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India – Tamil Nadu: Resolving the Conflict Over Rural Groundwater Use Between Drinking Water & Irrigation Supply

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In rural water-supply provision, resource availability has not received the attention it deserves. Illusions of abundance have clouded the reality that renewable freshwater is an increasingly scarce commodity, especially in more arid and densely-populated areas. Some 73% of Tamil Nadu State is underlain by a low-storage variably-weathered crystalline basement aquifer, which is heavily exploited for dry-season irrigated agriculture and the predominant source of rural domestic water supply. In recent years it has also been seriously impacted by drought, making rural groundwater supply provision both more-and-more costly and less-and-less reliable, with new water wells commonly drilled to depths of 100-150 m and sometimes encountering unacceptable quality. A key question is to what extent can carefully-deployed, low-cost, recharge structures be used to enhance groundwater resources and rejuvenate drinking water wells preferentially – and thus provide at least a medium-term solution to the problem. But no matter how merit-worthy, such structures will generally not be sufficient alone to halt the current trend of aquifer depletion without concomitant action on irrigation demand management. This profile summarizes the socially-responsive and technically-pragmatic approach developed by the Tamil Nadu Water & Drainage Board (TWADB) and GW•MATE to this issue, in preparation for the Tamil Nadu Rural Water Supply & Sanitation Program – Groundwater Recharge & Resource Component (valued at US$ 68 million over 6 years), A major water-supply program rooted at the territorial level of districts and villages (panchayats) represents an excellent opportunity to pilot local groundwater management initiatives and mobilize the local community on finding ways in which groundwater supply and demand can be balanced through a combination of enhancing aquifer recharge and constraining consumptive use in agriculture.

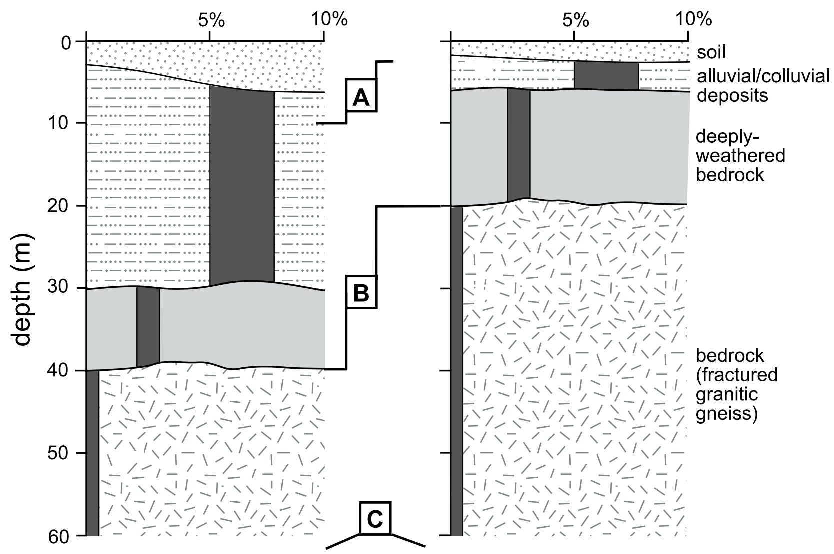
CONTEXT OF GROUNDWATER RESOURCE CONFLICT

Tamil Nadu State covers an area of 130,058 km^2, of which 73% is occupied by variably-weathered crystalline basement rocks, forming an extensive but minor, low-storage, aquifer (Figure 1) – in which groundwater is mainly confined to the weathered mantle, with more localized flow in fractures, joints and lineaments of the underlying bedrock. The weathered basement region has three principal geomorphological zones exhibiting different hydrogeology with implications for groundwater regime and development potential:

- hill front (piedmont) zones with colluvial outwash deposits, and bedrock faulting or lineaments
- extensive upland plains with bedrock (pediment) locally at surface and more normally under a variable depth of in-situ weathering products
- minor alluvial tracts across the latter with some surficial alluvial re-deposition.

The major rivers tend to have eroded through the weathered zone, mainly flowing on beds of exposed bedrock, and today have no significant base flow.

