CONJUNCTIVE USE OF SURFACE AND GROUND WATER IN A WATER-ABUNDANT RIVER BASIN

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Abstract
The Indian State of Uttar Pradesh is located almost entirely on the Indo-Gangetic Plain, a vast alluvial formation to the south of the Himalayas. Despite a population of 175 million on an area of about 20 million km^2, the state is a net exporter of cereals. Agriculture is supported by deep silty-loam soils and two enviable sources of water: snow-fed rivers from the Himalayas and a huge resource of fresh groundwater. Over the past century or more, an extensive irrigation canal system has been constructed, and since the late 1970s, there has been a steady increase in the installation of privately-owned shallow tubewells with diesel pumps, now numbering 3.5 million. The state faces a growing problem of rising groundwater levels in areas that are well-served by canals, and falling groundwater levels in other areas. There is general agreement that conjunctive use of surface and groundwater is required to maximise crop production and stabilise groundwater levels. The technology is widely available and economically feasible, yet the governance arrangements do not currently support implementation. Several projects under the World Bank funded Water Sector Restructuring Project are directed at addressing these resource management issues, including consultancies for the institutional strengthening and restructuring of the Uttar Pradesh Irrigation Department and the development of a decision support system for management of conjunctive use in the Ghaghra-Gomti basin.

Keywords
Conjunctive use, groundwater, irrigation, governance.

INTRODUCTION

The Indo-Gangetic plain has supported agriculture for thousands of years and is one of the great cereal producing regions of the world. While water resources are abundant in most years, the area experienced serious famines in the 18th and 19th centuries that killed millions. The most recent drought-related food shortage was in the early 1960s. Within the State of Uttar Pradesh, an extensive network of irrigation canals delivering water from the snow-fed Himalayan Rivers across the plain has been constructed over the past century. This system was designed as a protective system to mitigate the effects of drought, but not to fully irrigate all crops in the command areas. In recent years the construction of new canal systems has slowed, and the role of the Irrigation Department in operation and maintenance has grown. This represents a major change for the organisation, both in the skills required and in the measures of performance.

Over the past decade or so the State has experienced a steady increase in the number of privately-owned shallow tubewells, encouraged by government subsidies that favour disadvantaged groups. Almost all the private tubewells use diesel-powered pumps, usually of 5-HP capacity. A water market has developed where small-scale entrepreneurs sell tubewell water to neighbours (Shah 2001, Pant 2004). Government regulation of the tubewell system is currently minimal. A new state Ground Water Act has the potential to restrict further development, but currently the only restriction is for subsidies where a minimum distance between tubewells is specified based on regional hydrogeological assessment.

There is a sharp contrast between the canal supply system, which is large scale, highly engineered and operated by one of the oldest and largest irrigation bureaucracies in the world and the tubewell supply system which is new, small-scale, highly responsive to farmers and almost anarchic. The canal irrigation system still follows legislation from the 19th century, relies heavily on government subsidies to operate and has few formal mechanisms to assist Departmental staff to meet farmers' water needs, or to assess the success of the department in meeting those needs.

The state faces a growing problem of rising groundwater levels in areas that are well-served by canals, and falling groundwater levels in other areas. There is general agreement that conjunctive use of surface and groundwater is required to maximise crop production and stabilise groundwater levels. The challenge is to operate the two systems in a way that is economically, socially and environmentally sustainable. This paper discusses the governance issues to be dealt with by two projects assisted by the World Bank that aim to address the issue of conjunctive use. The projects will introduce knowledge-based management processes as a catalyst to the transformation of the Irrigation Department.

Water Resources of Uttar Pradesh

The State of Uttar Pradesh is located almost entirely on the Indo-Gangetic Plain. Studies (GOI 1996:3) indicate an enormous fresh groundwater reservoir down to 600 m or more below land surface, with recharge averaging 500 to 750 mm per year. An average of about 100 mm recharge is estimated to come from the canal irrigation and surface irrigation reflows (UP-GWD 1996a). There are 35,000 deep tubewells in public ownership. These are designed to irrigate up to 100 ha each, but thehere are over 3.5 million private shallow tube wells (UP-MID 2004), typically 100 mm diameter and 30 m deep, irrigating an average of 3.9 ha; yields are commonly 7-10 L/s per tubewell.

In Uttar Pradesh, average annual rainfall varies from around 800 mm in the south west near Agra to over 1400 mm in the north east. The Jaunpur irrigation area, in the east of the state, shows the typical pattern of rainfall. The average monsoon (June to September) rainfall is 876 mm, 89% of the annual average; however, in 10% of years the monsoon rainfall is below 580 mm. Even in years with normal rainfall there may be extended periods without significant rain.

