Accounting for Changes in Water Use and the Need for Institutional Adaptation

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Abstract

A key determinant of high performing water resource systems is an effective institutional arrangement. An essential research question is what is an effective institutional arrangement? We argue that there is no single best institutional model, as institutional requirements vary depending on the phase of development of the basin. Based on water accounting studies we observe that water use patterns can be used to identify stages of river basin development. The hypothesis presented in this paper is that depending on the phase of development, institutions will be concerned with different tasks. Thus an important feature of a well-functioning set of water management institutions is the ability to adapt to changes. We use a water accounting methodology to illustrate the concept of phases of development in river basins. We argue that to meet increases in demand over time, institutions must change their focus from development of infrastructure, to better utilising and conserving water resources, then to improving allocation and regulation of water resources. Institutions must be dynamic entities that change with changing phases of development of the basin. At their inception, serve a single purpose. Then as the basin develops, they either expand their number of functions, or other institutions evolve to fulfil management requirements. These concepts are illustrated in two cases derived from Nepal and China.

1. Preface

Imagine a river basin a long time ago... Before the arrival of humans, the basin's renewable resources could be measured at a point in the river nearby the sea. Now imagine a progression of events in the history of the development of the river basin. At first human demands on the water resource were modest. Water was used for crops, fishing, washing and navigation. With increasing population, there was more demand for food, and river diversion structures were built on tributary streams. Communities built up an agricultural basis for their livelihoods.

Then, as years passed by, many more people settled in the area placing significantly greater demands on water resources, and communities constructed diversion structures along the main river. The area was used to produce food for the entire country, so it was thought wise to construct a dam and reservoir to store and regulate flows. Initially, some farmers benefited, while water scarcity remained a reality for other less fortunate people in spite of plentiful reservoir supplies. Significant water re-entered the river as drainage return flows, and navigation remained possible. Yet prosperous farmers needed more water to produce more food for the nation, so serious efforts were placed in improving management and serving all users. Return flows dwindled, and navigation was no longer possible.

To further expand irrigated agriculture and to meet urban demands, individuals installed pumps to extract water from aquifers and drains. Conflicts developed as upstream users infringed on the traditional rights of downstream users. Pollution became a concern as urban and industrial effluents increased, and little water remained to dilute flows. Wetlands near the coast dried up. Poor people were left struggling to get sufficient drinking water. Alarmed, communities decided to take action...

2. Introduction

Over the last 50 years, changes in the way humans use water have been enormous. Major driving factors have been a growing population, economic development, improved living standards, and increasing demands. Irrigated agriculture has played a significant role in changing the face of water resource utilisation as dam, diversion, delivery and drainage structures have been developed to store and distribute water for irrigation and to drain out surplus supplies. With more development, we find ourselves in a situation where we have widely different and competing interests in our water resources.

Our working hypothesis is that changing patterns of water use require adaptive institutions for sustainable, equitable, and productive management of basin wide resource. There is no one set of institutional arrangements that is capable to adequately manage the present situation, then meet future needs. An important feature of institutions is the mechanisms they employ to adapt to change.

In order to understand present uses of water, past trends, and future projections, it is essential to understand the physical resource base. Here we present basic concepts of water accounting as a means of providing this understanding. We use water accounting to develop and present various phases of water resource development, and problems that are faced during the various phases. We illustrate these concepts by examples from Nepal and China.

3. Accounting for Water Use

How much water is available for use within basins or sub-basins? Who are the major users of the water resource? How much do they use? Is there scope for water savings, or scope for more development of water resources? These are the types of questions that can be addressed through the IWMI water accounting framework (Molden and Sakthivadivel, 1998).

