GW•MATE

THE WORLD BANK
global water partnership associate program

Sustainable Groundwater Management
Concepts & Tools

Briefing Note Series Note 11

Utilization of Non-Renewable Groundwater
a socially-sustainable approach to resource management

2005

Authors (GW•MATE Core Group)

Stephen Foster[1] Marcella Nanni[1] Karin Kemper[2] Héctor Garduño Albert Tuinhof
([1]lead author [2]main supporting author)

What is a non-renewable groundwater resource?

- Groundwater resources are never strictly non-renewable. But in certain cases the period needed for replenishment (100s to 1000s of years) is very long in relation to the normal time-frame of human activity in general and water resources planning in particular (Figure 1). For this reason it is valid in such cases to talk of the utilization of non-renewable groundwater or the 'mining of aquifer reserves'.

- The focus here is on management of aquifers with non-renewable groundwater such as:
  - unconfined aquifers in areas where contemporary recharge is very infrequent and also of small volume, and the resource is essentially limited to aquifer storage reserves
  - the 'confined sections' of very large aquifer systems, where groundwater development intercepts or induces little active recharge, and the piezometric surface falls continuously with abstraction.

  Both involve the abstraction of so-called 'fossil (or palaeo) groundwater', which originated as recharge in past, more humid, climatic regimes. The volumes of such groundwater stored in some aquifers is huge (e.g. an estimated 150,000 km^3 in the Nubian Sandstone and 15,000 km^3 in the Arabian Rub-al-Khali basin).

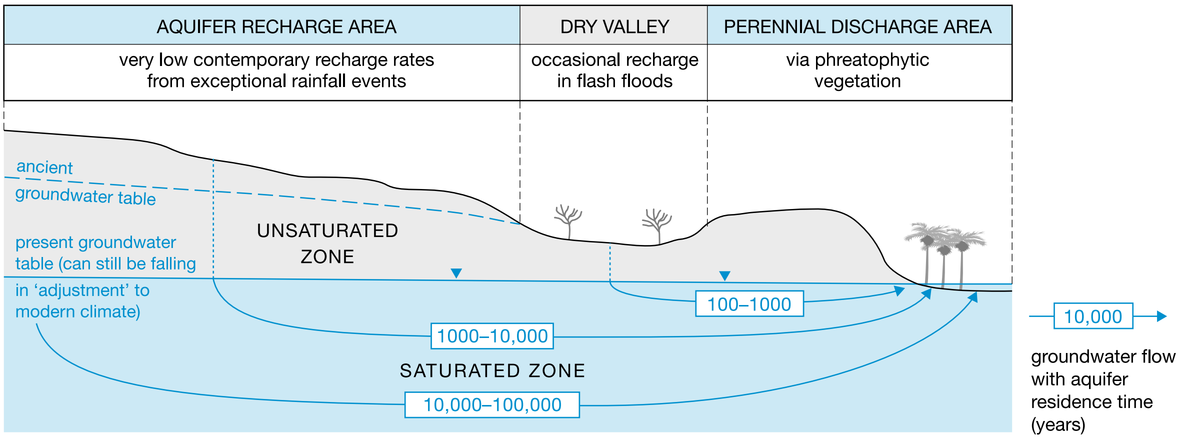
- The use of the term 'sustainability' in this context requires clarification. It is interpreted here in a social (rather than a physical) context, implying that full consideration must be given, not only to the immediate benefits, but also to the 'negative impacts' of development and to the 'what comes after' question—and thus to time horizons of 100–1000 years.

How does the exploitation of non-renewable groundwater arise?

- There are two very different situations under which the utilization of non-renewable groundwater occurs:
  - planned schemes in which the mining of aquifer reserves is contemplated from the outset, usually for a specific development project in an arid area with little contemporary groundwater recharge
  - on an unplanned basis with incidental depletion of aquifer reserves, as a result of intensive ground-water abstraction in areas with some contemporary recharge but where this proves insufficient or where there is limited hydraulic continuity between deep aquifers and their recharge area.

  Worldwide, some important examples of the former can be found (e.g. in the Southern Kalahari of Botswana and the Libyan Sarir Basin), as well as numerous examples of the latter (e.g. the North China Plain Quaternary Aquifer and various aquifers in Rajasthan, India).