In large areas of the State it is possible to grow rice during the monsoon without irrigation, except in years when the monsoon "fails". The canal system has been designed as "protective irrigation" to ensure enough crop can be produced to prevent famine when the monsoon fails. It is not designed to provide full irrigation over the complete command area. During the post-monsoon period, October to April, wheat is the dominant crop. While the residual soil moisture from the monsoon assists crop growth in the early stages, irrigation is required to achieve good yields in most years. As an example, in the Jaunpur irrigation area (around 0.5 million ha) the canal system is planned to provide an average 420 mm irrigation over the total area for the monsoon crop. Only 50-60% can be delivered at present because of canal siltation and other constraints. The post-monsoon crop is planned to receive 240 mm, although this cannot be delivered in some years due to inadequate river flows during this season.

The canal systems are supplied predominantly by diversion from major rivers as they exit the Himalayan foothills. These include the Ganges, Yamuna, Sarda and Ghaghra. These rivers are fed by rainfall during the monsoon and by snow melt during the pre-monsoon period (March to May). Flows are lowest during winter months (December to February). Smaller irrigation systems in the south of the state rely on rivers flowing off the Deccan Plateau which receives monsoon rainfall but has no snow melt.

The canal irrigation system was extended and enhanced from the late 1970s to the early 1990s, the most significant being the Sharda Sahayak Feeder Canal. Over the same period there was rapid growth in the installation of shallow tubewells as a result of a poverty-targeted free boring scheme. Under this scheme, shallow tubewells were drilled free of charge by the Minor Irrigation Department for small and marginal farmers, and subsidies were provided for pumps and fittings. This was initially hampered by the complexity of accessing the scheme, and it was not until the mid-1980s, when the government made the private dealer of diesel pumps into the central coordinator for the scheme, that the number of installations began to rapidly increase (Shah

2001:25). The subsidies cannot fully explain the rapid increase over the past two decades as the 2001 census indicates that only 30% of the 3.5 million private tubewells received any government financial assistance (UP-MID 2004). Private savings, often combined with bank loans sourced from the National Bank for Agriculture and Rural Development (NABARD), funded the majority of the shallow tubewells.

Shallow tubewells play an important role in irrigation in the State. The canal irrigation systems based on Himalayan rivers do not incorporate any storage. Even if there were storage, the delivery system has only a fraction of the capacity required to meet peak irrigation demands. Shallow groundwater is a valuable resource which is widely distributed and accessible to individual farmers. It can be accessed as required by farmers. In many locations canal irrigation serves to supplement groundwater for irrigating crops, as well as playing a role in groundwater recharge.

The characteristics of the shallow tubewell system tend to encourage good management. A cost-efficient way to utilise the aquifer is with a network of shallow tubewells about 30 m deep at 200 m centres. With this spacing, water needs to be transferred no more than 100 m from the pump to the crop allowing fabric hoses to be used. The pumping rate is such that the drawdown in the tubewell is limited to a few metres so that energy usage is minimised. Also, no large or specialised drilling or lifting rigs are required to bore the well or maintain the pumps/motors. The pump and motor is located above-ground for groundwater depths to 5-6 m, or the pump is placed in a dug well and belt driven from an above-ground motor for groundwater depths to 10-12 m.

The preference for diesel pumps over electric is probably linked to difficulties in getting an electrical connection and the unreliability of the power supply in most rural regions of the State. While the use of diesel as an energy source has some drawbacks, generation of electric power using small diesel generator sets is common within the state to supplement mains power. The use of electric pumps would exacerbate the electric power situation and trigger the use of more diesel generators. The power shortage is unlikely to be resolved for several decades, so the use of diesel pumps may in fact be an economically efficient response to this situation. The alternative would be investment in large generators and a very extensive transmission system that would be used relatively infrequently.

Institutional Setting

The Uttar Pradesh Irrigation Department (UPID) has been the premier water sector organisation in the State for over a century. It operates on the basis of the Northern India Canal and Drainage Act No. 8 of 1873 (Canal Act) and its UP-specific amendments, and of the Irrigation Manual of Orders (IMO), which is a collection of Government Orders (GO) adopted and updated from time to time. The Canal Act, reflecting the period of its genesis, contains provisions covering the broad range of matters relating to state-wide development and distribution of surface water, including matters of jurisdiction and pricing. Other major legislation having a bearing on UPID operations includes the UP Minor Irrigation Works Act No. 1 of 1920, the State Tubewells Act, 1936 (as subsequently amended), and the UP Panchayat Raj Act No. 26 of 1947.