Water balance and water accounting. Water accounting relies on water balance studies. We define a domain bounded in space and by time. For example, we may include a portion of a basin over a year's time, bounded spatially so that runoff is captured by the sub-basin, and vertically to include the bottom of the aquifer up to the top of the vegetation canopy. We perform a water balance to quantify water flows across the boundaries including rain, evaporation, surface and subsurface inflows and outflows. Changes in storage internal to the water balance domain, such as changes in reservoir levels or groundwater levels must be considered. Essentially, water accounting divides hydrological variables of discharge, rain and evaporation into water accounting categories (Box 1).

Diversions, depletions, and recycling: Water is diverted to various uses. Water is depleted when it is rendered unavailable for further downstream use—either through evaporation or by directing the water to sinks. Since not all water diverted to a use is depleted, some remains within the basin and is available for further use. Water recycling or reuse is prevalent in water resource systems. City effluents discharged back into river systems are often used again downstream. It is common to underestimate how much reuse exists in river systems, especially in those that are highly stressed.

Accounting for Precipitation: In many analyses of water resources, only the "developed" water supply is considered—supply we tap from rivers by diversion structures. In IWMI's water accounting framework, rain is considered as a supply.

Water commitments. All uses of water in a basin could be captured if the boundaries of a basin were defined to extend to an ideal salt-freshwater interface. Most often it is practical and useful to consider only part of a basin, but when we do this we have to make sure and define commitments of water to downstream uses to meet ecological or other human requirements downstream.

Open and Closed Basins. When all available water has been allocated to various uses we consider the basin to be closed. When there is water remaining in the basin to develop and allocate, we say the basin is open. In many basins, there is ample water during part of a year, and at other parts it is dry. We consider the basin to be seasonally closed.

4. Phases of water resources development

Phases of river basin development are defined and illustrated (Figure 1) using the water accounting methodology, building on work presented by Keller et al, 1998. The rainfall onto a basin or sub-basin plus any trans-basin diversions represents the gross inflow into the basin. Even if all feasible structures were built, in many cases it is not possible to tap the entire amount of gross inflow. In addition, some water may be committed to downstream environmental uses. The amount of water potentially available for depletive use within the domain is the gross inflow less non-utilisable flows, less any water commitments.

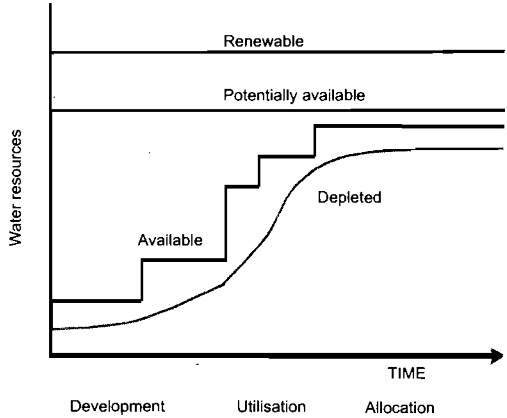
Box 1: Water Accounting Categories

Water Accounting Definitions

- *Gross inflow* is the total amount of water flowing into the water balance domain from precipitation, surface and subsurface sources.
- *Net inflow* is the gross inflow plus any changes in storage.
- *Water depletion* is a use or removal of water from a water basin that renders it unavailable for further use. Water depletion is a key concept for water accounting, as interest focused mostly on the productivity and the derived benefits per unit of water depleted. It is extremely important to distinguish water depletion from water diverted to a service or use as not all water diverted to a use is depleted. Water is depleted by four generic processes:
  - *Evaporation:* water is vaporised from surfaces or transpired by plants.
  - *Flows to sinks:* water flows into a sea, saline groundwater, or other location where it is not readily or economically recovered for reuse.
  - *Pollution:* water quality gets degraded to an extent that it is unfit for certain uses.
  - *Incorporation into a product:* through an industrial, or agricultural process such as bottling water, or incorporation of irrigation water into plant tissues.
- *Process consumption* is that amount of water diverted and depleted to produce a human intended product.
- *Non-process depletion* occurs when water is depleted, but not by the process for which it was intended. Non-process depletion can be either *beneficial*, or *non-beneficial*.
- *Committed water* is that part of outflow from the water balance domain that is committed to other uses such as downstream environmental requirements or downstream water rights.
- *Uncommitted outflow* is water that is not depleted, nor committed and is therefore, available for a use within the domain, but flows out of the basin due to lack of storage or sufficient operational measures. Uncommitted outflow can be classified as *utilisable* or *non-utilisable*. Outflow is utilisable if by improved management of existing facilities it could be consumptively used. Non-utilisable uncommitted outflow exists when the facilities are not sufficient to capture the otherwise utilisable outflow.
- *Available water* is the net inflow minus both the amount of water set aside for committed uses and the non-utilisable uncommitted outflow. It represents the amount of water available for use at the basin, service, or use levels. Available water includes process and non-process depletion, plus utilisable outflows.
- A *closed basin* is one where all available water is depleted. An *open basin* is one where there is still some uncommitted utilisable outflow.
- In a *fully committed basin*, there are no uncommitted outflows. All inflowing water is committed to various uses.

