Sustainable Groundwater Management
Concepts & Tools

Briefing Note Series Note 10

Groundwater Dimensions of National Water Resource and River Basin Planning

promoting an integrated strategy

2006

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Which are the advantages of incorporating groundwater into national and river-basin water resource planning?

- Groundwater and surface water are intimately linked, being part of the **same overall hydrological cycle**. Aquifers discharge to surface water bodies, and can be recharged by them, depending on local conditions. However, **while river systems are naturally dominated by flow most aquifers are dominated by storage**, and this has some fundamental implications:
  - aquifers have a large capacity to buffer surface water variability and drought cycles
  - the time-scale of groundwater flow systems is orders-of-magnitude slower
  - for groundwater upstream-downstream considerations neither predominate nor are necessarily fixed.

  Full characterization of aquifers is needed to address the complexity of groundwater flow systems. Through a **step-by-step approach starting with available information, it is generally possible to integrate groundwater and surface water planning**. Given adequate monitoring, groundwater system behavior can be predicted with equal confidence to that of surface water, and the 'buffering effect' of aquifer storage also provides capacity with which to accommodate uncertainty.

- **Specific hydrogeological settings require a different approach**. The following cases illustrate the wide range of situations potentially involved:
  - **significant aquifers with more limited extension than the river basin catchment** (e.g. the Lerma Basin of Mexico) – for which specific aquifer units or groundwater bodies will require independent local management plans, but these plans also need to take account that groundwater recharge may be dependent upon upstream riverflow and downstream riverflow may be dependent upon aquifer discharge
  - **river basins underlain extensively by a shallow Quaternary aquifer** (e.g. the Middle-Lower Indus Basin of Pakistan) – for which surface water-groundwater relations (and their management) are critical to avoid such problems as salt mobilization on land clearance, soil water logging and salinization from irrigated agriculture, and thus fully integrated water resource planning and management is essential
  - **extensive deep aquifer systems occurring in more arid regions** (e.g. the Nubian Sandstone of North Africa) – where the groundwater flow system dominates, there is little permanent surface water and thus it is not helpful to establish a 'river basin organization', and more valid to define a groundwater resource management plan and to manage at 'aquifer level'
  - **minor aquifers predominant**, characterized by shallow depth, patchy distribution and low potential. (e.g.

many parts of the Sub-Sahara African continental shield) – these will have limited interaction with the overlying river basin and their storage is not sufficient to justify comprehensive groundwater resource planning and administration, but given their social importance in rural water supply it is appropriate to put the main effort into the optimum design of waterwells so to maximize their yield and drought security, and to identify the constraints imposed by any potential naturally occurring groundwater quality problems.

- Although there is no technical reason why groundwater and surface water resource management should not be integrated, it has to be accepted that some river basin agencies or boards have tended to overlook or to understate the value of high-quality drought-resilient groundwater resources and not to highlight their management needs, since they are not manifest in the short-term as 'upstream-downstream' conflicts. The underlying reason for this is the reality of very different spatial and time scales. In some ways successful groundwater management requires a much more 'integrated approach' to the land-water management interface in the interest of conserving groundwater recharge and quality (Table 1) and to the spatial allocation of resources to different uses (including that of ecosystems) than is usually attempted in river basin management.

- Furthermore, **integrating groundwater into river basin planning often requires addressing constraints presented by weak and fragmented legal and institutional frameworks:**
  - water legislation that does not adequately cover institutional responsibility for groundwater resources, or places the responsibility under a different agency to that for river basin planning
  - groundwater user associations or groups not being represented in the river basin agency
  - basin water resource managers who do not fully understand the importance of groundwater due to lack of specialist personnel in their agency
  - lack of reliable data and systematic monitoring of groundwater use, levels and quality
  - inadequate socio-political understanding and/or consensus on the role of groundwater (size and nature of the groundwater-based economy, its social development benefits and ecological interests).

  Thus integration may be premature for countries whose priority concern is building minimal water supply infrastructure from groundwater to meet basic human needs.