Figure 1: Typical weathered basement aquifer profiles with estimates of available groundwater storage



PROFILE		FAVOURABLE AREA	TYPICAL AREA*
drainable ground-water storage (mm)	A-B	**1200 - 1950**	**275 - 475**
	B-C	**0 - 100**	**0 - 200**

* unfavourable areas have no alluvial/colluvial deposits and thinner weathering zone with total storage equivalent to less than 250mm

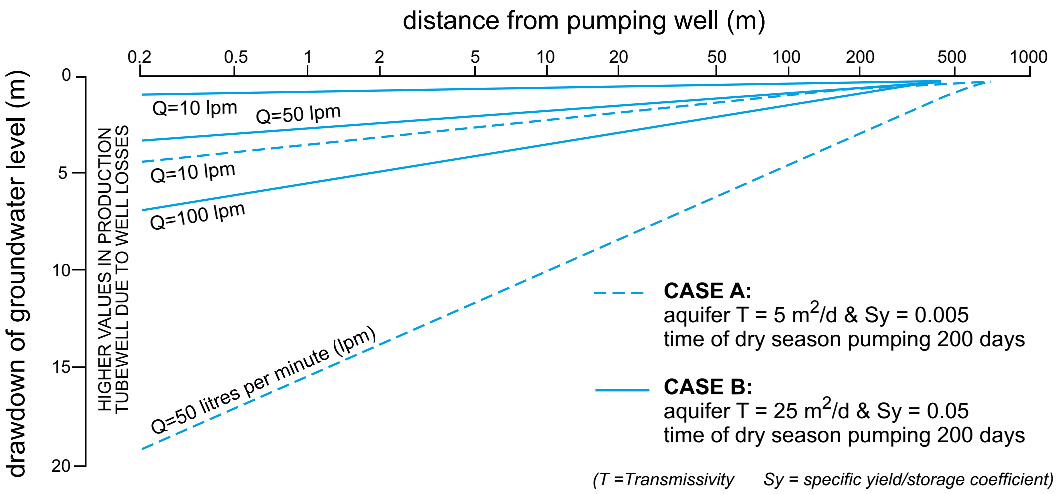
The properties of the weathered crystalline basement aquifer result in:

- well yields severely constrained by low aquifer transmissivity, such that the use of motorized pumps is not feasible at many locations
- radical reduction in well yields (compounded by decreased well pump efficiency and service life) with falling water table, because the most productive aquifer horizons are at shallow depth
- limited aquifer storage in relation to typical irrigation water demands and significant seasonal depletion even in years with average rainfall in some areas
- cones of pumping depression (and also 'groundwater mounds' from recharge structures) generally of limited aerial extension (Figure 2), with significant lateral groundwater flow existing only locally in association with some structural lineaments.

The climatic regime of the interior of Tamil Nadu State is humid tropical – the major rainfall (more than 50% of the average total of 650-850 mm/a) occurring during the North-East Monsoon (October-December), with a subsequent cooler dry season (January-February) followed by an extended 'summer' season in which some rainfall occurs in most months with greatest likelihood during the South-West Monsoon (June-September).

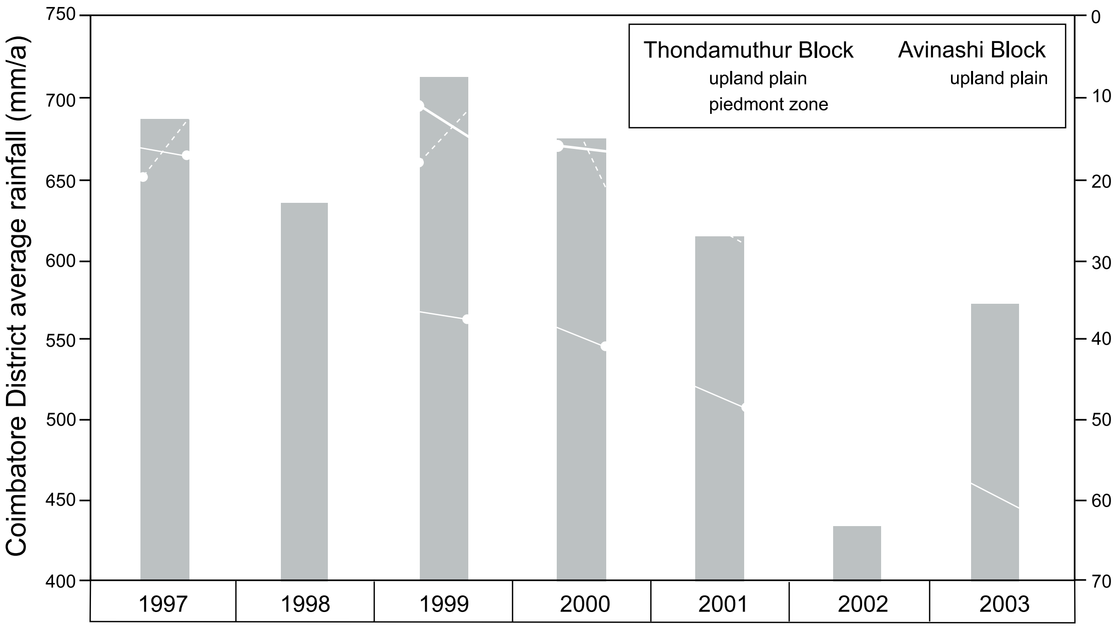
Primary groundwater recharge occurs directly as a result of monsoon rainfall in excess of plant moisture requirements and soil moisture deficits, but is limited by soil infiltration capacity with higher intensity rainfall being rejected as surface runoff. Some indirect primary recharge also occurs under favorable conditions as a result of streambed and irrigation tank infiltration, but overall average rates are not believed to exceed 10% of average total rainfall (less than 100 mm/a). Secondary groundwater recharge also occurs as a result of infiltration returns from irrigated agriculture and urban water mains leakage/sanitation percolation, but this does not represent 'new water' to the groundwater system unless the original water supply was derived from a surface water source.