The actual available water at any time in the course of river basin development is a function of the existing infrastructure. With all feasible structures built, the available water is equal to the potentially available water. As time passes, and more infrastructure is built, more water is made available. When a new structure comes on line, there is an increase in the quantum of available water indicated by the stair-step pattern in Figure 1.

Figure 1: Phases of river basin development



As demand increases and more water is made available, more water is depleted. Eventually, the depleted water approaches the available water, and a new structure may be required. In a highly developed basin, depletion approaches the potentially available supplies. In some cases, water depletion even exceeds the potentially available resource—in the long-run, a non-sustainable situation. The potentially available water represents the maximum water that can sustainably be made available, unless more water is brought in through a trans-basin diversion. This is equivalent to a "frontier production function" in the field of economics.

Three important stages can be identified (Figure 1):

1. *Development.* In this phase the amount of naturally occurring water is not a constraint. Rather, expansion in demands drives the need for construction of new infrastructure. Institutions are heavily concerned with building infrastructure for providing supplies. Institutions typically emerge to serve a single function, like construction organisations.

2. *Utilisation.* Significant construction has taken place, and goals are to make the most out of these facilities. Water savings and improved management of water deliveries are important objectives. Managing the supply of water to various uses is a primary concern. Early in this stage, scarcity is not a major problem, and inter-sectoral competition is minimal. Institutions are primarily concerned with sectoral issues such as managing irrigation water, or managing drinking water supplies.

3. *Allocation.* As closure is approached, and depletion approaches the potential available water, there is limited scope for further development. Efforts are placed on increasing the productivity or value of every drop of water. An important means of accomplishing this is to reallocate water from lower to higher valued uses. Managing demand becomes increasingly critical.

Infrastructure construction is limited to those that aid in regulation and control. Little scope remains for "real water savings." Institutions are primarily involved in allocation, conflict resolution, and regulation. Several important management and regulatory functions gain prominence, including inter-sectoral allocation. To effectively carry out these functions, either a single entity emerges (like the Brantas River Basin Organisation in Indonesia), or several inter-linked organisations manage these functions (as in the South Platte River Basin in Colorado). Co-ordination becomes important, involving significant transaction costs.

5. Different Phases – Different Needs

Institutional concerns differ depending on the stage of development. These concerns may exist at all times, but their importance or emphasis may change over time as illustrated in Table 1.

