

Sustainable Groundwater Management Concepts & Tools

Briefing Note Series Note 13

Groundwater Resource Development in Minor Aquifers management strategy for village and small town water supply 2002-2005

Authors (GW•MATE Core Group)

Stephen Foster¹ Albert Tuinhof¹ Héctor Garduño² Karin Kemper Phoebe Koundouri Marcella Nanni
(¹lead author ²main supporting author)

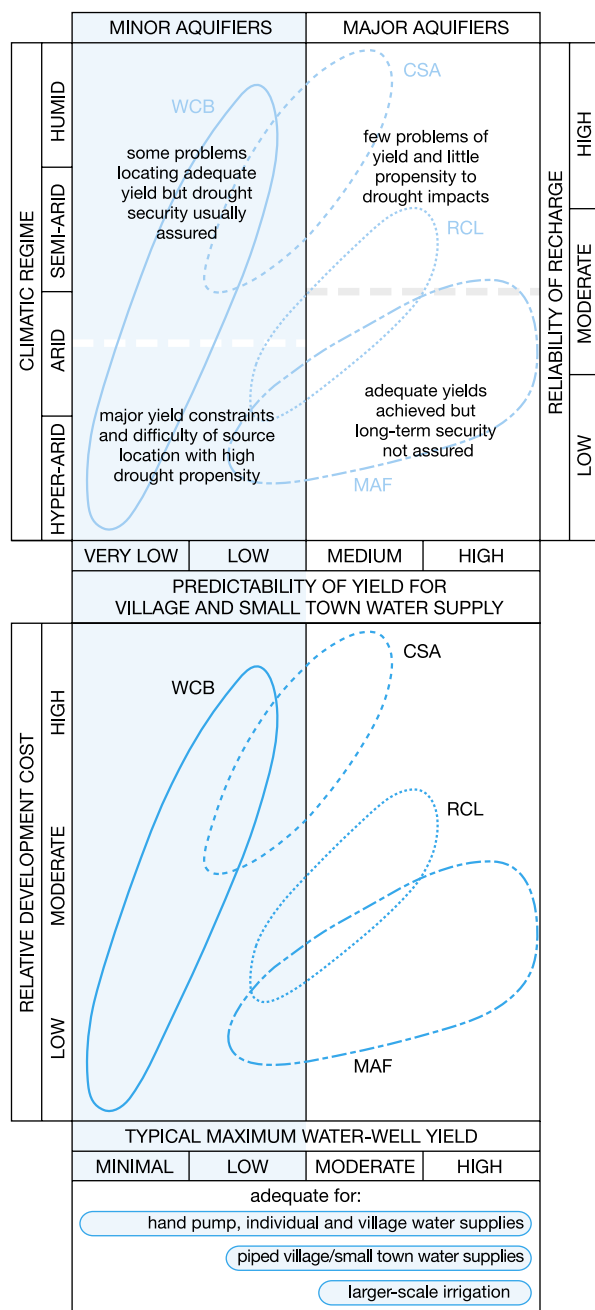
Why is groundwater extremely important for the water supply of villages and small towns?

- **Groundwater has major advantages** for small-scale water supply provision:
 - normally **excellent microbiological and chemical quality**, avoiding the added financial burden and logistic complexity of a water treatment facility
 - **naturally-provided storage and drought resilience**, eliminating the need for construction of expensive surface water-storage facilities
 - **widespread distribution facilitating phased development** close to demand location, reducing the scale of distribution infrastructure with the implication of lower (and flexible) investment requirements.
- It is precisely for these reasons that groundwater development will often be the only affordable and sustainable way of providing improved access to safe water in rural areas. But all too often in the past the development and expansion of village and small-town water supply has not been planned or managed—with water provision simply being taken for granted. This piecemeal approach will have to change if the ‘UN Millennium Development Goals’ for rural water supply are to be met.
- The focus of this Briefing Note is to identify more effective management strategies for the development of groundwater supplies in the rural environment, especially in terms of program evolution, project design and investment planning. The intention is not, however, to provide a guide to water well siting, design, construction, operation, maintenance and financial sustainability, most of which are amply covered by existing published manuals or other work currently in hand.

Why is a special strategy needed for groundwater supply development in areas with only minor-aquifers?