Table 1: Typical Land Protection Implications of Groundwater Resource Utilization

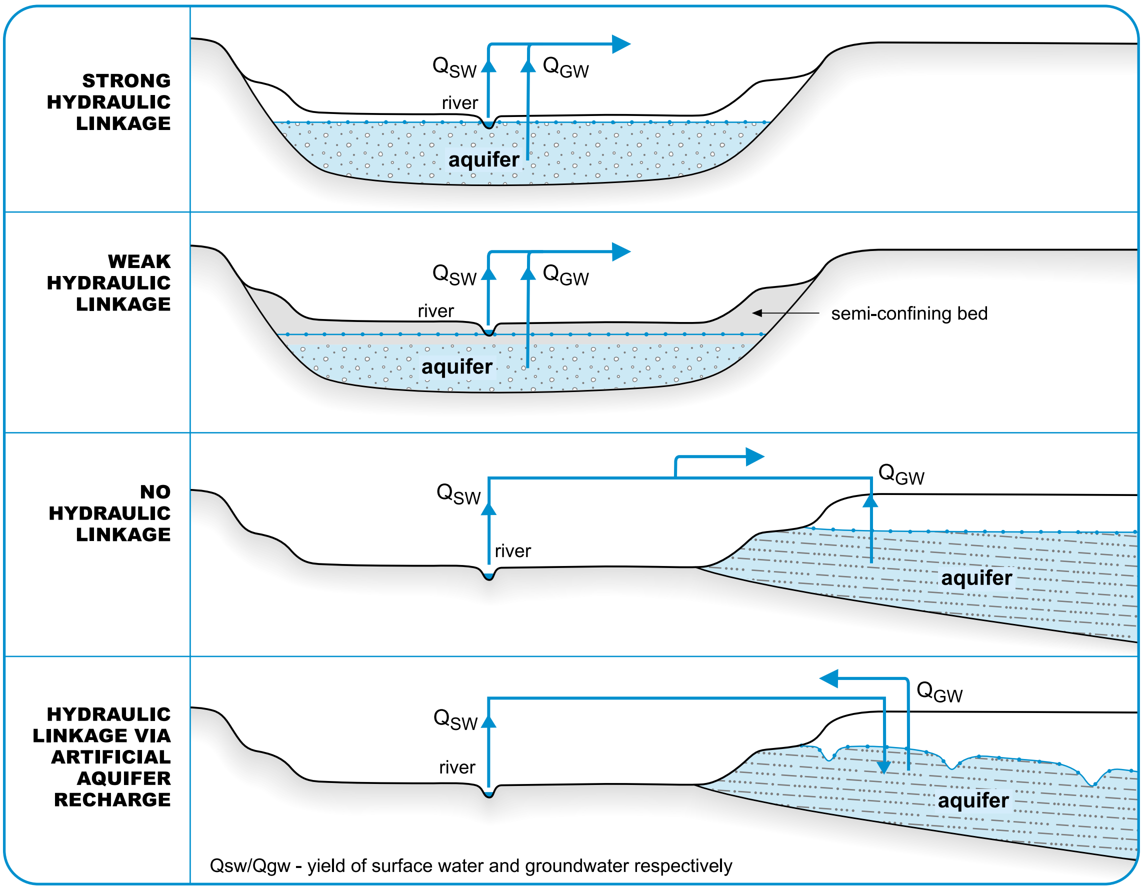
GROUNDWATER RESOURCE USE	LAND AREA NEEDED FOR 'HARVESTING' RECHARGE*
urban water-supply for 10,000 population**	**5 km^2**
100 ha of double-cropped irrigated agriculture	**10 km^2**
100 ha of groundwater-dependent wetland ecosystem	**15 km^2**

* *based on semi-arid region with average excess rainfall of 100mm/a*
** *based on 150 lpd/cap and an urbanized area of 100 ha with a population density of 100/ha, but this use is essentially 'non-consumptive' and water will become available for re-use*

Why and how should conjunctive use of groundwater and surface water be promoted?