Table 1: Various concerns at different phases of river basin development

Development	Utilisation	Allocation
Construction	Improving O&M services	Shifting to higher value uses
Managing supply distribution	Investing in O&M	Managing demand
Low value of water	Increasing value of water	High value of water
Large structures	Modernisation/rehabilitation	Measurement, regulating
Utilising groundwater	Conjunctive management	Regulating groundwater
Diluting pollution	Emerging pollution/salinity	Cleaning up pollution
Fewer water conflicts	Within-system conflicts	Between-system conflicts
Economic water scarcity	Localised water scarcity	Physical water scarcity
Water data – not so important	System water delivery data important	Basin water accounting data important
Including/excluding poor in development of facilities	Including poor in O&M decision making	Cutting off water to poor

In the development phase, infrastructure construction plays a dominant role. Institutions in the last 50 years have been set up to build major dams, canals, drinking water treatment and wastewater plants. Some agencies are dominated by civil engineers who have the important job of getting high quality work done quickly. Examples include the Mahaveli Development Authority or Pakistan's Water and Power Development Administration. In Nepal's East Rapti Basin, building infrastructure is a major concern of residents, government agencies, and donors.

Constructing canals and managing canal water are two different types of tasks. Infrastructure projects, especially those serving large areas and numerous people are difficult to manage. The task is to provide water service to people with varying levels of expectations and demands subject to variations in climate. Even in ideal situations, this can take a long time to learn how to do. In the early stage, water utilisation may not be so effective. Reliable and equitable service deliveries can be difficult standards to reach. As a consequence, water scarcity for individuals may be a reality because water is poorly managed, or construction quality or design is poor. Responses vary. Some institutions quickly adapt, and improve water delivery service. In other cases, problems persist. In response, people under their own initiative, develop alternative decentralised sources like groundwater, small ponds, or drains.

Eventually through better service, reuse, local initiatives; and with growing demands, the physical supply of water becomes limiting. Water depletion approaches available supplies. There are two typical responses. If there is more water remaining for development (available water < potentially available water), exploitation through more infrastructure development is possible. In the development and early utilisation stages, developing more supplies may be an economically attractive solution compared to more careful management. Later, as the easier locations are exploited, or as concerns about environment increase, infrastructure development gets more costly. Finally, during the allocation phase, the water resource limits. Different kinds of infrastructure development prevail: measurement and regulation structures to control water become more important; rehabilitation and modernisation efforts are common; there may be scope for transbasin diversions.

Over time, the value of water increases. Early, when water is plentiful, water has low value, but when the basin is closed, and demands for a scarce resource intensify the value of water can shoot up dramatically. This leads to a situation where early in the phases of development we are more concerned with developing supply of low valued water; while later in the development process, managing demand prevails. When low valued water is plentiful, conflicts can be mitigated with more supplies. As supplies become limiting, the potential for conflict increases.

Scarcity takes on different characteristics during various phases of development. Initially, scarcity is felt because there is no way to tap water. "Water, water everywhere but not a drop to drink..." is a reality for many people who do not have the technology to access water. In the utilisation phase, the technology may be present, but when it is poorly managed, people feel water scarcity. This is common where head-tail problems exist. Water accounting examples from Sri Lanka show that there is sufficient water, but due to poor management, people still feel scarcity (Molden and Sakthivadivel, 1998). During the allocation phase, the absolute supply of the physical resource limits.

Water scarcity in its various forms during the advancing phases of development has implications for poverty. During the development phase, an important consideration is the identification of beneficiaries. Will infrastructure benefit poor people? Will more powerful people capture benefits? The problems change during the utilisation phase. Even though conveyance structures exist, management may not fit the demands of the poor. Are the voices of disadvantaged people heard when making management decisions? During the allocation phase, water is reallocated amongst sectors and people. When water moves away from agriculture to cities and industries, will the poor and less powerful be able to maintain their right to water; or capture the economic gains when water moves to higher valued uses?

Environmental concerns also change over time. During development stages, huge changes in nature can take place. During the utilisation phase, water use and depletion intensifies, further removing water that has environmental functions. A solution to scarcity is to tap into natural heritage sites for more water, resulting in damaged wetlands. During early phases of development, dilution can be sufficient to solve pollution problems. During allocation phases, dilution is not an option, because there simply is not enough water. Clean-up at the source becomes increasingly critical.