Figure 2: Estimates of the dimension of cones of water-level drawdown around production wells based on a typical range of aquifer properties for weathered basement rocks



Tamil Nadu has been suffering extended drought since 2001, which is well illustrated by the decline in average rainfall in Coimbatore District, and the corresponding groundwater level data for selected monitoring wells in different geomorphological settings (Figure 3). Routine surveys of groundwater levels are undertaken twice per year – a post-monsoon measurement (usually in January), as an indicator of aquifer recuperation from monsoon recharge and antecedent abstraction, and a pre-monsoon measurement (usually in May), as an indicator of the effects of dry-season abstraction.

Figure 3: Rainfall and groundwater levels for Coimbatore District during 1997-2003



The state-level statistics of groundwater exploitation are believed to be as follows:

- 253,000 shallow tube wells equipped with hand pumps for domestic water supply
- 56,000 (mainly deeper) tube wells equipped by power pumps, some of which provide domestic water, but are mainly privately-owned and used for agricultural irrigation and industrial production
- 680,000 dug wells (many of considerable depth) which are used for agricultural purposes, but 50% of which are currently dry and 10% of which have been formally abandoned.

The state population is 62.1 million (2001 census) with 34.9 million living in rural areas. The growth of rural population and major increase in dry-season irrigated agriculture has led to over-exploitation of groundwater resources across wide areas. The typical double-cropping pattern is a monsoon-season (karif) rice paddy crop followed by a dry-season (rabi) crop of pulses, groundnuts, vegetables and rice on a proportion of the land, with sugarcane or bananas as more localized perennial crops. Although 80% of urban and rural drinking water needs (51.400 Mm^3/yr with a 2020 estimate of 76,700 Mm^3/yr) are met from groundwater – this represents only 5% of total abstraction, with irrigation pumping accounting for 85% and other sectors 10%.

In 2003 the Government of India – Groundwater Resource Estimation Committee categorized the 385 'administrative blocks' of Tamil Nadu State as follows:

- 138 over-exploited – extraction more than 100% of estimated recharge
- 37 critical – extraction 90-100% of estimated recharge
- 105 semi-critical -- extraction 70-90% of estimated recharge
- 97 safe – extraction less than 70% of estimated recharge.

But in the case of Tamil Nadu, assessment accuracy is limited by lack of district-level data and dependency on block-level information, together with uncertainty over cultivated area and crop proportions between monsoon and non-monsoon periods, and within and outside tank irrigation commands. The methodology is dependent on various empirical assumptions and gives only a general indication of groundwater resource status, although the 'overexploited areas' are usually corroborated by observed long-term groundwater level trends.

Groundwater levels range quite widely across the state with the detail of the hydrogeological setting, but current average maxima are around 25m and seasonal fluctuation averages 9m. Long-term analysis indicates recent declines of more than 5 m/year in many districts. Aquifer depletion has serious consequences for all groundwater users including falling well yields, drying-up of most traditional large-diameter irrigation wells early in the dry season and an 'explosion' of deep water well drilling (to depths of 100-200 m) for agricultural irrigation, industrial water supply and even village water wells. Even in 'safe category blocks', the pace of growth in groundwater exploitation over the last 20 years has resulted in a large number of dugwells and borewells failing in the dry season.

