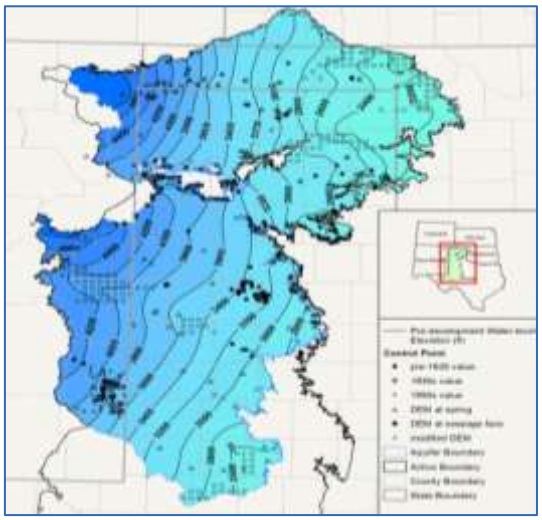
NMR Services Australia

Aquifer Hydrogeology
NMR Answer Products

Need

Hydrogeology involves the study of the distribution and movement of groundwater in the soil and sedimentary rocks. Groundwater is a vital resource of great social, environmental and economic importance, with known supplies dwindling through continuous population growth and industrial expansion. Hydrogeology therefore plays a critical role in the development of comprehensive groundwater management strategies to meet growing consumption.

To assess water distribution within an aquifer the hydrogeologist must determine vertical and lateral variation in total porosity across the resource and differentiate the fraction that is occupied by free (mobile) water, versus the remaining fraction occupied by bound (immobile) water. To map groundwater movement the hydrogeologist needs to investigate aquifer flow potential, which depends on its hydraulic conductivity, the specific yield and specific retention of the rock.



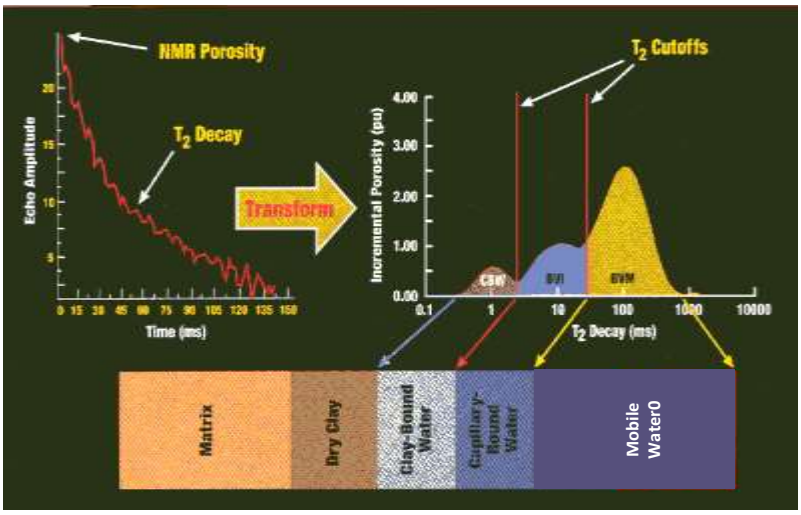
Existing Methods

Total porosity, specific yield and specific retention as well as permeability, can be directly measured *ex-situ* on clean, dried core test plugs However, accuracy of such tests is influenced by core quality, which can be impacted by practices used to capture the cores, extent of filtrate invasion, damage to cores during retrieval, poor core preservation at surface and scaling effects. Accuracy is also influenced by test methods and test procedures, as well as quality of the test apparatus.

Total porosity and permeability can also be determined *in-situ*. However, bulk density log-derived porosity values are prone to error if matrix density is not precisely known. Also, as it is not possible to measure permeability directly, complex multi-parameter lithology-dependent correlations are used instead that equate permeability with other measured geophysical characteristics. These correlations are calibrated against core-derived permeabilities from discrete depths, which as mentioned previously can be prone to sizeable errors.

Bulk permeability can also be estimated from monitoring and analysis of *in-situ* pressure transients induced using pipe or wireline conveyed packer tests. However, tests can last hours, even days, to obtain a single measurement.

New In-Situ Method



Total porosity, specific yield and specific retention can all be directly measured *in-situ* using Nuclear Magnetic Resonance (NMR) technology. Borehole NMR is specifically tuned to sense the fluid-filled pores only, so measurement accuracy is completely unaffected by matrix composition, with no special calibrations to formation lithology therefore required. This superior response capability contrasts completely with the lithology-dependent measurement principle of conventional logging tools. Aquifer permeability can also be derived from analysis of NMR responses.

BMR Features & Benefits

While NMR has been used routinely in the oil and gas logging industry for decades, uptake by the groundwater industry has been hindered by NMR tool size and cost of the logging service. NMRSA have addressed this capability gap through development of an advanced miniaturised, slim borehole Magnetic Resonance (BMR) logging tool.

- Advanced NMR pulse sequences and signal processing techniques enable aquifer pore structure and mobile water content to be determined with a high degree of precision and accuracy.
- An appropriate theoretical model is used to also estimate intrinsic permeability.
- Ultrafast wireline telemetry, complemented by a powerful analysis software, enables a detailed log of these geophysical parameters to be generated real-time.
- Despite miniaturisation, the BMR logging tool has impressive signal-to-noise (SNR) characteristics, resulting in a large depth of investigation.
- High SNR, coupled with rapid data acquisition and processing, enables variation in geophysical parameters through the aquifer to be mapped while continuously logging at 1 m/min (~200ft/hr).
- The BMR logging tool can be run centered in open-hole, fiberglass or PVC lined boreholes.

The Right Data for the Best Value

To fit inside the typically small diameter boreholes drilled to explore and delineate new aquifers, development of the BMR logging tool necessitated a high degree of hardware miniaturization and implementation of new, advanced NMR excitation and NMR relaxation measurement techniques, posing major technical challenges. These challenges were successfully overcome through pioneering applied research, innovative design and a number of inventive steps. As a consequence of these breakthrough achievements, BMR is able to deliver high quality, high resolution data, on a wide range of geophysical pore-related parameters, providing an in-depth view of aquifer hydrogeology. Furthermore, owing to the simple method of use and minimal support equipment and personnel requirements, the BMR logging service also delivers the best value, as showcased in the comparison table below.

	BMR Logging	Conventional Logging	Packer Testing	Core Retrieval & Testing
In-situ measurement	✓	✓	✓	✗
Measurement accuracy[1]	✓✓✓✓	✓	✓✓✓	✓✓
Total porosity	✓	✓	✗	✓
Free water porosity	✓	✗	✗	✓
Clay-bound porosity	✓	✗	✗	✗
Capillary-bound porosity	✓	✗	✗	✓
Permeability	✓	✓	✓	✓
Real-time data	✓	✓	✗	✗
Continuous depth profile	✓	✓	✗	✗
Rig-less operation	✓	✓	✗	✗
Crane-free operation	✓	✗	✗	✓
Test speed[1]	✓✓✓✓	✓✓✓	✓✓	✓
Test efficacy[1]	✓✓✓✓	✓✓✓	✓✓	✓
Test cost[2]	$	$$	$$$$	$$$
Cost benefit ranking	1	2	4	3

NOTES

1. ✓ = worst, ✓✓✓✓ = best
2. $ = least costly, $$$$ = most costly

