Integrated Water Resources Management (IWRM): How does groundwater fit in?

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Why an essay on this topic now?

Over the last decade, the world has been confronted with several concurrent challenges—fuel price shocks, escalating food prices, accelerating carbon emissions and declining ecosystem services. Their seriousness has questioned our optimistic vision of continuing progress under the 'conventional model' of economic development—with realisation that natural resources cannot indefinitely go on meeting the demands of growing global population.

There is a great risk of negative feedback from climate change on water resources, economic activity and political stability. Water-resource security is an issue that is common to these global threats—a gossamer that links one to another—and it is under severe pressure from escalating population, rapid urbanisation, dietary changes as countries develop, excessive abstraction and increasing pollution. Today, water concerns remain high on many national agendas especially in developing nations—since past 'compartmentalised approaches' to water management have generally failed to achieve sustainable outcomes. In particular, the links between groundwater management, economic development and land-use planning have rarely been recognised. There is now a clear need for taking a more holistic approach, by integrating groundwater into development planning in order to strive for improved economic efficiency, social equity and environmental sustainability—the pillars of Integrated Water Resources Management (IWRM).

IWRM is the process of managing water resources holistically and of promoting coordinated consideration of water, land and related natural resources during developmental activity. It recognises that freshwater is a finite and vulnerable resource, essential to sustain human livelihoods and the natural environment, and a public good that has social and economic value in competing uses. Water-resource management should be based on a participatory approach, involving users, planners and policy makers at all levels. Such conceptual and practical changes in water management take time to implement and many countries are still having to grapple with:

- Insufficient policy coordination and/or complex sector organisation, which impair policy integration
- A strong supply-driven legacy, in conflict with integrated resource-management objectives
- Allocations of public finance, which fail to reach strategic, longer-term, issues
- Weak mechanisms for stakeholder participation

While consensus is growing around the urgent need to improve water security, opinions on how to achieve this remain divergent and are continuing to evolve. They include voices that advocate leaving the IWRM approach—presumably returning to more narrowly focused sectorial water strategies that are seen as less complex and easier to implement (e.g. Biswas 2004). However, a return to the fragmented water-resource development policies of the last century could widely compromise the sustainability of the resource base. It is evident that more clarity and pragmatism is required on how IWRM can best be implemented, so as to achieve outcomes of better economic, social and environmental balance.

The IWRM approach: relevance to groundwater

IWRM is not an end in itself, but a means of ensuring that water-resource development is more balanced—maximising socioeconomic welfare in an equitable manner without compromising ecosystem sustainability (GWP 2000). A brief critical overview of the relevance of taking an IWRM approach to groundwater is presented, including

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an appraisal of the conceptual and practical difficulties sometimes encountered. Groundwater is a very widely distributed resource, and thus affected by a plethora of local users and polluters, whose behavior in turn is influenced by national policy affecting land and water use. Thus, mobilisation on improved groundwater management and protection needs to be multidisciplinary, strongly participatory and bridge across sectors. Therefore, at first sight, it is quintessentially an integral part of the IWRM process, and the axioms of IWRM are gaining increased acceptance by groundwater specialists.

IWRM is fully compatible with so-called 'adaptive management', in which provisional decisions and measures are taken based on best-available scientific evidence with full stakeholder consultation. Subsequent monitoring of social outcomes and aquifer responses (coupled with numerical modelling) are used to adapt the management plan according to evolving circumstances. This approach is highly appropriate for groundwater, given the limited information on, and scientific uncertainty often associated with, this resource.

The critical importance of the nexus between groundwater and agricultural policy, urban infrastructure and energy consumption has to be stressed, since without integrated vision and action at these interfaces, the major challenge of groundwater-resource sustainability cannot be effectively addressed (Garduno and Foster 2010; Foster et al. 2010). Irrigated agriculture has widely become the major user and predominant consumer of groundwater, and questions of resource sustainability and irreversible degradation are arising, which lead to a number of key cross-sector policy issues:

- Role of irrigation technology improvements: desirable from the standpoints of energy savings and water productivity, but not comparable to equivalent groundwater-resource savings, unless accompanied by parallel measures
- Influence of rural energy policy: flat-rate electricity tariffs for irrigation waterwells provide zero incentive to constrain groundwater pumping, but the effect of modest subsidies may be less counterproductive
- Impact of intensive agricultural cropping: where the key to improved groundwater recharge quality lies in negotiations and trade-offs which reduce land areas under intensive cultivation and/or use of certain agrochemicals in vulnerable zones

Likewise, urbanisation has an intimate relation with groundwater, with both the land-use interface and sanitation nexus being especially critical. Without improved metropolitan and municipal planning based on an integrated vision, the problems arising often turn out to be highly persistent and very costly.