The current trend of 'chasing' the declining water table in search of deeper water-bearing zones entails a high risk of drilling dry or very low-yielding wells in the crystalline basement (except close to major fault zones associated with up-lifted hill blocks). An alternative for village water supply might be the acquisition of local higher-yielding irrigation wells – but the demands of dry-season crops under severe water stress and the pressure on irrigators to secure dry-season production to pay off bank loans secured to invest in deep water well construction tends to work against this option. On reflection it is difficult to identify 'winners' amongst the enormous hardware investment chasing a limited groundwater resource – except perhaps water well drilling companies and equipment manufacturers.

Elevated fluoride (F) concentrations (above the WHO drinking water guideline of 1.5 mg/l) are present in groundwater across significant areas of the weathered basement. While localized occurrences of up to 8.0 mg F/l occur, concentrations do not generally exceed 3.0 F mg/l and quite widely remain below troublesome level, and it would appear that:

- fluoride builds up in groundwater from dissolution of F-bearing minerals in pockets of deeply-weathered granitic gneisses not effectively flushed by natural groundwater flow, which is then encountered and mobilized by water wells
- concentrations reduce following 'monsoon recharge', but increase in extended drought and under heavy exploitation when water wells draw more on deeper aquifer layers.

Many larger villages and small towns are becoming more densely-populated and rapidly industrializing, in part to provide alternative livelihoods to an agricultural sector suffering from water scarcity. There is evidence of groundwater quality deterioration as a result of infiltration of wastewater from small-scale textile factories and tanneries, discharged to the land or to unlined drains causing elevated groundwater salinity (mainly $NaCl$ and $MgSO_4$) and the possibility of trace toxic contaminants, especially during drought when there is little dilution by 'monsoon recharge'.

In such areas decisions (based on local circumstance) will have to be made on the relative technical and economic feasibility of removing the industrial effluent from the area in lined channels or pipes, and discharging at acceptable quality to a surface watercourse or relocating village water-supply wells up-gradient with reticulation of water supply from higher yielding wells to village standpoints.

There is also occurrence of elevated NO_3 concentrations during the dry season at numerous locations (more than 20% of drinking water wells in Coimbatore and Dharmapuri Districts currently exceed 50 mg/l and a substantial proportion peak over 100 mg/l). In many cases the chemical signature of the pollution is quite distinct from that associated with industrial effluents and appears more likely to be associated with the infiltration or leaching of human and animal excreta. More attention needs to be given to the lateral and vertical spacing between latrine soakaways and water well intakes, and to undertaking sanitary surveys and pollution risk assessment for entire village areas.

The need for provision of improved water supply is especially evident in the current drought, when substantial numbers of the rural population are down to 10 lpc/d or less, with increased water-fetching distances and inadequate quality of supply an added complication in some locations. Community-acceptable solutions for water supply are identified through iteration with local social leaders on possible designs and associated costs – with the aim of providing an acceptable quality supply of at least 30 (and preferably 55) lpc/d at a distance of less than 1.6 km. In general terms replacement sources are preferred to treatment plants (because of the operational implications of the latter), but reticulation or tankering of water is considered in exceptional situations. The financing approach of TWADB is to fund 90% of the capital cost of improved water-supply provision, if the village (panchayat) agrees to pay 10%, plus 100% of subsequent system operation and maintenance costs.

INSTITUTIONAL POSITION ON GROUNDWATER RESOURCES

In essence the framework comprises the following rather disparate elements:

Constitution of India: when this was promulgated in 1949 the well-drilling boom had not yet started, groundwater over-exploitation problems were not anticipated and thus no provisions for groundwater, drinking-water priority or civil-society participation in water management were included – but despite this legal opinion is that 'much can be done to promote a constructive relationship between state and civil society within the ambit of existing constitutional entries'.

'Common Law': has been assumed to prevail in the absence of specific provisions and implies an 'asymmetry' between groundwater and surface water – since in the case of groundwater (unlike water flowing in channels for which only 'use rights' are recognized) the ownership of land carries with it the ownership of groundwater, subject to 'regulation and control by the state'.

1st National Water Policy (NWP) of 1987 was approved by a ministerial group chaired by the Union Minister of Water Resources, with seven Chief State Ministers and four Federal Ministers. For groundwater it laid down the principle that extraction should not exceed recharge and talked about conjunctive use of surface water and groundwater – but neither has been translated into action. An amended NWP was developed in 2002, but this does not explicitly deal with groundwater – although it does address water issues in the context of the environment, ecology, sustainability, equity, social justice, conservation, participation of stakeholders and role of women.

