIb Strata with essentially no groundwater resources
   - **brown stripes** IIIc Where there is an extensive aquifer immediately underlying a thin cover, the option may be used of continuing the appropriate aquifer colour crossed by brown stripes (one mm wide three mm with separation)

**Note**

Certain aquifers combine intergranular and fissure characteristics. In such cases the relevant colours described in sections 1 and 2 should be further used depending on which characteristic is dominant; an explanation, if required, may be added to the map legend.
2. **Representation of detailed data**

Signs are printed in several colours, grouped as shown below:

1. **violet:** groundwater and springs
2. **orange:** groundwater quality and temperature
3. **blue:** surface-water and karst hydrography
4. **red:** man-made features and alterations of the natural groundwater regime
5. **dark green:** horizon contours (isopachytes) and limits of certain features
6. **black:** geological formation
3. **Groundwater and springs**

Colour violet

- Contours of the potentiometric surface (solid or broken lines with height in metres relative to reference level)
- Direction of groundwater flow
- Connection between loss and resurgence: a) proven, b) inferred
- Groundwater divide: a) stationary, b) periodically changing
- Limit of area with confined groundwater
- Limit of artesian flow
- Spring with salinity (mg/L total dissolved solids)
- Group of springs (enclosed by circle)
- Groundwater seepage area
- Radiometric age of groundwater (thousands of years BP)
- Water struck
- Water level
- Water rise
4. **Aquifer type/yield classification: interpretation used for Hydrogeological Map of Australia**

<table>
<thead>
<tr>
<th>AQUIFER DISTRIBUTION</th>
<th>YIELD</th>
<th>AQUIFER TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Intergranular (Not fissured or fractured)</td>
</tr>
<tr>
<td><strong>Extensive</strong></td>
<td>High (more than 50% bores yield more than 5 L/s)</td>
<td>Dark blue (Ia)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Light blue (Ib)</td>
</tr>
<tr>
<td><strong>Local</strong> (more than 50% bores yield less than 0.5 L/s)</td>
<td></td>
<td>Light brown (IIIa)</td>
</tr>
<tr>
<td></td>
<td>Effectively nil (more than 90% bores yield less than 0.5 L/s)</td>
<td>Dark brown (IIIb)</td>
</tr>
</tbody>
</table>
## Australian salinity-yield classification

<table>
<thead>
<tr>
<th>SALINITY mg/L TDS</th>
<th>BORE YIELD (L/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;0.5</td>
</tr>
<tr>
<td>&lt;500</td>
<td>10%</td>
</tr>
<tr>
<td>500-1500</td>
<td></td>
</tr>
<tr>
<td>1500-3000</td>
<td></td>
</tr>
<tr>
<td>3000-7000</td>
<td></td>
</tr>
<tr>
<td>7000-14000</td>
<td></td>
</tr>
<tr>
<td>14000-100000</td>
<td></td>
</tr>
<tr>
<td>&gt;100000</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>COLOUR</th>
<th>D</th>
<th>C</th>
<th>B</th>
<th>A</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
6. Groundwater quality and temperature

Colour orange:

- 500 -

Lines of equal groundwater salinity (ticks optional, to point to lower values)

- - 50 ---

Contours of the interface between fresh and saline groundwater, in m below reference level

\[\text{Area of sea water intrusion}\]

\[\text{Area with high-salinity water overlying fresh groundwater}\]

\[\text{Lagoon or lake with saline or brackish water (blue shore line with orange band inside)}\]

\[\text{Periodical salt-water lake (broken blue shore line with orange band inside)}\]

\[\text{Shotts (playas) with episodic water (dotted blue shore line with orange band inside)}\]

\[\text{Salt marsh}\]

\[\text{Cold mineral spring}\]

\[\text{Thermomineral spring}\]

\[\text{Thermal spring}\]

\[10^\circ\]