- 'Conjunctive use' (in effect joint use) is an expression to describe the **complementary abstraction of surface water and groundwater resources, which is normally focused on providing water supply to a specific water-user sector** (irrigated agriculture or urban water supply) generally within a sub-zone of a river basin (Figure 1). It has many advantages primarily because:

Figure 1: Conjunctive water resource use under different types of 'river-aquifer linkage'



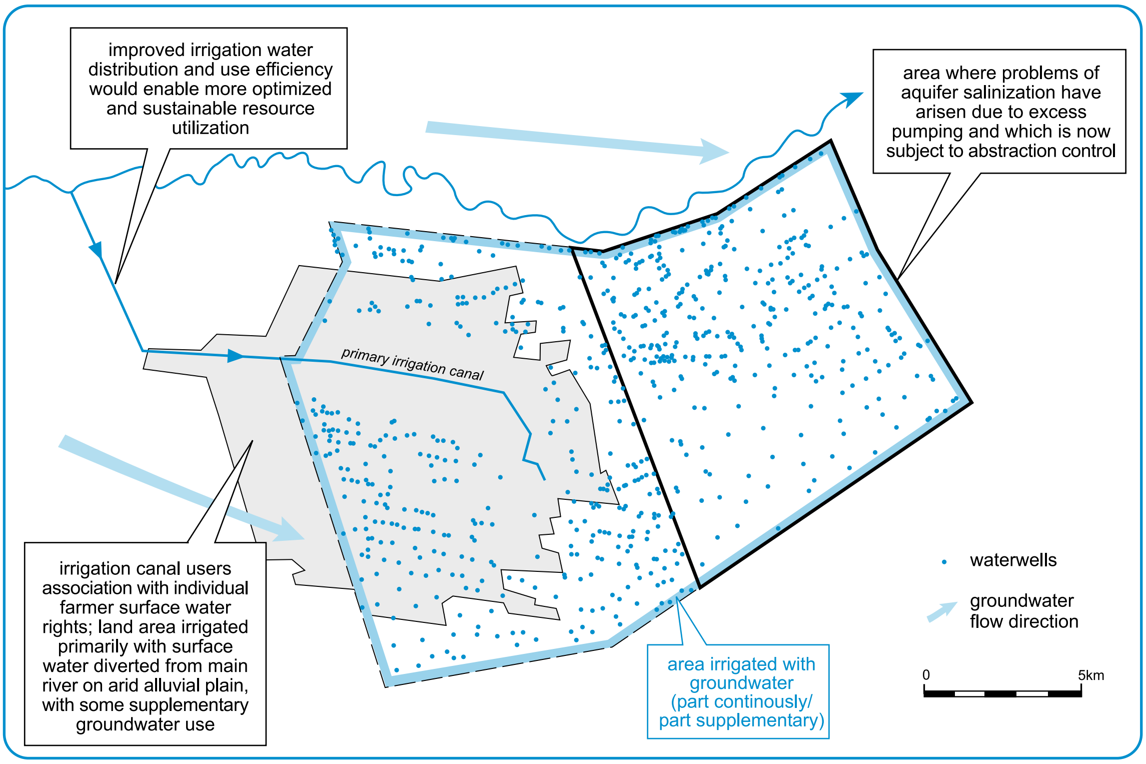
- the natural storage of groundwater bodies can be used to buffer the climatic variability of riverflow and together provide a more reliable water supply at lower cost and higher efficiency than would otherwise be possible
- the utilization of groundwater can provide important vertical drainage in the lower-lying parts of river basins, reducing the incidence of soil water-logging and salinization.

Two distinct situations should be recognized: (a) spontaneous (or unplanned) conjunctive use and (b) planned conjunctive management of groundwater and surface water resources.

- In the case of irrigated agriculture conjunctive use is rarely planned. Typically individual farmers construct waterwells in an attempt to cope with unreliable irrigation canal flows as a result of climatic drought, inadequate maintenance and/or ineffective allocation (Figure 2). While the water supply so obtained is more costly than canal water, its greater reliability and availability at critical times of crop growth has proved highly beneficial in terms of securing crop yields and farmers incomes, and has also raised the overall productivity of irrigation systems, extended the cultivated areas under irrigation command and (in some cases) reduced the need for public and private investment in land drainage.