In the allocation phase, a host of potential problems exist: pollution, conflict management, resource overdraft. Managing more and different types of information becomes increasingly important. Information needs at the development phase are different. For design, information on river flows to assess supply, and climate and population to assess demands are necessary. During the utilisation phase, more information is needed on the delivery of water services.

6. Adaptive Institutions

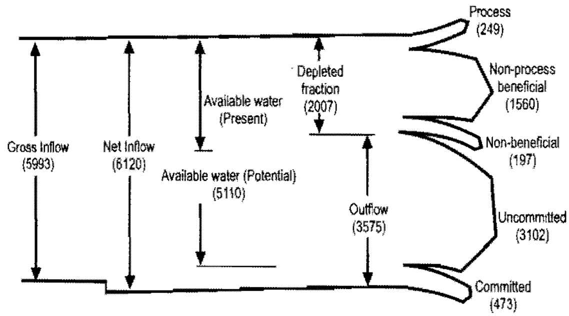
If early in the development phase, we try to design an institutional framework that deals with all these issues—pollution, poverty, allocation, regulation, construction—it is likely that we would fail. At certain phases of development, some of these are not major concerns. It is probably right that there are construction agencies to make sure that there is safe and sound construction. It is probably not right that the same institutional set-up is used to manage service delivery. A different set of rules is required, different skills are required. And those who manage service delivery are probably not appropriate to regulate allocation and pollution of resources when these problems emerge.

The implication is that water resource management institutions must adapt to meet different challenges as patterns of water use change. Common water problems are seen because agencies, at one time competent to carry out tasks, do not change. When evaluating an institution, we may find that they do 7 out of 10 tasks fairly well. The seven may not be so important, while the three missing ones, may be critical. When analysing institutions then, we need to understand the mechanisms that exist to adapt to change. Are there rules to change rules?

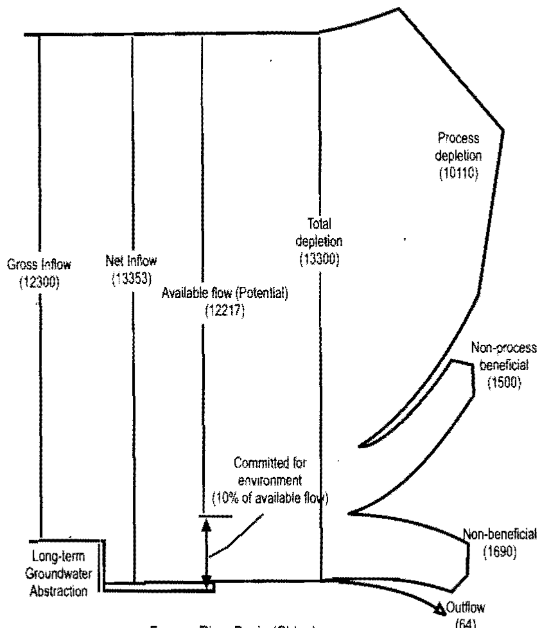
7. Examples

Let us explore two examples—one taken from Nepal, and one from China to illustrate these concepts. The water accounting finger diagrams are given in Figure 2. The Nepalese example illustrates a case of a basin in the development phase, while the Chinese basin is closed, and is clearly in an allocation phase. Basic information on the two basins is presented in Table 2.

Figure 2: Water accounting finger diagrams



East Rapti (Nepal)



Fuyang River Basin (China)