In regard to groundwater: the UP Ground Water Department - formerly the groundwater cell of UPID – is responsible for groundwater monitoring, assessment and forecasting; the Minor Irrigation Department plays a role in the construction of shallow tubewells; and the Central Ground Water Board has modelling and assessment capabilities, develops guidelines and maintains a regional office for groundwater monitoring and related issues.

Water resources management is currently in the hands of a range of institutions, each with variable but still limited relationships with others. In substance, there is modest exchange of data and information, and so little coordinated resource development planning takes place. The new (1999) Uttar Pradesh State Water Policy (SWP) follows India's National Water Policy. The SWP sets objectives for protecting, sharing and managing water resources and entails a progressive coordination of efforts among all institutions presently involved in water resources development and management. It implies the embrace of integrated water resources management (IWRM) principles. The separation of the roles of tariff setter, resource manager and service provider are also implicit. A new agency, the State Water Resources Agency (SWaRA) has been formed to undertake water resources planning, inter-sectoral allocation and guidance for sustainable management of the State's water resources through the use of tools including decision support systems (DSS) for all the river basins, the first for the Ghaghra-Gomti basin. Legislation for control of access to groundwater has recently been passed, and new legislation is being drafted to provide for regulation of water pricing.

Governance model

It is widely acknowledged that multi-faceted governance arrangements are necessary for successful management of smallholder surface water irrigation systems. In managing conjunctive use of surface and ground water, these arrangements become more complex. Conjunctive use of surface and groundwater enhances water availability and provides an opportunity to avoid adverse effects on land and water resources experienced when surface or ground water irrigation is used in isolation, such as waterlogging, salinity and excessive falls in groundwater levels. Management of water supplies could also serve to induce farmers to switch to cropping patterns more consistent with soil characteristics and to balance groundwater draft and recharge. The greater complexity in management arises from the need for coordinated management of the two resources through greater participation and networking of stakeholders at each stage of water allocation, use and management.

Two projects under the UPWSRP have identified the current governance systems and explored possible governance models that better address the complex management issues. It has been suggested (Livingston et al, 2005) that governance models for water supply systems can be categorized as Bureaucracy, Community or Market. All three models currently exist within the irrigation areas of Uttar Pradesh:

- Irrigation bureaucracies are responsible for operating large, complex canal systems and over 35,000 State Tubewells to supply water directly to each Chak (irrigation outlet area, typically 10 ha or 25 farmers).
- A community-based system manages the distribution of canal water from the point of delivery by the irrigation bureaucracy to the farmer.
- Over 3.5 million privately-owned shallow tubewells (30% receiving some government subsidy or funds) operate in a type of groundwater market (Mukherji 2004, UP-MID 2004, Shah 2004).

For various reasons, management of many small canals nominally operated by the irrigation bureaucracy has passed to the community in an *ad hoc* way. The community-based systems vary widely in the size of area managed, formality of structure, function, capacity and effectiveness. Efforts are being made to formalize community-based management through formation of Water User Associations. Improvements to the other two governance systems are also being targeted under the projects in order to increase the socio-economic benefits of irrigation. The governance framework required for improved management of conjunctive use is presented in the following table.

Governance Objectives	**Governance Framework**		
	Irrigation Bureaucracy	**Community (Water User Assn)**	**Groundwater Market**
Resource management	Implement SWaRA guidelines for resource management. Monitor and report resource status.	Coordinate conjunctive use; educate farmers. Group pressure and/or formal mechanisms to reduce adverse impacts of individuals.	Individuals responsible for soil and groundwater management on their own land.
Economic benefits	Provide irrigation water to match user needs, preferably defined in an agreement with users.	Ensure efficient distribution of water within the group. Maintain assets under their care.	Individuals assumed to maximize their own economic benefits.
Social welfare	Address equity of access to resources in line with Government policies. Ensure safety of irrigation system assets.	Address equity issues in decision-making and implementation. Mitigate differences in power and wealth, and promote cohesion.	Provide financial capacity to disadvantaged to enable them to participate in the market. Reduce barriers to entry and potential for local monopolies.
Performance Indicators	Delivery of water in accordance with agreed schedules. Monitoring reports on the state of water and land resources in irrigated areas.	Extent of participation in decision-making. Level of community satisfaction with processes and outcomes. Status of irrigation system assets.	Price of groundwater. Social profile of tubewell owners, especially those accessing subsidies. Status of groundwater resource (waterlogging/depletion).