- While conjunctive use of groundwater and surface water resources usually occurs by default it can produce important overall gains – and a big opportunity exists for enhancing such gains through planned 'conjunctive management' which will require substantial investments in:

Figure 2: Typical unplanned conjunctive use of surface water and groundwater for irrigated agriculture



- institutional strengthening to increase groundwater management capability for water-use rights reform, use planning, monitoring and data basing
- infrastructure improvement and modernization to enable re-allocation of both groundwater and surface water resources.

Where groundwater quality imposes additional constraints the challenges will be more difficult and the investment needs greater.

- Planned conjunctive resource management has proved, as yet, beyond the capacity of many water resource administrations, and examples are mainly restricted to urban water supply development rather than in irrigated agriculture. Implementation requires an understanding of the level of physical interaction between the two resources, a mature and integrated water institutional planning and coordination framework, and powers to renegotiate surface water-use rights and emplace a groundwater use rights system. It is also be important to create incentives (and avoid perverse disincentives) for conjunctive water management amongst stakeholder groups.

Which are the essential elements and contributions to groundwater resource planning?

- An integrated approach to groundwater planning implies a need to:
  - balance increasing resource demands with the needs of aquatic or terrestrial ecosystems and baseflow in upper river reaches as appropriate

- consider the efficiency, equity and sustainability of existing groundwater use, and its relationship with surface water abstraction where appropriate
- decide how priority to basic drinking water supply can be enforced
- take into account two-way relationships between macro-economic policies, broader social and environmental goals, and groundwater development, management and use
- consider cross-sectoral integration in policy development
- represent groundwater interests in land-use management
- consider the relation between water abstraction permits and wastewater discharge controls
- give stakeholders a voice (with particular attention to women and the poor).

The economic consequences of not taking this type of integrated approach to groundwater can be very high, and there are numerous examples from developed and developing countries alike to prove it. Much unnecessary expenditure can be avoided by judiciously integrating groundwater planning into other activities.

- Whatever approach is required by the specific hydrogeological setting the essential building block will be the management plan for each discrete aquifer system or groundwater body. Careful attention should be paid to the delineation of groundwater management boundaries reconciling the hydrogeological setting, political/administrative boundaries and resource management issues/needs (**Briefing Note 6**). The 'entry points' for strengthening groundwater governance will be building stakeholder awareness ('bottom-up') and providing an enabling legal and economic climate ('top-down'). There is, however, no 'simple blueprint' for groundwater planning that will fit all cases, although **international experience** (as distilled in Table 2) **may be useful in identifying the essential elements of a plan for a specific aquifer. Minor aquifers do not usually require the level of sophistication** implied in Table 2, but special attention should be given to ensure a more rational development and integration between water supply needs and resource management (**Briefing Note 13**).

- **From the outset, an IWRM approach is best taken by focusing on specific real issues** and dealing with them in a direct manner (Table 3). This is especially true in groundwater planning and management, where different stakeholders can take the lead from specific 'entry points' (even before the plan is completed) and according to the issue at stake. In this respect, the identification of easily achieved initial targets to secure clear short-term benefits ('harvesting the low-hanging fruit') can help bolster political support for implementation.

- At aquifer level, the **key actors in groundwater resource planning are the groundwater users themselves and other local stakeholders**, since they should best know the issues at stake (**Briefing Note 6**). But it has to be recognized that social participation alone will seldom lead to sustainable groundwater management, and government will normally be needed to facilitate a complementary 'bottom-up' and 'top-down' approach (**Briefing Note 6**).

- The leadership of a local government and/or NGO interdisciplinary professional team (hydrogeologists, environmental engineers, economists, sociologists and lawyers) is a *sine qua non* pre-requisite for a **balanced groundwater resource plan** which will:
  - be based on sound scientific and technological principles
  - recommend economically feasible management options
  - be environmentally sustainable, socially acceptable and institutionally implementable.