Tamil Nadu Groundwater Act was adopted in 2003, but full implementation has not yet begun and some farmers have shown disagreement, in part as a result of lack of public discussion before the bill was enacted. It has provision for the establishment of a State Groundwater Authority and the declaration of critical areas in which no deepening of existing wells or drilling of new wells should be permitted, but groundwater abstraction rights as such are not contemplated.

Taking all this into account, it appears best to treat groundwater as a 'common pool resource' and place it under community management (bearing in mind existing customary law), delineating priority groundwater bodies, forming user groups, formulating rules for use and conservation and creating conflict-resolution mechanisms, under a cautious pilot approach and with support at state level.

The tiered structure of federal and state government offers both considerable opportunity and certain challenges for the practical implementation of groundwater management measures:

State Level: in the local government structure the 30 District Controllers could play the role of enforcing regulations agreed by village consensus amongst groundwater users, and at village level the 12,619 Panchayat Presidents could maintain well inventories and groundwater-user profiles and play a prominent role in public awareness on groundwater resources and in reaching a groundwater-user consensus on required aquifer management measures.

Federal Level: the Central Ground Water Board (CGWB) of the Ministry of Water Resources was set up in 1950 from the merger of the Exploratory Tube wells Organization and the Geological Survey of India–Groundwater Division, and much more recently in 1997 the Ministry of Environment & Forests established a Central Groundwater Authority (CGWA), after the Supreme Court ruled that the depletion of groundwater resources was an 'environmental concern of public interest' but it has not yet become fully operational as a regulatory body.

Consideration of the present influence of the electrical energy situation on groundwater use, and scope for reform is an important issue with the following background:

- to mobilize the 'green revolution' in Indian agriculture and simplify the collection of electricity charges, rural electricity begun in 1985 to be provided at a nominal flat-rate charge (per HP/year) for water well pumps rated at more than 5 HP and free of charge for lower-rated pumps – neither the influence of subsidized energy on the trend towards aquifer depletion nor the serious effects of aquifer depletion on electricity consumption and associated generating problems were anticipated
- recently provision of subsidized energy to farmers with water well pumps of 5 HP capacity or larger was suspended, but there is information to suggest that this measure has been partly negated by family sub-division of land holdings and installation of various boreholes each with a pump of less than 5 HP capacity
- there is scope for District Controllers not to allow new rural electricity-supply connections so as to restrict the number and location of agricultural wells – although the current constraints on obtaining a power connection may also be socially divisive through keeping some poorer farmers out of dry-season irrigated cultivation

- more generally there may be scope to control the number of hours of electricity provision as a surrogate for regulating groundwater extraction for irrigated agriculture – at present in rural Tamil Nadu the supply is generally available for at least 6 hours/day
- given the current cost and availability of electrical energy, diesel-engine water well pumps are not an attractive investment to farmers, except in a few isolated areas outside grid coverage.

TECHNIQUES FOR GROUNDWATER RECHARGE ENHANCEMENT

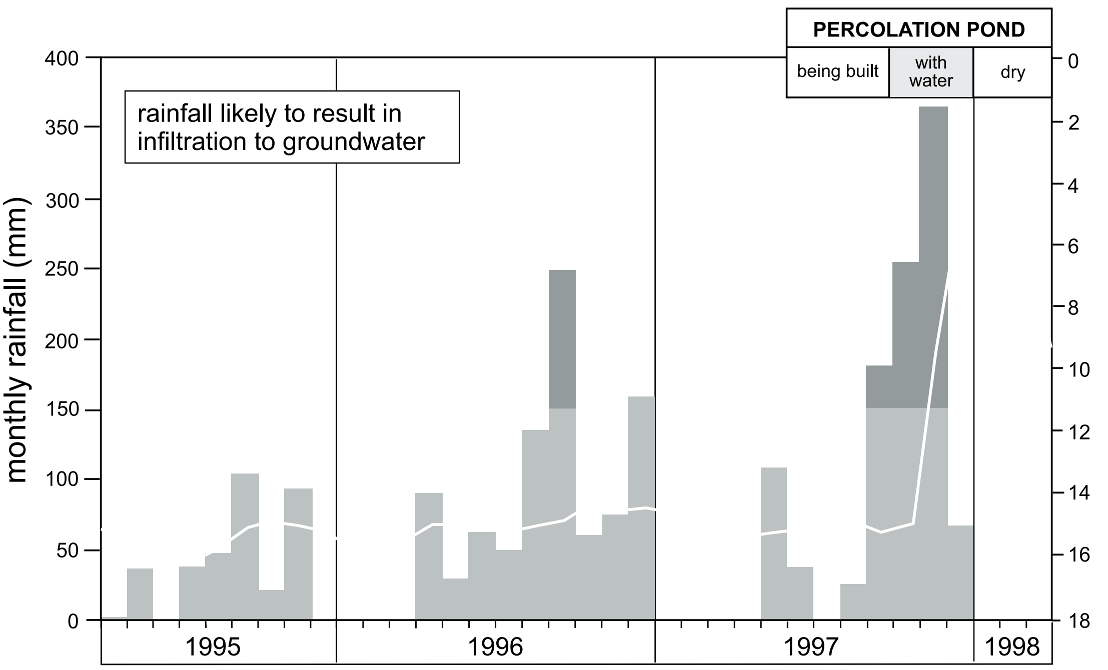
The low-cost groundwater recharge enhancement structures that can be employed include:

- in-channel methods – the emplacement of check dams on ephemeral surface watercourses to enhance streambed infiltration
- impoundment methods – the construction of earth-bunded percolation ponds or the renovation of village ponds, for the retention and infiltration of surface water run-off
- injection methods – the excavation of recharge pits or shafts (including disused agricultural water wells) to overcome the presence of impermeable surface strata, with channeling or pumping of surface water into them.

In addition there has already been a major statewide effort on roof rainwater harvesting, in part for direct water collection and use, and in part for recharge via domestic and institutional dug wells.

In general terms such efforts are to be welcomed and under suitable conditions recharge enhancement structures have been shown to be effective (Figure 4). This especially where they comprise part of systematic watershed management and act as a focal point for local community action on water conservation. Key considerations for design and operation must include the control of silt accumulation at the infiltration surface and care to prevent the entry of surface water polluted by persistent contaminants.

Figure 4: Evidence of groundwater recharge in the Agrahara Valavanthi micro-watershed (Namakkal District) following construction of percolation pond



It is anticipated that the criteria for site selection, structure design and field management will be further refined on the basis of the accumulating experience being gained through the following on-going TWAD Board recharge enhancement works:

UNICEF-supported experimental research work on 16 structures in 2 fully-monitored research watersheds (in Namakkal & Dindigul Districts) during 1999-2002, which are still under observation

182 operational structures completed under national loan assistance funding and 890 under a recent rural water supply program completed during the period 2001-04, which are the subject of continuing monitoring at groundwater source level, with recharge structure installation (involving a further 923 locations) continuing under these two funding mechanisms in 2004-05.

As cumulative investment grows, it will be important to review critically the effectiveness of recharge structures and how this varies with site selection, structural design and routine maintenance. Such assessments will require research-level monitoring to evaluate:

- the recharge volume achieved over and above that naturally-occurring from monsoon rainfall
- how this incremental recharge varies with size of monsoon, and whether (as would be hoped) the proportion of recharge enhancement is more significant in years of limited monsoonal rainfall
- the unit cost of the recharge water, making reasonable estimates for routine maintenance needs and useful life before major de-silting and/or reconstruction is needed
- the cost effectiveness of recharge enhancement measures, including allowances for the savings on electrical energy for groundwater pumping, avoiding the construction of replacement drinking-water sources, the reduced time spent on domestic water-fetching, and in community health costs.