Water temperature (degrees C)
7. **Surface water and karst hydrography**

Colour: blue

- Perennial stream
- Ephemeral stream
- Stream ending in land depression
- Stream with mineralized water (blue stream with orange band)
- Karstic loss in river valley
  - a) perennial flow downstream
  - b) seasonal flow downstream
  - c) no flow downstream
- Sinkhole
- Doline filled with water
- Dry doline
- Limit of karst area
- Main surface water divide
- Secondary water divide
- Flow gauging station
  - mean annual runoff \([\text{m}^3/\text{s}]\)
  - catchment area \([\cdot 1000 \text{km}^2]\)
- Waterfall
- Freshwater lake
Lagoon or lake with mineralised water (blue shore line with orange band inside)

Periodical salt-water lake (broken blue shore line with orange band inside)

Shotts (playas) with episodic water (dotted blue shore line with orange band inside)

Periodical fresh water lake

Dry lake with only episodic water

River marsh

Bog
8. Man-made features and alterations of the natural groundwater regime

Colour: red

- Pumping station, pumped well
- Pumping station from spring (red square with violet dot inside)
- River intake
- Pipeline
- Bore drain or irrigation channel
- Storage reservoir or pond
- Dam or weir, with capacity of the reservoir in million m$^3$
- Flood-tide barrage or tidal power plant
- Groundwater recharge site
- Installation for desalination
- Limit of area of intensive groundwater exploitation
- Area of underground mining
- Area of open cut mining
- Limit of groundwater control area
• Bore - uncased or destroyed

○ Bore - cased

□ Bore - equipped

● Observation bore with recorder

○ Observation bore

▲ Bore with windmill

▲ Artesian bore

□ Well

● Irrigation well

■ Well - equipped

● Observation well - not equipped

● Observation well - equipped

○ Bore - location not confirmed

● Irrigation bore

● Sandspear point

● Injection bore

돼 300

Bore with average quantity of discharge or pumping (in million m³/year)
9. Horizon contours (isopachytes)

Colour: dark green

Horizon contours or isopachytes (solid or broken lines with depth in m relative to reference level)

Thickness of aquifer in m

Boundary of subsidiary aquifer

Age symbol of subsidiary aquifer
10. **Geological information**

Colour: Black

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Legend</th>
</tr>
</thead>
<tbody>
<tr>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>------</td>
<td>Fault</td>
</tr>
<tr>
<td>------</td>
<td>Boundary of infilled erosional channel</td>
</tr>
<tr>
<td>-------</td>
<td>Fractured belt of hydrogeological importance</td>
</tr>
<tr>
<td>-------</td>
<td>Anticline</td>
</tr>
<tr>
<td>-------</td>
<td>Syncline</td>
</tr>
</tbody>
</table>

Symbols for approximate, inferred and concealed boundaries or faults can be shown by broken or queried lines.

Other symbols in 'Symbols used on geological maps' (BMR 1978) may be used.
11. **LITHOLOGY**

- Clay
- Sand
- Gravel
- Mudstone
- Sandstone
- Conglomerate
- Limestone
- Gypsum
- Halite
- Granite
- Dolerite
- Rhyolite, andesite
- Basalt
- Tuff
- Schist
- Gneiss

17:HYDRO8
12. Stratigraphic symbols (after BMR 1974)

PHANEROZOIC

CAINozoIC Cz

QUATERNARY Q

Holocene Qh
Pleistocene Qp
Pliocene Tp
Miocene Tm

TERTIARY T

Oligocene To
Eocene Te
Paleocene Tl

MESOZOIC M

CRETACEOUS K
JURASSIC J
TRIASSIC R
PERMIAN P

CARBONIFEROUS C

PALAEOZOIC Pz

DEVONIAN D
SILURIAN S
ORDOVICIAN O
CAMBRIAN E

PRECAMBRIAN

ARCHAEOAN Ar

Lower case symbols l, m, e follow the above symbols indicate Late (l), Middle (m), and Early (e).