- This Briefing Note deals primarily with issues affecting initial development and subsequent expansion of groundwater supplies in areas underlain by **minor aquifers**, whose yield to water wells is both

Figure 1: Variation of waterwell yield predictability and drought security with aquifer type and climatic regime



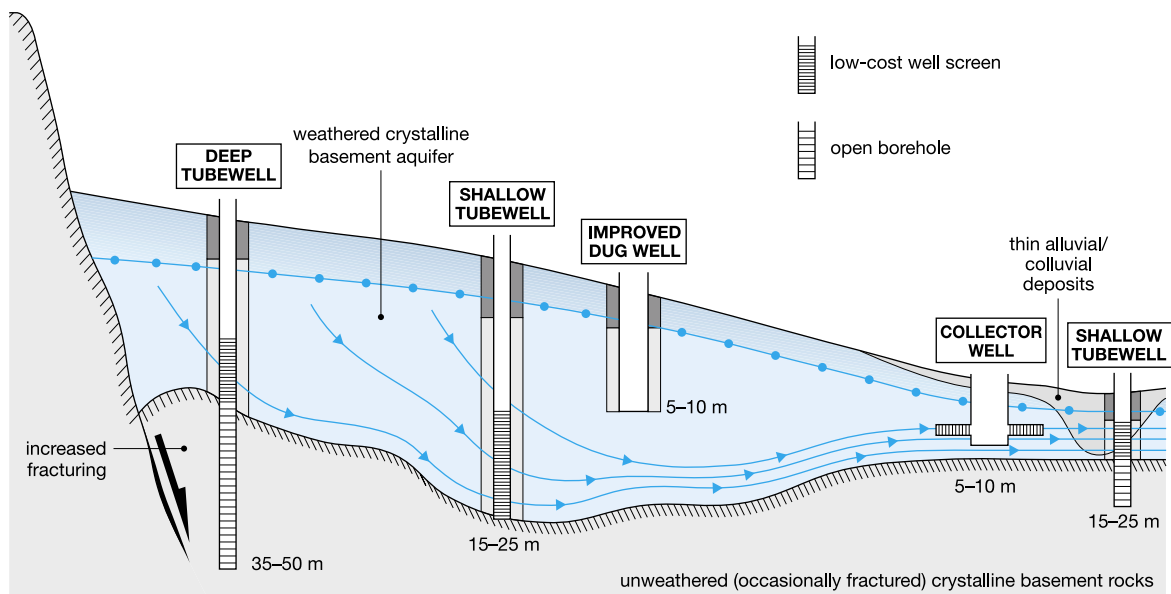
Typical ranges for aquifer type indicated:

- WCB: Weathered Crystalline Basement
- - - CSA: Consolidated Sedimentary Aquifers
- RCL: Recent Coastal Limestones
- - - MAF: Major Alluvial Formations

more limited and less predictable (Figure 1). These aquifers include weathered basement rocks (crystalline metamorphics and metasediments) and other local or patchy aquifers (notably thin Quaternary deposits and older consolidated sedimentary or volcanic rocks). Where situated along rivers or streams the latter group sometimes also allow the development of supplies through bankside infiltration.

- Where villages and small towns are situated over **major aquifers** containing naturally high-quality groundwater, water supply development does not normally encounter significant constraints in terms of access to, and sustainability of, groundwater resources, unless the same aquifer is intensively developed for agricultural irrigation. The principal issues to be confronted are mainly restricted to water well operation and maintenance, which can seriously prejudice the reliability and sustainability of groundwater sources (but are not dealt with here).
- In territory underlain by only **minor aquifers** the availability of a groundwater resource of adequate quantity and acceptable quality is the principal concern, although issues of supply reliability and resource sustainability can also arise. Such aquifers usually offer the only feasible prospect for development of low-cost, drought-reliable, acceptable-quality, rural water supplies over extremely large land areas, especially in Sub-Saharan Africa but also in parts of Asia and Latin America.
- During the 'UN Water Supply & Sanitation Decade' (1980s), the conclusion was drawn by many 'developmental organizations' that minor aquifers were ubiquitous and thus small quantities of water could almost everywhere be obtained without need for hydro-geological expertise and/or investigation—such that (in effect) community considerations and demands could be allowed to override technical considerations in water-supply planning and development.
- This conclusion was, in fact, only valid for more favorable conditions (less arid regions underlain by deeply-weathered crystalline metamorphic rocks) in the context of village hand-pump boreholes or dugwells (yields of up to 10 l/min), and did not take

Figure 2: Harmonization of water well design with local hydrogeological conditions—an important criterion for successful and sustainable groundwater supplies at village and small town level



into account water quality considerations nor growth in population and water demand. And even under favorable conditions it is important to harmonize well design with local hydrogeological conditions if hydraulically-efficient and drought-reliable water wells are to be constructed (Figure 2)—in this regard the likely conditions in extreme drought are an especially critical factor which is all too often overlooked.