These three governance systems are likely to be retained and strengthened. Two other governance models which eliminate the "community" as the middleman between the bureaucracy and the market have also been considered but are not favoured:

- The current practice in Uttar Pradesh where UPID, the irrigation bureaucracy, is responsible for providing irrigation directly to each *Chak*.
- Take-over of a canal system by a private sector organization who either sells water to farmers or issues water to farmers who function as "out growers" of an industrial crop. This would establish a "market" in canal water as well as in groundwater.

Hurdles to improved management of conjunctive use

Each of the three governance systems needs to perform effectively to achieve the objectives of IWRM. There is also a need for coordination of the three systems, a role that should be played by the State Water Resources Agency (SWaRA). Key characteristics of the main stakeholders in the governance model are described below to enable the impediments to improved management for each system to be determined:

The ***"Irrigation bureaucracy"*** in Uttar Pradesh has been conditioned to give precedence to planning, design and construction over efficient canal operation and sustainable asset management. In fact, data on the latter are not generally available. Changes to the relationship between the bureaucracy and water users may be seen as a threat to the position and power of some individuals, although few at the interface between bureaucracy and farmers are comfortable with current arrangements.

The "***Community***" in the governance model comprises the water user communities (i.e., farmer groups) under irrigation supply outlets[1]. Although many are unhappy with the level of service currently provided by the bureaucracy, they may be reluctant to take up responsibilities for system management, operation and maintenance without adequate technical support and funding. In fact, the current Government Order for the establishment of outlet committees under the UPWSRP provides for the gradual transfer of O&M responsibility for the system to these committees.

The "***Market***" in the model is made up of the roughly 3.5 million farmer-entrepreneurs who utilized the package of opportunities afforded by the evenly dispersed nature of the shallow aquifer, and government subsidies and bank loans to install tubewells and pumps to irrigate their crops and sell water to their neighbours[2]. (Shah 2001).

The hurdles to improved management of conjunctive use for each key stakeholder are:

Type of Hurdle	**Stakeholder constraints**		
	Irrigation Bureaucracy	**Community (Water User Group)**	**Market**
Legislative	Currently based on the British period Act of 1873. (The State Water Policy has no legislative backing.)	Current legislation too generic.	Groundwater Act, 2005 can restrict usage and may inhibit development of the market in water abundant areas.
Organisational	UPID not structured to manage conjunctive use and has no effective performance indicators. SWaRA is in its infancy. Other organizations have fragmented rules.	Unfamiliar, risky and unsure obligations arising from becoming a player. May cut across existing local government boundaries and political alliances.	No formal organisation is required, so hurdles are few.
Capacity	Little capacity for resource management. Unfamiliar with modern technologies of data collection, sharing and reporting.	Limited educational, technical and financial capacity. May not have the skills or legal powers to resolve conflicts.	Financial capacity. Awareness of good land and water management principles.
Socio-political	Resistance to change. Strong links with political power structures. "Protective irrigation" mindset.	Disparity in power and wealth among members. Long history of distrust and exclusion between some social groups.	Government subsidies favouring particular groups. Political power of farmers may inhibit good resource management.

Pathways to a Governance Model

There are several consultancies under the Uttar Pradesh Water Sector Restructuring Project. This paper reflects two consultancies being undertaken by SMEC that aim to facilitate moves to improve governance in the following ways:

[1] The introduction of a community level of governance aligns with the 73rd amendment of the Indian Constitution promoting decentralization of services to the Panchayati level.

[2] It is only in areas with decreasing water table - mainly experienced at present in Western UP - that farmers may eventually be forced to come together to invest in deeper tubewells. However, for simplicity, the dominant section of tubewell irrigators – over 3.5 million across the State as against some 35,000 deep tubewells – are here regarded as the "Market".

- The Decision Support System project aims to provide the databases and models needed to plan and manage water resources in the Ghaghra-Gomti Basin (nearly half the state) in an integrated way, and demonstrate their use by developing Basin Plans; and
- The project on Institutional Strengthening and Restructuring of UPID aims to assist the department to meet its obligations in the new governance framework by clarifying its role, improving its structure and strengthening its capacity to interact with SWaRA as a regulator and with Water User Associations as clients.

These consultancies are current and their effectiveness in overcoming hurdles to improved management is not yet clear. What has become clear is that changes of this nature require drivers as well as facilitating mechanisms. Drivers often include State fiscal constraints, political pressure from client groups, or pressures for change from within organizations. While all these exist in Uttar Pradesh, it is not yet clear if they are sufficiently powerful to overcome the inertia of the existing bureaucracies and political organizations.

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