The issue of scale: an important conceptual challenge

Groundwater and surface water are intimately linked—with aquifer discharge to surface-water bodies or recharge from them, depending on local conditions. However, while river systems are flow-dominated, most aquifers are characterised by large storage (stocks) and much lower flux (flow rates) with the implication that for groundwater:

- Upstream-downstream considerations neither predominate nor are necessarily fixed
- The storage buffer makes it is easier to accommodate uncertainty in management decision-making and the cost of applying the 'precautionary principle'
- Management and protection actions, of necessity, must cover a wide scale range

The river basin is the fundamental spatial unit for application of the IWRM process; however, this has to be reconciled with the fact that groundwater bodies, defined by hydrogeological criteria, are the appropriate spatial framework within which to address groundwater management and protection (Garduno et al 2006). Thus, some specific hydrogeological settings will require a modified approach (Table 1):

- For 'Hydrogeological Condition C', it may be preferable to work primarily with the groundwater system and not the river basin.

Table 1 Hydrologically consistent approach to reconciling river basin catchments with groundwater bodies for integrated water-resources management

Hydrogeological condition	Water-resource management implications
A. Important aquifers of limited extent compared to river basin in either humid or arid region	Independent local groundwater-management plans required, but these should recognise that aquifer recharge may result from upstream riverflow, and downstream baseflow will often be dependent on aquifer discharge
B. River basin underlain by extensive shallow aquifer system	Surface-water/groundwater relations (and their management) require fully integrated appraisal to avoid double resource-accounting and various problems (including salt mobilisation on land clearance, soil water logging and salinisation from irrigated agriculture, etc.)
C. Extensive deep aquifer systems in arid regions	Groundwater flow system dominates: there is little permanent surface water and, thus, it is not helpful to adopt a river-basin approach
D. Minor aquifers of shallow depth and patchy distribution predominate	Limited groundwater interaction with river basin and (despite socioeconomic importance of minor aquifers for rural water supply) integrated groundwater/surface-water planning and management is not really essential

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- For ‘Hydrogeological Conditions A and D’, decentralisation of IWRM operations to component groundwater bodies is favoured, which in many ways is comparable to the nested (polycentric) approach advocated by Lankford and Hepworth (2010).

The Global Water Partnership (GWP) has issued guidelines for National IWRM Plans and on the practical steps needed for implementation (GWP 2004). These constitute the basis of what is recommended here for groundwater, essentially developing and aggregating specific groundwater-body management plans as the hydrological realities dictate. Successful management also requires a much more integrated approach to:

- The land–water management interface in the interest of conserving groundwater recharge and quality
- Spatial allocation of resources to different uses (including ecosystems) than is usually attempted in river basin management

Other potential impediments to groundwater integration

There is an emerging concern in some countries that the major effort required on IWRM promotion, which involves thinking at the basin scale and decentralising the water administration, is spreading (the often-limited) hydrogeological expertise too thinly and acting as a diversion from vital infrastructure development (urban and rural water-supply improvement). This is not the fault of the IWRM process as such, but the need for a pragmatic approach to conserve critical mass under experienced leadership needs to be recognised where professional capacity is very limited.

It must also be recognised that incorporating groundwater into IWRM plans has encountered some impediments given that:

- Many senior water-resource managers who are putting IWRM principles into practice, have a limited grasp of groundwater scales, dynamics and vulnerabilities.
- Most hydrogeologists, who understand groundwater dynamics, ‘up-gradient linkages’ and ‘down-gradient dependencies’, tend not to focus on the socioeconomic drivers of resource use and pollution load nor on the institutional framework for addressing land-use and water management.
- There is a question mark in some peoples mind as to whether IWRM can reach sufficiently down the social scale, recognising that in numerous developing nations, and some industrialised countries, much groundwater-resource abstraction is concentrated in the ‘informal sector’ (as a result of very large numbers of small-scale users that in reality are at best unregulated or at worst illegal).