- In reality, increasing difficulty in obtaining the desired yield and/or acceptable quality from **minor aquifers** will often be encountered in:
 - the more arid regions, where the water table commonly occurs below the base of the weathered zone containing the bulk of potential aquifer storage
 - in escarpment areas, where the weathered zone has suffered significant erosion
 - in areas underlain by metasediments (as opposed to crystalline metamorphic rocks), which weather to more uniform lower-permeability products.
- In all such cases reduction in the proportion of unsuccessful wells will require:
- development planning based on sound hydrogeological information derived from national archives of past water well drilling experience
 - combinations of hydrogeological and geophysical investigation.

How does the strategy for groundwater supply development need to differ between village and small town level?

- The general characteristics and main differences between water supply provision at village and small-town level are summarized in Table 1. Many essentially rural regions are experiencing extremely rapid urbanization, with many villages growing into small towns with populations in excess of 2000 and many small towns expanding to populations of 5000–20,000. Most of these small towns are expecting

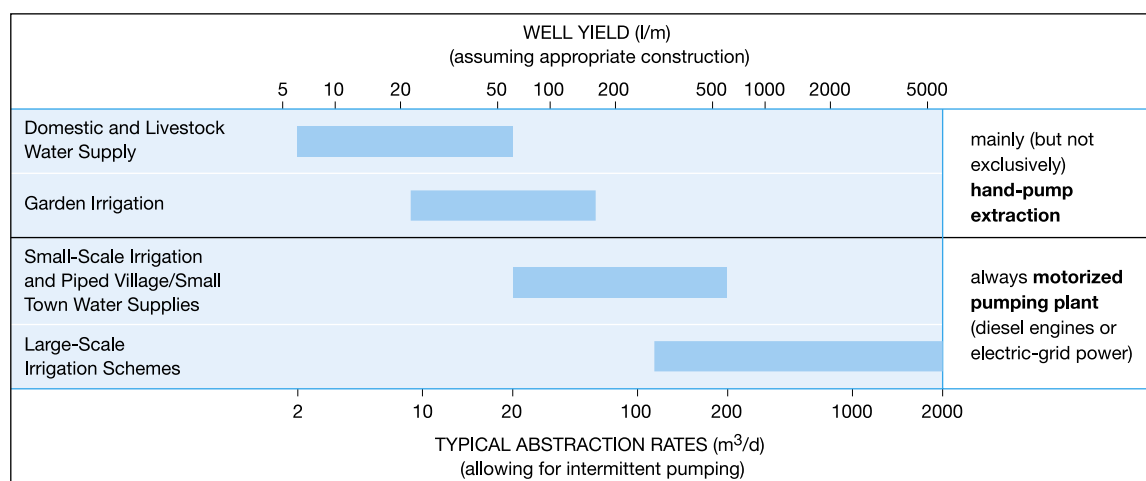
Table 1: Comparison of typical water-supply needs and provisions at village and small town level

FACTOR	VILLAGES	SMALL TOWNS
Population Range	up to 2000	2000–20,000
Water Supply Sources	communal/individual wells or rainwater collection	groundwater or surface water (where a drought-reliable high-quality watercourse available)
Water Supply Criteria	ready availability of 25–50 lpd/capita for manually pumped and carried supply	regular availability of 50–100 lpd/capita, depending on distribution network and sanitation system
Water Well Technology	improved shallow dug wells or tubewells	motorized electric (sometimes diesel) pumps in tubewells or deep improved dug wells, with piped distribution to communal standpipes and/or individual connections
Water Treatment	generally none	usually disinfection (with slow sand filtration for surface water)
Operator Responsible	individual householder or local community	municipal/provincial water supply departments or concessionaires, small-scale independent water supply providers, some communities
Financial Basis	capital cost normally met by government or charitable NGO, with operational cost by user community	operational cost, together with contribution to capital investment, normally met through water charging or indirectly via local taxation
Operational Monitoring	none, other than general observations of operators	some limited operational (but no hydrogeological) data usually collected

groundwater to meet their rapidly-increasing needs for water supply provision, with the growth in demand not only resulting from the expanding population but also the introduction of piped systems with improved distribution via standpipes and dwelling connections.