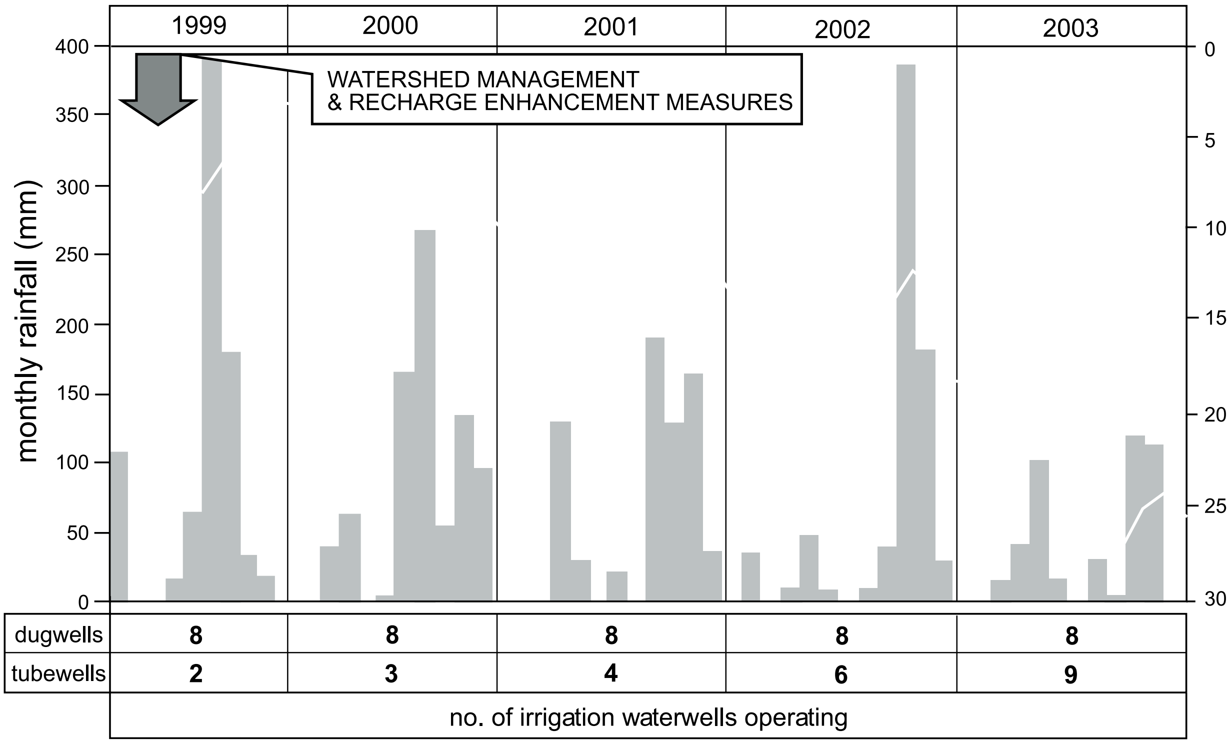
It is important to stress that recharge enhancement structures will only be effective for easing the problems of drinking-water sources if:

- a suitable site for groundwater recharge is located close to the drinking-water source(s) requiring rejuvenation or convenient to the demand foci of the habitation
- community administration (Panchayat Leaders and District Controllers) can assure that new irrigation wells are not permitted in the vicinity (say within 500 m) of the recharge structure – this through their power to refuse new connections to the rural electricity grid.

A further concern in this context is the frequently large number of dormant irrigation wells – unused because of falling groundwater levels but still with electricity connection. There is clear evidence from the Dindigul District research area (Figure 5) that the introduction of recharge enhancement structures led to reinstatement of irrigation wells (thus stimulating dry-season demand) and that falling groundwater levels and difficulties for drinking water sources continued.

No matter how merit-worthy in general terms recharge enhancement measures may be, the question of the extent to which such measures benefit the sustainability of specific rural water supply sources has to be addressed. Moreover, while (under suitable ground conditions) the incremental enhancement of groundwater resources that can be achieved by artificial recharge measures is significant in terms of the demand represented by rural drinking water supply, it will often not be sufficient to meet the much larger actual or potential demand represented by the number of equipped irrigation water wells. Thus for a long-term trend in aquifer depletion to be reversed, a more integrated approach is required which addresses both optimization of recharge enhancement opportunities and complementary demand-side management actions.

Figure 5: Evidence of increased groundwater abstraction for agricultural irrigation following emplacement of recharge enhancement structures in the Mallampuram micro-watershed (Dindigul District)



TOWARDS SUSTAINABLE GROUNDWATER RESOURCE USE

The proposed structure is essentially a pragmatic compromise between the short-term need for recharge enhancement structures to provide additional groundwater resources to rejuvenate existing village groundwater sources and the longer term reality that comprehensive resource administration at the local scale (including demand management for dry-season irrigated agriculture) will be required to achieve long-term groundwater resource and drinking water source sustainability.

Two critical project sub-components in the initial stage are thus:

> **150 Full-Scale Village (Panchayat) Groundwater Supply Pilots**: including the construction of an estimated 763 recharge enhancement structures (at a cost of over US$ 5 million), for rejuvenation of existing drinking-water sources, at a representative selection of villages where recharge enhancement structures appear technically feasible and economically effective, current rural water supply does not meet minimum quantity and quality criteria, and community interest to restrict the operation of irrigation wells in the immediate vicinity of recharge structures and drinking water sources exists.