Table 2 : Checklist for the elaboration of groundwater management plans

GROUNDWATER STATUS & REQUIRED SERVICES	**Resource Assessment** • describe local hydrogeology in regional context with simplified maps and representative profiles • calculate aquifer water balances, including surface water interactions • appraise hydrogeological uncertainty and groundwater-level historical trends • describe links to surface water and wastewater (as potential resource and threat (**Briefing Note 12**) • assess policies and subsidies (power, waterwells, crops) affecting groundwater abstraction **Quality Characteristics** • assess natural quality variations (**Briefing Note 14**) and presence of brackish/saline groundwater • evaluate evidence for extent and possible causes of current pollution • assess potential pollution risks from land use & aquifer pollution vulnerability (**Briefing Note 8**) **Required Services** • discuss alternative socioeconomic scenarios with political leaders and water users • predict future demands over planning period (10 or more years) • assess aquifer target yields, allowing for environmental discharges • draft options for aquifer stabilization or rational mining with exit strategy (**Briefing Note 11)**
CURRENT MANAGEMENT ARRANGEMENTS	**Institutional Provisions** • appraise legal framework, customary arrangements and water permit system (**Briefing Notes 4 & 5**) • assess responsibilities of all relevant organizations • identify groundwater allocation criteria and priorities • review resource-fee policy and enforcement **Water Allocation & Usage** • summarize current position by sector graphs of historical trends in water use • establish water-user profiles and waterwell inventory **Monitoring Networks** • status of abstraction metering and estimation • status of wastewater discharges affecting groundwater • arrangements for aquifer water level and water quality monitoring **Institutional Capacity** • assess 'enforceability' of water, land use and environmental law • scope of user and other key stakeholder participation
FUTURE MANAGEMENT OPTIONS	**Economic Analyses** • estimate groundwater economic value **(Briefing Note 7)** • assess feasibility of implementing direct and/or indirect groundwater pricing • assess consequences of modifying macro-economic policies • undertake systematic cost-benefit analysis of short-listed options **Definition of Options** • describe management options to achieve stated aquifer services (**Briefing Note 3**) • consider conjunctive use and compare demand management options to supply-side augmentation • appraise need to integrate groundwater and surface water planning • conclude on preferred option to pursue • identify key tasks, responsible institutions, financial needs and implementation timetable
IMPLEMENTATION PROGRAM	**User/Stakeholder Participation** • appraise improvements in user/stakeholder participation required **(Briefing Note 6)** • define action plan for their engagement • prepare program for training, communication & publicity **Monitoring & Review Requirements** • define improvements in monitoring needed for new management plan (**Briefing Note 9**) • install improved management monitoring network • propose timetable and process for internal/external evaluation of plan effectiveness

- Planning and implementation should be closely interlinked – thus the preparation of a groundwater management plan should take place in progressive stages, starting from a first draft version that should be assessed in the light of possible institutional impediments to implementation. One or more of the following actions may be taken both to improve groundwater resource governance and to prepare more realistic subsequent versions:
  - enhancing institutional arrangements
  - establishing capacity building programs
  - setting-up public education campaigns
  - improving groundwater resource and use information
  - assuring that goals are attainable and implementation strategies straightforward.

- The final version of the plan should be approved by the competent authority and should be binding on both the groundwater resource administration and groundwater users, without prejudice to periodic revision and updating at intervals which will be indicated by the legislation. The plan can then be gradually implemented, and the lessons drawn from implementation will lead to better subsequent plans.

Table 3: Entry points for main actors in groundwater management planning and implementation

KEY GROUNDWATER *ISSUES* & MANAGEMENT *NEEDS*	COMMUNITY ORGANIZATIONS			GOVERNMENT OFFICES	
	USERS	AMOR	RBO	MU/ST	NAT
Rural Development					
economical access – need for sound hydrogeological information to ensure groundwater sources can be constructed at tolerable cost		c		s	L
operational supply reliability – need for solid/pragmatic standards, sound design, O&M, adequate financial arrangements	c	c		e	L
aquifer depletion – control groundwater abstraction avoiding well interference, affecting downstream flows, freshwater wetlands or brackish lagoons, saline water intrusion or land subsidence	c	L	c	e	sc
diffuse groundwater pollution – aquifer pollution control and groundwater source protection through mainly land use planning and control	c	s	c	e	L
Urban Development					
inadequately controlled groundwater abstraction within city – reserve deeper groundwater for sensitive uses and encourage use of shallow polluted groundwater for nonsensitive uses	c	c	s	e	L
inadequately controlled groundwater abstraction around city – reserve good quality groundwater for potable water-supply and substitute treated wastewater or shallow polluted groundwater for irrigation	c	L	s	e	s
excessive subsurface contaminant load- define source protection zones for priority control of contaminant load to municipal wellfields and plan wastewater handling taking account of groundwater interests	c	c	s	e	L
excess urban infiltration –reduce infiltration by control of mains leakage, on-site sanitation seepage through main sewer installation and increase abstraction of shallow polluted groundwater for nonsensitive uses	c	s	s	e	L