Figure 1: Typical groundwater cycle in more arid regions where underlain by major aquifers



- In the **'planned depletion scenario'** the management goal is the orderly utilization of aquifer reserves (of a system with little pre-existing development), with expected benefits and predicted impacts over a specified time-frame. Appropriate 'exit strategies' need to be identified, developed and implemented by the time that the aquifer is seriously depleted. This scenario must include balanced socioeconomic choices on the use of aquifer storage reserves and on the transition to a subsequent less water-dependent economy. A key consideration in defining the 'exit strategy' will be identification of the replacement water resource, such as desalination of brackish groundwater

- In the unplanned situation a **'rationalization scenario'** is needed in which the management goal is:
  - hydraulic stabilization (or exceptionally recovery) of the aquifer, or
  - more orderly utilization of aquifer reserves, minimizing quality deterioration, maximizing groundwater productivity and promoting social transition to a less water-dependent economy.

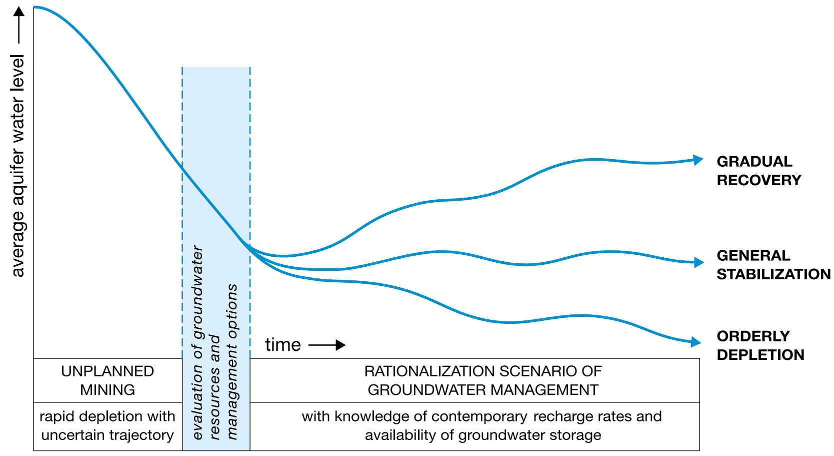
  In both cases the groundwater abstraction rate will have to be reduced, and thus the introduction of demand-management measures (including realistic groundwater charges and incentives for real water-saving) will be needed. In the longer run potable water supply use will have to be given highest priority and some other lower productivity uses may have to be discouraged. This briefing note deals with groundwater management in situations where an orderly approach to the utilization of aquifer reserves is the target, either from the outset in a 'planned depletion scenario' or subsequently in a 'rationalization scenario' (Figure 2).

Which are the key management needs with respect to non-renewable groundwater system characterization?

- If the utilization of non-renewable groundwater is to be managed effectively, special emphasis must be put on aquifer system characterization to facilitate adequate predictions of:
  - groundwater availability, and the distribution of wells to abstract it over a given time horizon
  - the impact of such abstraction on the aquifer system itself, on third parties (especially traditional users) and on any related aquatic and terrestrial ecosystems
  - anticipated groundwater quality changes during the life of intensive aquifer development.

- Such characterization requires special hydrogeological investigation to evaluate certain key factors (Table 1). In contrast to the characterization of renewable groundwater resources (**Briefing Note 2**) a critical

Figure 2: Targets for groundwater resource management in 'rationalization scenarios' following indiscriminate and excessive exploitation



component will be assessment of the storage of those parts of the aquifer that will be (or are being) drained by groundwater pumping, together with the susceptibility of the aquifer system to saline intrusion. The application of environmental isotope analyses is particularly valuable for interpretation of the origin of both fresh and saline groundwater in aquifer storage and the quantification of any contemporary recharge.

- System characterization will inevitably be subject to considerable initial uncertainty and it is thus recommended that 'worst-case parameter values' be used in the numerical aquifer modeling as a basis for planning. The level of confidence in hydrogeological prognosis will increase greatly with the availability of some years of monitoring data on aquifer response to large-volume abstraction. Thus a carefully-designed and systematically-operated monitoring program is essential.

- In the 'planned depletion scenario' the impacts of the proposed exploitation of aquifer reserves on all traditional groundwater users need to be assessed, and some form of compensation provided for predicted or actual derogation. The fundamental concept should be to ensure that there are sufficient reserves of extractable groundwater of acceptable quality left in the aquifer system at the end of the proposed period of intensive exploitation to sustain the pre-existing activity (albeit at additional cost). Another way of achieving this end would be to restrict the 'design drawdown' of intensive exploitation to less than a given average figure over a stated period (for example, 20 meters after 20 years).