- This normally implies trying to site water wells with yields that allow motorized pumping (more than 100-l/min for 12–24 hours per day) (Figure 3), and this requires more detailed hydrogeological data and systematic investigation because:
 - these yields can only be achieved where conditions are more favorable and/or by more refined water well design and construction (Figure 2)
 - careful attention will be needed to be given to drought reliability
 - of constraints on sustainability determined by the rates of local aquifer recharge
 - groundwater quality and protection issues will be all the more important.

Similar considerations can also apply in the case of village water supplies in hydrogeologically-difficult areas, where there is an increasing tendency to use single higher-yielding water wells with motorized pumps and distribution to standpipes. This allows more effort to go into well siting and construction, and is considered likely to be more economical (given the high failure rate of community-sited hand-pump wells), but has implications in terms of more complex maintenance requirements.

Figure 3: Well yield and abstraction requirements for different types of rural groundwater use

- The other major difference between village and small town water supply relates to the type of organization responsible for initial development and subsequent operation (Table 1):
 - village water supply provision will normally be through local government programs, NGO campaigns, independent providers and self-help schemes with subsequent communal operation
 - small town water supply development will more often involve municipal or provincial water-supply departments, or increasingly, small-scale independent water supply providers.
 And these institutional differences can be significant in terms of their implications for the collection, evaluation and archiving of operational data on water well performance.

What management strategies are needed to increase the effectiveness of groundwater supply provision?

(a) at village level

- In the case of minor aquifers, and especially in more difficult conditions, water well siting requires more systematic hydrogeological consideration. A rounded understanding of aquifer characteristics and properties, including the factors controlling their depth/spatial distribution (and thus well depths/spacing, storage properties, drought resilience, etc.) and their groundwater quality, needs to be built up since such information will not generally be available from existing literature.
- Addressing the need for improved information in the longer term will require:
 - **revitalizing hydrogeological databasing at national and/or provincial level**, through the use of inexpensive hardware and simple software
 - a modest component of **well-focused research in parallel with groundwater development**.
In some countries the latter has been seriously neglected since the late 1980s, with the 'erosion' of government offices charged with acting as a repository for water well data. As a result those data (on hydrogeology, groundwater availability and quality) that are being collected during community

water-supply campaigns (of local government, NGOs and bilateral development agencies) are now less frequently being effectively archived—even international NGOs alone do not have the technical capacity to process, interpret and store hydrogeological data.

- The role of community associations at village level can be significant in the routine operation, sanitary protection and basic monitoring of water wells—if some awareness raising and organizational support is provided. Moreover, there needs to be investment in **post-case evaluation or benchmarking of groundwater supply schemes**, so as to collect systematic information on well performance, drought reliability, quality concerns, etc. Such information will be of great value both for rectifying existing village water supply problems and assessing groundwater availability for the design of future projects.

(b) at small town level

- At small town water supply level (where the resource demand per unit area is much higher) the cost-effective way of generating the required hydrogeological data for use in future decision making is through **medium-term monitoring of aquifer and well behavior in response to operational pumping**. If appropriate data is systematically collected and archived by the municipal or local authority (over a period of some years) it will form a reliable basis for defining the preferred strategy for the development of future water wells and expanding small wellfields as demand grows.
- The prospects for development of groundwater resources in thin alluvial deposits for small town water supply can be enhanced by siting wells alongside streams (either permanent or ephemeral) and thus augmenting aquifer recharge by induced streambed infiltration. This requires proper well siting to afford flood protection and avoid obvious quality problems.
- Local government or town water service providers can play an important role in water-supply quality surveillance, water well sanitary protection, and monitoring of groundwater levels, use and quality, if adequate guidance and inspection is provided by the agency responsible for groundwater resource management. Rudimentary local management measures, such as water development planning and water well registration, will help to support this process.

By way of summary a systematic check-list of recommended procedures for the development and expansion of rural and small town water supplies using the groundwater resources of minor aquifers is given as Table 2.

How should concerns about groundwater quality be addressed?