USERS (including large individual users/polluters such as industries or water service providers and water user associations **AMOR** Aquifer Management Organization (including USERS and other key stakeholders, such as NGOs, professional and drilling associations, media representatives, research & training institutions) **RBO** River Basin Organizations **MU** municipal **ST** state **NAT** national
L lead **c** contribute, **e** enforce, **s** support.

At what level should groundwater enter into National IWRM and WUE Plans?

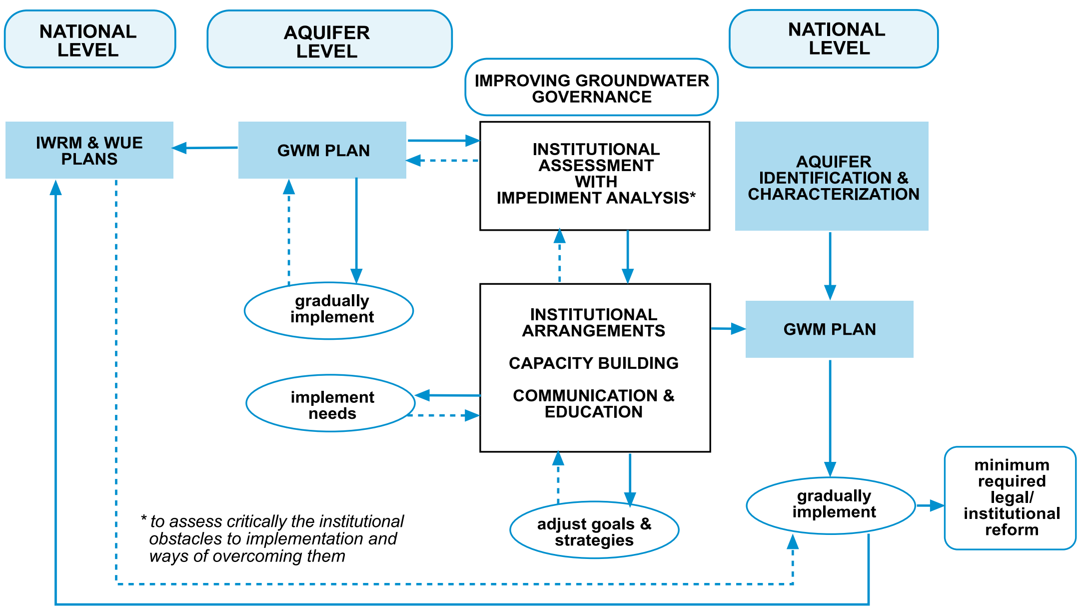
- Groundwater figured prominently at the **World Summit on Sustainable Development** (WSSD) of 2002 in Johannesburg. The WSSD Plan of Implementation states that nations should 'develop and implement national/regional strategies, plans and programs with regard to integrated river basin, watershed and groundwater management, and introduce measures to improve the efficiency of water infrastructure to reduce losses and increase water recycling'. The Global Water Partnership has subsequently issued guidelines on the conceptual framework of the IWRM (Integrated Water Resource Management) process and of WUE (Water Use Efficiency) plans, and on the practical steps needed for implementation, and these form the basis of what is recommended here for groundwater.

- **The groundwater component of National IWRM and WUE Plans may be developed from specific aquifer management plans** as illustrated in Figure 3. First, all available information on national aquifers needs to be compiled, the groundwater systems classified according to their hydrogeological characteristics and management issues, and their 'hot spots' identified. This process can be refined with feedback from local aquifer level and will facilitate the assessment of groundwater management needs at national level.