- It is equally important (Table 1) to identify all aquatic and/or terrestrial ecosystems that may be dependent on, or actively using, the aquifer concerned and to make predictions of the likely level of interference that will occur as a result of the proposed development. A degree of doubt over impact assessment is likely to arise for two reasons:
  - hydrogeological uncertainty in the prediction of groundwater drawdown, especially at large distances from the proposed abstraction
  - difficulties in estimating how the given ecosystem will react to a certain level of drawdown.

  It has to be recognized that some aquatic ecosystems may only be capable of being sustained (even in a reduced form) through the provision of compensation flows, sometimes accomplished by local irrigation and/or aquifer recharge. This consideration will need to be realistically factored in to the evaluation of the acceptability of the proposed groundwater development.

Table 1: Checklist of special factors and provisions required for the socially-sustainable management of non-renewable groundwater resources

SPECIAL FACTORS & PROVISIONS	IMPORTANCE IN GIVEN SCENARIO 'planned depletion'	'rationalization' *
Aquifer System Characterization		
• quantification of aquifer storage reserves	●●	●●●
• assessment of contemporary recharge rates	●	●●
• prediction of risk of salinity/quality changes	●●●	●●●
• appraisal of depletion effects on 'traditional users'	●●●	●
• prediction of ecological impacts of aquifer depletion	●●●	●
Resource Management Strategy		
• comprehensive socioeconomic assessment	●●●	●●
• maximization of productivity of groundwater use	●●	●●●
• identification of post-depletion 'exit strategy'	●●●	●●●
Institutional Provisions		
• high-level political decision making	●●●	●
• establish government 'aquifer regulatory unit'	●●●	●●●
• mount intensive public awareness campaign	●●●	●●●
• constitute AMOR for stakeholder participation	●●	●●●
• issue time-limited abstraction permits	●●●	●●
• set aquifer management targets	●●	●●
• groundwater monitoring network and databank	●●●	●●●

* certain factors/provisions may be less important in this scenario because effects and impacts will have already occurred

What are the special socio-economic considerations for the management of non-renewable groundwater?

- A comprehensive socio-economic assessment of options for mining aquifer reserves and their impacts will also be a pre-requisite (Table 1) including consideration of:
  - the potential alternative uses (present and future) of aquifer reserves
  - the value of the proposed use(s) in relation to the *in-situ* value of groundwater (**Briefing Note 7**)
  - considering the 'what happens after' (aquifer reserves are depleted) question, and thus broadly identifying and costing (at outline level) the probable 'exit strategy'.

- It is vital that the groundwater is used with maximum hydraulic efficiency and economic productivity, and this implies full re-use of urban, industrial and mining water supplies and carefully-controlled agricultural irrigation. An acceptable system of measuring or estimating the volumetric abstraction will be required as the corner-stone for both realistic charging and enforcing regulations to discourage inefficient and unproductive uses.

- Public awareness campaigns on the nature, uniqueness and value of non-renewable groundwater will be essential to create social conditions conducive to aquifer management, including wherever possible full user participation. In this context all groundwater data (reliably and independently synthesized) should be made regularly available to stakeholders and local communities.

- Non-renewable groundwater in aquifer storage must be treated as a public-property (or alternatively common-property) resource. It is also important to agree the level in government to which the decision on mining of aquifer reserves must be referred. In countries with a non-sectoral water resources ministry the decision could rest with the corresponding minister, but in others it would be better taken by the president's, prime minister's or provincial governor's office (according to the territorial scale of the aquifer) with advice from a multi-sectoral committee. 'High-level political ownership' of the 'rationalization plan for aquifers', whose reserves have been subject to mining on an unplanned basis, is also highly desirable.

What institutional arrangements are required to achieve socially-sustainable utilization of non-renewable groundwater?

- The preferred institutional arrangement is for all groundwater management functions to be handled by a single government agency, with representation at a territorial scale appropriate to the aquifer concerned (**Briefing Note 4**). If this is not possible then all ministries and agencies with a stake in groundwater development and environmental management should be involved, through a coordinating committee. In both instances the water resources administration should have authority to:
  - declare the aquifer that is, or will be, subject to mining of non-renewable resources as a 'special area' subject to specific demand management programs (**Briefing Note 3**)
  - establish, under the appropriate government minister (at national or provincial level), a special unit to coordinate the resource management of the aquifer concerned.