All units $10^6 m^3$

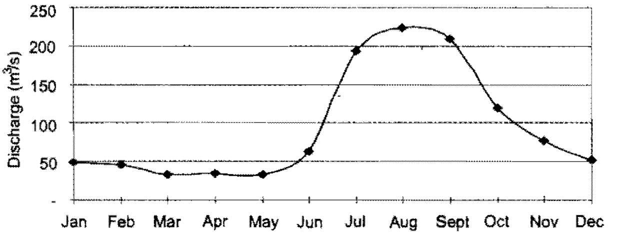
Table 2: Basin characteristics

Particulars	Fuyang River Basin China	East Rapti Nepal
Type of basin	Sub-basin of Huihe Southern Basin	Sub-basin of Narayani Basin
Basin area	22814 sq. km.	312.0 sq. km.
Land use cover		More than 60% forest
Mean annual precipitation	569.2 mm	1866 mm
Average annual potential evapotranspiration	800 mm.	1460 mm
Population density	685/sq. km.	212/sq. km.
Percent involved in agriculture	-	80 percent
Farm size per household	-	0.9 ha
Major crops grown	Wheat and corn, cotton, oil bearing crops	Wheat, rice and maize
Average yields/ha	4.26 t/ha – wheat 4.90 t/ha – corn	1.85 to 2.5 t/ha
Major issues	1. Physical water scarcity 2. Inter-sectoral competition for water 3. Water pollution problem due to rural industrialisation 4. Over-exploitation of groundwater	1. Concern about impacts of increased diversion on natural habitat. 2. Population resettlement and its impact on present water use patterns. 3. Soil degradation in catchment and sedimentation 4. Seasonal scarcity

7.1 East Rapti, Nepal

East Rapti River Basin (ERB) is a part of the Chitwan valley within the inner tarai of Nepal, draining an area of 3,120 sq. km. The East Rapti river originates from the Mahabarat range of mountains (MSL 1,500 m), traverses 122 km and meets the Narayani River, one of the four major rivers in Nepal, at MSL 140 m. The Narayani, called the Gandak in India, eventually discharges into the Ganges River. Forests cover 60% of the area. The average annual rainfall is 1,937 mm, while the average annual potential evapotranspiration for the basin is 1,460 mm. Rainfall is concentrated during six months of monsoon period from middle of May to end of October. July and August are the rainiest months receiving nearly half the annual rainfall. Rainfall during the dry period of six months is only 7 percent of annual rainfall. The river hydrograph at the confluence of the Narayani River is presented in Figure 3.

Figure 3: The long-term average monthly discharges at the confluence point



The area has a growing population, urban and industrial base. Most people remain engaged in agriculture. The Nepal Water Supply Corporation is engaged in constructing water supply and sanitation facilities to serve the needs of growing cities and villages. Irrigation projects are aimed at rehabilitating farmer managed irrigation systems, or recently in rehabilitating then turning-over agency run systems to farmers.

There is no major dam or storage facility along the East Rapti. Farmers have constructed several small diversion structures along the main river and its tributaries. Government agencies have built a few diversion structures, and have recently been involved in the modernisation of farmer constructed works.

There is one major transbasin diversion project where water from the Kulekhani reservoirs flows through a hydroelectric station into the East Rapti. The purpose of this project is power generation rather than storage augmentation for the East Rapti.

7.2 Fuyang, Hebei, China

Fuyang River Basin (FRB), a sub-basin of Haihe Southern Basin in Hebei province of North China, drains an area of 22,814 sq. km. The basin is divided into three broad regions: Fuyang river mountainous area, Fuxi plain and the Hufu inter-zone plain. The annual mean precipitation for the basin is 569 mm.

In contrast to the East Rapti, the Fuyang River Basin is heavily equipped with a large number of storage structures. In FRB, there are 3 large reservoirs, 11 medium reservoirs and 212 small reservoirs. These protect from floods, supply water for irrigation, industry, domestic and power production. Three-quarters of water is allocated to agricultural use, 15 percent for industry, and 10 percent for domestic use.