25 Comprehensive Groundwater Resource Management Pilots: at a subset of above (with an additional investment of about US$ 2 million), where attempts will be made through community action to develop a social consensus for constraining dry-season agricultural irrigation from groundwater, so as to make the investments in recharge enhancement structures a sustainable solution for domestic groundwater supply in the longer run.

It is recognized that it will not be straightforward for village panchayats to define, agree and enforce a set of community rules to moderate dry-season groundwater pumping, and they will need consistent support and encouragement from both the TWADB and the corresponding District Controllers in this process. But while comprehensive management is not achievable overnight, it is widely believed that the current water crisis in Tamil Nadu could be harnessed to foster the first critical steps in resource management, in response to the social demand for relief from extreme domestic water shortage.

Major advances have been achieved during the course of project preparation in terms of raising the profile of groundwater resource sustainability issues and the need for both macro policy level and micro local level action on demand-side management. These included landmark meetings:

- at state level involving TWADB and the Tamil Nadu Agricultural Engineering Department headquarters staff and corresponding representatives from many district offices (5-6 August 2004)
- at village level (Pagalmeda Panchayat-Ellampuram Block-Tiruvallur District), involving numerous stakeholders including various NGOs and the general public (15 August 2004).

Both had very positive results and provided indications that progress could be made in the complex area of groundwater demand management, with possible interventions at the:

- micro-level by the newly-created VP Water-Supply Committees supported where necessary by the corresponding District Controller and policy on rural electrical-energy connections
- macro-level in terms of the policies on electrical-energy, guarantee-prices on food crops, attitudes to self-food supply, and incentives for converting to lower water-use crops.

Control of individual extractions from the 100,000s of irrigation and industrial water wells in Tamil Nadu is unrealistic, thus some other approach capable of constraining overall aquifer extraction based on social consent is required. This might be founded on annual dry season allocations to panchayats from districts according to post-monsoon groundwater levels, coupled with dry-season cropping area and irrigation-well spacing criteria.

Even taking a 'bottom-up approach' to groundwater resource management with stakeholders playing a central role, one has to be aware of the national and state framework in order:

- not to propose local arrangements in flagrant contradiction of the overall framework and that run substantial risk of being cancelled by court decisions on user appeals
- that lessons can be learned which could inform state level and contribute to the formulation of more realistic water policy and regulation.

International experience shows that application of a single groundwater management tool will generally not be enough, and that a finely-tuned balance of stakeholder participation, minimum agreed rules and economic incentives, coupled with substantial efforts on IEC (information-education-communication) tailored to local realities, will be necessary noting the following:

Profiling Groundwater Users: the most recent water well inventory in Tamil Nadu dates from 1999 – updating and complementing it with social information (at least at a pilot level) is a must for the implementation of any groundwater management measures

Institutional Arrangements: it will be necessary to ensure that all groups of relevant stakeholders are properly represented and a district and village-level command must be outlined as soon as possible, together with the required linkages with state government

Economic Incentives: addressing aquifer depletion issues will generally call for reductions in dry-season groundwater extraction, and farmers will require an element of financial and logistical support for the introduction of water-saving technology, crop substitution, modern agronomic practices (aimed at making real water savings while sustaining farmer incomes) and for market facilitation

Minimum Agreed Rules: because of the common-pool nature of groundwater resources it is necessary to put in place a set of minimum management rules, which will have a higher enforcement rate if they are agreed upon with all relevant stakeholders

IEC: based on sound social understanding can contribute substantially to the implementation of groundwater resource management and should embody the following key messages:
- groundwater conservation measures will be essential for community survival
- groundwater resources are limited but sufficient to support livelihoods if the community adopt a participatory demand-management approach
- state groundwater legislation can only be effective if it is implemented by the community themselves and refined from community feedback.

The systematic monitoring of groundwater levels, water well performance and quality, and recharge structure behavior is of prime importance to assess the effectiveness and guide the operation of any scheme of groundwater recharge enhancement. Moreover, soundly monitored operational experience at pilot level is of great value to the successful execution of statewide programs. Prior to construction, monitoring data on surface water flows and groundwater levels greatly aid site selection and structure design and the observation well network at this stage can be of low density over a large area. But after siting and design of feasible recharge structures this network will need to be fortified locally. The objective of the monitoring system should be to evaluate the impact of the recharge structure on the natural groundwater system, in terms of groundwater levels, flow directions and qualities changes – and thereby determine the physical efficiency and cost effectiveness of the recharge enhancement measures.

Publication Arrangements

The GW•MATE Case Profile Collection 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).

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