In the application of IWRM to groundwater, certain misconceptions are often encountered and need to be addressed:

- Resource deficits can be met by supply-side measures alone: when in reality measures to control demand will always be necessary because aquifer-recharge enhancement is likely otherwise to stimulate increased groundwater abstraction
- Groundwater-resource replenishment is always assured: whereas, in reality, large abstractions from weakly recharged or non-renewable aquifers are quite widely occurring without corresponding high-level resource planning, enhanced management and major socioeconomic returns (Foster and Loucks 2006)

However, not withstanding these impediments and misconceptions, IWRM reforms remain the key to achieving balanced and sustainable water-resource allocations—and as such their implementation deserves political and technical reinforcement.

A pragmatic framework for integrated action

When trying to promote groundwater-resource sustainability, experience demonstrates there is no simple blueprint for action due to intrinsic variability of:

- The hydrogeologic setting of the resource, which tends both to define the nature and scale of the problem and to constrain the solution
- The socioeconomic context of resource utilisation: it being different to manage a few large abstractions from controlling a very large number of small users.

Thus, an interdisciplinary pragmatic framework for the definition of groundwater-management plans (Garduno and Foster 2010) has been devised (Fig. 1), using local hydrogeological realities and resource-use dynamics to identify an appropriate mix of:

- Local institutional arrangements: with an empowered government agency facilitating community awareness and participation, and, where appropriate, self-regulation
- Finance and implementation of technical demand-side and supply-side measures
- Macro-policy modifications: to constrain groundwater demand
- Enhanced resource administration and targeted use regulation

Groundwater-quality protection should follow a comparable strategy comprising the systematic assessment of groundwater-pollution hazard (based on mapping of aquifer-pollution vulnerability and subsurface contaminant loads) and definition of a ‘groundwater protection plan’ (to reduce this hazard in

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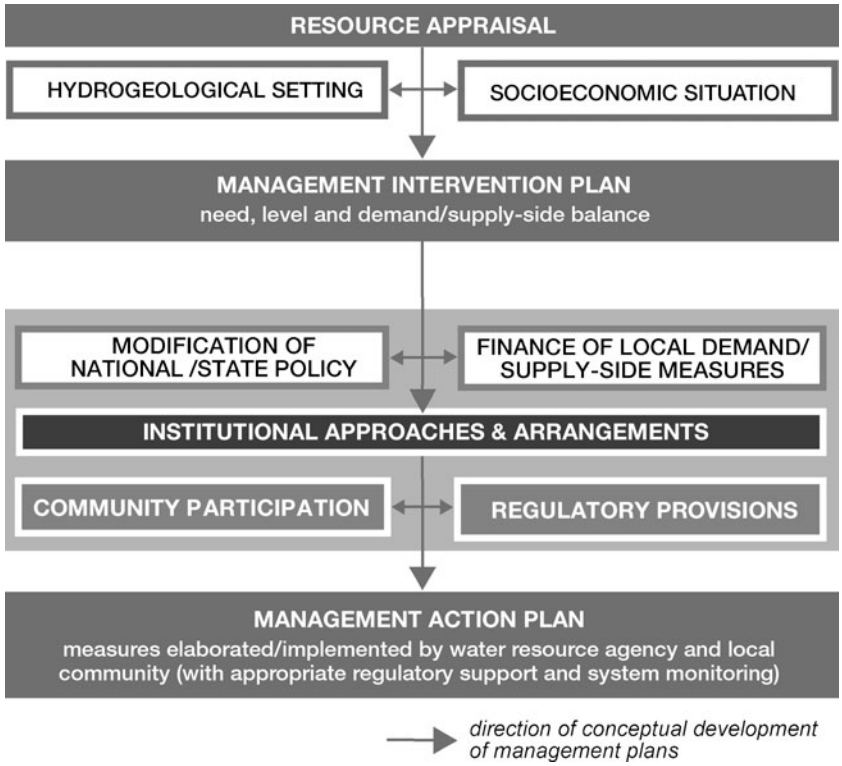

Fig. 1 The Groundwater Management Advisory Team (GW-MATE) pragmatic framework for elaboration of groundwater-resource management plans in highly stressed aquifers

priority areas through differential land-use management and, where necessary, restrictions on the sale and/or use of certain chemicals, especially those hazardous to groundwaters).

Progress will require a balance between ‘bottom-up’ and ‘top-down’ action, with political support for prioritised, sequenced, practical and patient interventions. It is believed that application of this pragmatic framework (Fig. 1) will ensure an appropriate level of policy interdisciplinarity and cross-sector integration in groundwater management, and transform what to some is a fuzzy concept into practical reality.

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