Differences in water accounting indicators are striking (Table 3). At Fuyang, 109 percent of available water is depleted showing that there is now over exploitation. At East Rapti, this indicator is only 39 percent, meaning that the amount of water in the basin is not constraining future water resource development. This is further illustrated by considering the ratio of uncommitted outflow to available water—nearly 0 at Fuyang, and 61 percent at East Rapti. At Fuyang, process depletion (by industries, cities, and agriculture) is 83 percent of the available water, while at East Rapti this is only 5 percent. At Fuyang, water resources are heavily developed and effectively placed in process use, while the process fraction for East Rapti indicates that humans have harnessed very little of the water. Productivity of water in agriculture has reached high levels in Fuyang, while at East Rapti it remains quite low. One possible explanation is that with increasing competition for water, the value of water increases, which exerts pressure to increase productivity of water in agriculture.

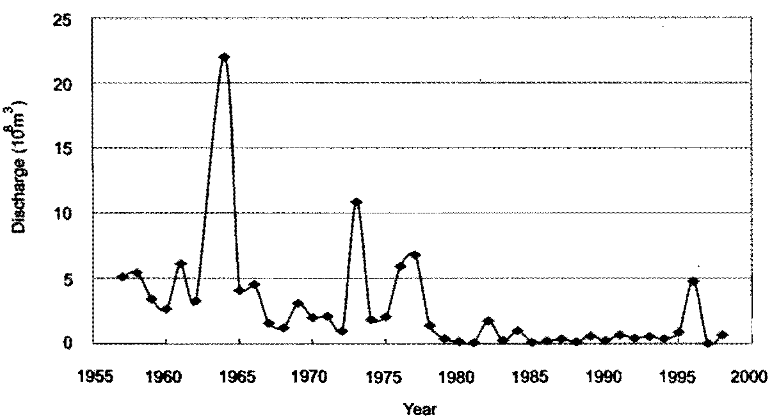
According to historical records, during 1950s and 1960s, Fuyang River was an important shipping channel for Hebei province. In contrast, from 1990s onwards, the river had over 300 dry days annually. The outflows from the basin dramatically decreased from the late 1970s to less than 100 mm^3 with no outflow in 1997 (Figure 4). The basin has become a closed basin for all practical purposes.

Table 3: Water accounting indicators

	Unit	Fuyang River Basin China	East Rapti Nepal
Depletion/available water – DF_{Avail}	%	109	39
Process/consumption/ Avail water – PF_{Avail}	%	83	5
Non-process beneficial use – BF_{Avail}	%	12	31
Non-process non-beneficial use – NBF_{Avail}	%	14	4
Uncommitted outflow/avail water	%	0.5	61
Committed outflow/avail water	%	01.0*	9
Productivity of water depleted by agriculture	US$/$m^3$	0.29	0.09

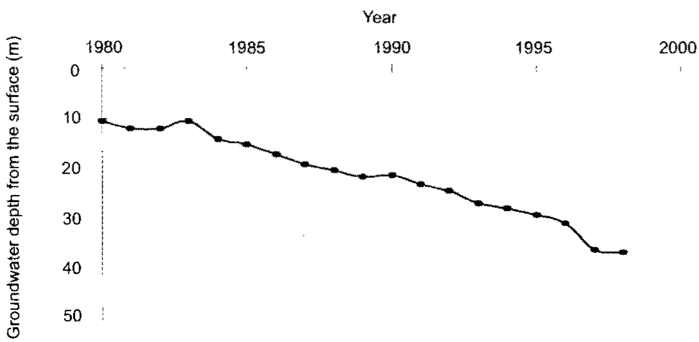
*not supplied.

Figure 4: Variations of discharge measured at Aixinzhuang Hydrology Station from 1957 to 1998



In Fuyang, groundwater accounts for 80 percent of supply, while at East Rapti, groundwater remains a relatively minor source although considerable groundwater potential exists. As a conscious allocation decision, water managers of Fuyang have allowed cities and industries first priority on reservoir water, and have supported farmers in their efforts to tap groundwater. Groundwater overdraft led to a dramatic drop of groundwater level, especially in the recent two decades (Figure 5). The groundwater table dropped at a rate of 0.68 m/year for the county located at the upstream and at a rate exceeding 1 m/year for the middle and downstream counties. There is apparently no institutional mechanism for dealing with this groundwater overdraft problem.