- Issues such as modifying national food production policy and re-targeting well drilling or pumping subsidies obviously cannot be handled at local aquifer level and require **decisions to be made nationally**. Moreover, at national level emphasis should also be placed upon:
  - appraisal of the legal and institutional framework
  - evaluation of available technical and institutional capacity
  - assessment of political will and impediments for moving forward
  - preparation of an 'action-oriented road map', including capacity building where appropriate

- **Once the national groundwater plan has been consolidated, a positive interaction with National IWRM and WUE planning will follow** with the necessary institutional coordination to achieve the following objectives as appropriate:

Figure 3: The groundwater management planning and implementation process



- agronomic technical and management measures are taken to improve irrigation use efficiency and result in 'real water savings' (Briefing Note 3).
- municipal water supply and irrigation development consider resource sustainability as a primary issue by taking action to protect and conserve groundwater
- use of urban wastewater as an additional resource for irrigated agriculture, while paying attention to related groundwater pollution and health risks (Briefing Note 12)
- initiatives to enhance rainfall recharge are technically and economically effective, and equitable as regards benefits
- a groundwater dimension is introduced in land-use planning, so as to direct land-use changes in the interest of groundwater quality (Briefing Note 8).

- **The groundwater resource planning process should be dynamic and iterative**, and allow for interaction/learning and monitoring/feedback between local aquifer and national levels. This should allow simultaneous implementation of practical management measures where most required, whilst not losing sight of the bigger picture and dealing judiciously with information gaps and uncertainties. A sound conceptual model of the groundwater flow and quality regime, and an appraisal of the impact of human activity, is indispensable for the effective management and protection of aquifers. Nevertheless, **lack of complete data should not be held as an excuse for not getting on with the job**, and much can be done without comprehensive database — filling key information gaps can become in reality part of the preliminary management monitoring process.

- Whether at aquifer or national level, **a groundwater management plan must be regarded as a 'road map'** to guide the changes needed to move from fragmented to integrated management of groundwater resources and to accelerate implementation. A plan should clearly establish the goals and the path to achieve them – with milestones along the way that can be readily monitored.

What approach should be taken in the case of international aquifers?

- There are only limited examples to date of international cooperation in the management of shared groundwater resources, although it is increasingly recognized that such cooperation is beneficial and should be institutionalized if conflicts are to be avoided. Efforts to develop international legal rules on the subject are only recent, and generally do not extend to groundwater planning as such.

- In the case of international groundwater resources it is not possible to adopt a uniform approach. Under given circumstances — for instance mining of non-renewable aquifer reserves — it would be advisable to develop an international groundwater resource plan which includes a 'depletion cum exit' strategy (**Briefing Note 11**). But the effects of much smaller scale groundwater development (for example in rural subsistence and small-town water supply) will only be felt very locally, so that there would be no need for a plan of the entire international aquifer system.

- Different institutional mechanisms may be selected to plan and manage international groundwater resources, depending on the existing level of cooperation among the states concerned (Table 4) and on the type and urgency of issues to be addressed. It should be noted that an institutional mechanism may evolve from a simple agreement for handling and exchanging data to an international river basin or aquifer commission that makes autonomous decisions in the interest of the member states. This latter mechanism would be expected to have strong synergy with national governments.

Table 4: Levels and evolution of international institutional mechanisms for groundwater resources planning and management

LEVEL OF COOPERATION	INSTITUTIONAL MECHANISM		
	TYPE	FUNCTIONS	INVOLVEMENT IN PLANNING
INCIPIENT	data exchange network of national agencies coordinated by neutral institution	administration of aquifer database and models	contributes the necessary information, but planning is still a national function
MODERATE	technical committee with secretariat	administration of aquifer database and models; preparation of possible strategies, plans and measures	recommends plan but decision on approval made by national governments
HIGH	joint commission with secretariat	administration of aquifer database and models; adoption of strategies, plans and measures, and approval of resource development projects	autonomous decisions on plans are made by commission itself and binding on member states; strong synergy between national government institutions

Further Reading

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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