- The full participation of groundwater users will be key to successful implementation of management measures. This will be best approached by establishment of an aquifer management organization (AMOR), which should include representatives of all the main sectoral and geographically-based user groups, together with those of government agencies, local authorities and other stakeholders (**Briefing Note 6**).

- National groundwater legislation (**Briefing Note 4**) will not generally provide a sufficient basis alone for addressing the management of non-renewable resources. Specific provisions for a given aquifer's storage reserves will have to be made through regulations which, in turn, need to be supported by administrative and technical guidelines. It is also important not to treat groundwater law in isolation from legislation in other sectors (such as land-use planning, public works construction, agricultural development, environmental protection, etc.), which can impact directly on groundwater resources.

- A high priority will be to put in place a system of groundwater abstraction rights (sometimes known as permits, licenses or concessions) (**Briefing Note 5**). These must be consistent with the hydrogeological reality of continuously-declining groundwater levels, potentially decreasing well yields and possibly deteriorating groundwater quality. Thus the permits (for specified rates of abstraction at given locations) will need to be time-limited in the long term, but also subject to initial review and modification after 5–10 years, by which time more will be known about the aquifer response to abstraction through operational monitoring. It is possible that use rules set by appropriately-empowered communal AMORs could take the place of more legally-formalized abstraction permits.

- The value of detailed monitoring of groundwater abstraction and use, and the aquifer response (groundwater levels and quality) to such abstraction, cannot be overemphasized (**Briefing Note 9**). This should be carried out by the water resource administration, stakeholder associations and individual users. The existence of time-limited permits subject to initial review will normally stimulate permit holders to provide regular data on wells. It will be incumbent upon the water resources administration to make appropriate institutional arrangements—through some form of aquifer database (databank or datacenter)—for the archiving, processing, interpretation and dissemination of this information.

- Many major aquifers containing large reserves of non-renewable groundwater are transboundary, either in a national sense or between autonomous provinces or states within a single nation. In such circumstances there will much to be mutually gained through:
  - operation of joint or coordinated groundwater monitoring programs
  - establishment of a common groundwater database or mechanism for information sharing
  - adoption of coordinated policies for groundwater resource planning, utilization and management, and of procedures for conflict resolution
  - harmonization of relevant groundwater legislation and regulations.

Further Reading

- Abderrahman, W. A. 2003 *Should intensive use of non-renewable groundwater resources always be rejected?* Intensive Use of Groundwater 191–203. Balkema Publishers. Lisse, Germany.
- Custodio, E 2000 *The Complex Concept of Overexploited Aquifers*. Papeles Proyecto Aguas Subterráneas Serie A:2 Fundacion Marcelino Botin. Santander, Spain.
- EC ENRICH, 2001 *Groundwater: A Renewable Resource?—focus on Sahara and Sahel*. British Geological Survey. Wallingford, UK for EC ENV4-CT97-0591
- Foster, S., Chilton, J., Moench, M., Cardy, F., and Schiffler, M. 2000 *Groundwater in Rural Development: facing the Challenges of Supply and Resource Sustainability*. World Bank Technical Paper 463.Washington, D.C., USA.
- Llamas, M. R., 2001 *Considerations on Ethical Issues in relation to Groundwater Development and/or Mining*. UNESCO IHP-V Technical Documents in Hydrology 42. 467–480. Paris, France.
- Lloyd, J. W., 1999 *An Overview of Groundwater Management in Arid Climates*. Water Management, World Bank-GW•MATE / urification & Conservation in Arid Climates 9-53. Technomic. Lancaster, USA.
- Puri, S. (editor), 2001 *Internationally-Shared (Transboundary) Aquifer Resources Management—their Significance and Sustainable Management.* UNESCO IHP-VI Non-Serial Documents in Hydrolgogy SC-2001/WS/40. Paris, France

Publication Arrangements

The GW•MATE Briefing Notes Series is published by the World Bank, Washington D.C., USA. It is also available in electronic form on the World Bank water resources website (www.worldbank.org/gwmate) and the Global Water Partnership website (www.gwpforum.org).

Funding Support

bnwpp

GW•MATE (Groundwater Management Advisory Team) is a component of the Bank-Netherlands Water Partnership Program (BNWPP) using trust funds from the Dutch and British governments.

DFID Department For International Development