Figure 5: Variations of groundwater depth from the surface, 1980 to 1998, Jiuzhou Station, Renxian County, Hebei Province



For Nepal, groundwater has been recognised as an important resource. But in spite of an ample groundwater resource, and funding for development efforts, groundwater development has remained limited. Institutional mechanisms to support groundwater development have not yet been effective.

Environmental considerations differ in the two areas. In the East Rapti Basin, non-process depletion by natural vegetation accounts for depletion of 35 percent of the water, a large portion in comparison to Fuyang (26%). An important feature of the East Rapti basin is the Chitwan National Park, an important nature reserve and popular tourist destination, situated near the tail end of the basin. Maintaining flows in the East Rapti is essential in maintaining the river ecosystem of the park. Efforts to build more diversion structures along the East Rapti have been hampered in part because of concerns about the river habitat of the Chitwan National Park. There have been no estimates of the flows required for environmental maintenance.

In the Fuyang Basin, people are alarmed at the levels of pollution in the water system. Dilution no longer works, as flows are too small to carry out excess pollutants. Industries continue to discharge polluted effluents. Salinity levels are also rising from agricultural practices. Institutions are at least showing some concern, but it is clear that they do not have the necessary clout to adequately deal with the problem.

In Fuyang, productivity levels are quite high giving evidence that water management in agriculture is effective at least promoting productive agriculture. In East Rapti, cropping intensity is quite high, but crop yields remain low. Farmer constructed and managed systems in this area have often been cited as model examples for irrigation management, while agency constructed systems struggle. Management transfer efforts are aimed at improving the quality of delivery services. Rehabilitation and modernisation of farmer managed systems is an important concern in the area to promote higher productivity.

In spite of ample water in East Rapti, many farmers do not have water during the dry months for crop—water scarcity is a reality for them. Within the Fuyang Basin, the amount of water limits the amount of productivity in the basin. They have met a stage of absolute, physical water scarcity.

Within the Fuyang River, institutions for providing water delivery services seem well-developed. Institutions for regulation of pollution and groundwater seem inadequate. At East Rapti, institutions for construction are active. It was recognised that this setup is not the best for managing water delivery services. Government agencies are still struggling to find the right formula for improved water management within government built irrigation systems. Mechanisms for allocation and regulation seem of little concern now, except for the major issue of allocation between water for food and water for nature. It is questionable whether existing institutions are equipped to handle this problem.

8. Summary and Conclusions

The growing recognition of a river basin as the most appropriate unit for the development and management of water resources has prompted the search for appropriate institutional arrangements for river basin management. This paper has argued that there is no single "best" institutional model. Rather, institutional requirements differ with the different phases of development of the river basin. Thus, a clear specification of the stage of development of the river basin is crucial in understanding or formulating institutional arrangements for river basin management. This paper outlines a framework to define the phases of development of a river basin on the basis of water accounting. The ideas presented in the paper are preliminary and research is underway to develop the methodology and test it empirically under various conditions.

We demonstrated that as the river basin progresses from an "open" to a "closed" basin, three phases can be identified: development, utilisation and allocation. These are not mutually exclusive and some overlap of functions may occur. At the early stages of development, institutional arrangements focus on a single or very limited set of objectives. Very often they are involved in developing infrastructure to supply water. Later, more concern is placed on managing water within various sectors. With increasing scarcity brought on by more development, competition increases, the value of water increases, and a host of other issues including environmental concerns, pollution, and groundwater overdraft may arise. Over time they need to deal with multiple functions that require complex institutional arrangements that involve several organisations, and function in the realm of a broader and often conflicting set of national objectives. Thus, institutions are dynamic entities that need to cater to different management demands as water use changes with the progression of time. Finally, a key feature of an effective institutional design is the ability to adapt to changing needs.

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