- The ‘decade philosophy’ tended to concentrate on ‘water-wash diseases’, and thus on water supply availability. This philosophy proved to be deficient in numerous regions because of the natural occurrence of elevated concentrations of certain trace elements in groundwater to levels well above WHO drinking water guidelines, with long-term health implications for water consumers. This was the consequence of the mineralogical character of some aquifers, and their sluggish groundwater flow and only partial flushing.
- Troublesome concentrations of fluoride (F) were the first to call attention, and this was followed by a severe arsenic (As) contamination in some locations—but the potential presence of manganese (Mn)

Table 2: Check-list for groundwater supply development and operation in villages and small towns

PROCEDURE/TASK/ACTIVITY	TYPE OF ORGANIZATION INVOLVED						
	GOV	NCs	PMA	NGOs	WSCs	PWPs	COM
• financing construction cost	■		T V	V	T	T	●
• hydrogeological reconnaissance (groundwater archives, satellite images etc.)		■	T V	V	T	T	
• hydrogeological field work (geophysical survey etc.)		■	T V	V	T	T	
• siting and design of water wells (including community consultation)		■	T V	T V	T	T	■
• water well drilling and completion (other engineering work where appropriate)		■	T V	T V	T	T	■
• water well testing (quantity and quality)	■	■	T V	T V	T	T	
• water well sanitary/pollution protection	■	■	T V		T		■ V
• community capacity/awareness building			T V	V	T		■ ●
• water well operation and maintenance		■	T		T	T	V
• water charging/cost recovery	■		T		T	T	■
• water well monitoring/inspection (water use, well levels, water quality)	■ ●	■ ●	■ ●		T	T	T V
• post-case evaluation of waterwell/ water supply performance	●	●	T V	V	T		■
• response to groundwater resource problems	■ ●	T	T				
• data feedback to national groundwater archive		■ ●	T V	V	T	T	

GOV* central government ministries

NCs national centers (e.g. geological survey)

PMA* provincial/municipal authority

NGOs international non-governmental organizations

WSC*s water and sanitation companies (public and private)

PWP*s small private water supply providers

COM community associations

* may use consultants and/or water well contractors

T for small town water supply

V for village water supply

■ consulted on procedure/task/activity

● also recipient of final output

and other trace elements also has to be considered in certain aquifer types, and an effective strategy for the avoidance or mitigation of such problems needs to be developed (**Briefing Note 14—*Natural Groundwater Quality Hazards***). Moreover, unacceptable water supply taste or color (as a result of excessive MgSO_4 , NaCl or soluble Fe) can also lead to social rejection of an improved source.

- In addition some shallow aquifers are highly vulnerable to pollution in the rural environment from the:
 - construction of village *in-situ* sanitation facilities
 - pesticide applications to neighboring fields with intensive market garden production
 - casual discharge of oils and solvents from vehicle maintenance facilities.

Thus more attention needs to be given to groundwater source sanitary surveys, protection measures and appropriate monitoring (**Briefing Note 8—Groundwater Quality Protection, and Briefing Note 9—Groundwater Management Monitoring**).

Further Reading

Chilton, P. J. and Foster, S. S. D. 1995. Hydrogeological Characterization and Water Supply Potential of Basement Aquifers in Tropical Africa. *Hydrogeological Journal* 3: 36–49.

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 DC. USA

Langenegger, O. 1994. *Groundwater Quality and Handpump Corrosion in West Africa*. UNDP-World Bank Water and Sanitation Program Publication. World Bank, Washington DC. USA.

Lloyd, B. and Helmer, R. 1991. Surveillance of Drinking Water Quality in Rural Areas. WHO-UNEP Publication. Longman, London.

MacDonald, A. M., Davies, J., Calow, R. and Chilton, P. J. 2004. *Developing groundwater: a guide for rural water supply*. ITDG Publishing, Rugby, UK.

Van Dongen, P. and Woodhouse, M. 1994. *Finding Groundwater: A Project Manager's Guide to Techniques and How to Use Them*. UNDP-World Bank Water and Sanitation Program Publication. World Bank, Washington DC. USA.

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).

The findings, interpretations, and conclusions expressed in this document are entirely those of the authors and should not be attributed in any manner to the World Bank, to its affiliated organizations, or to members of its Board of Executive Directors, or the countries they represent.

Funding Support



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.

