

Integrated Water-Resources

Management in a River-Basin Context

Institutional Strategies for Improving the
Productivity of Agricultural Water Management

Proceedings of the Regional Workshop,
Malang, Indonesia
January 15-19, 2001

Bryan Bruns, D. J. Bandaragoda and M. Samad, editors



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INTERNATIONAL WATER MANAGEMENT INSTITUTE

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Contents

Introduction	vii
Part I. Five-Country Regional Study—Framework and Comparative Analysis	
A Framework for Institutional Analysis for Water-Resources Management in a River Basin Context—D. J. Bandaragoda	3
Linking Water Accounting Analysis to Institutions: Synthesis of Five Country Studies—R. Sakthivadivel and David Molden	19
Socioeconomic Conditions in the Five River Basins—Madar Samad	43
Part II. Five-Country Regional Study—Country Cases	
Diagnosis of the East Rapti River Basin of Nepal—Keshav Raj Adhikari	57
Initiating the Improvement of River-Basin Management: The Ombilin River Subbasin in West Sumatra, Indonesia—Helmi	89
Development of Effective Water-Management Institutions: The Upper Pampanga River Basin, Philippines—Honorato L. Angeles, Marcelino S. Santos, Jose L. Tabago, Ma. Excesis M. Orden, Aurora S. Paderes, Carlito M. Gapasin, Lorna A. Bitangcol, Alejandro L. Duran, Lorie M. Cabanayan, Elizabeth D G. de Guzman and Rachelle E. Liberato	105
Contextual Challenges of Developing Effective Water Management Institutions: The Deduru Oya Basin, Sri Lanka—K. Jinapala, P. G. Somaratne, B. R. Ariyaratna, L. R. Perera and I. Makin	127
Water Policy, Management and Institutional Arrangements: The Fuyang River Basin, China—Jinxia Wang, Jikun Huang, Xurong Mei, Jiusheng Li, Hui Jun and Shuiling Lei	149
Part III. Study of Irrigation Investment, Fiscal Policy and Water-Resource Allocation in Indonesia and Vietnam	
Integrated Economic-Hydrologic Modeling of the Brantas Basin, East Java, Indonesia: Issues and Challenges—Charles Rodgers, M. Siregar, Sumaryanto, Wahida, Boby Hendradjaja, Sunu Suprpto and Rizaldi Zaafrano	173
Water Allocation and Use in the Dong Nai River Basin in the Context of Strengthening Water Institutions—Claudia Ringler, Nguyen Chi Cong and Nguyen Vu Huy	215
Part IV. Lessons from Some Best Practices in River-Basin Management	
Institutional Arrangements in the Murray-Darling River Basin—Darla Hatton MacDonald and Mike Young	245
Water Resources Management in the Omona Gawa Basin, Akita Prefecture, Japan—I. W. Makin, D. J. Bandaragoda, R. Sakthivadivel and N. Aloysius	265
Integrated Water Resources Management in a River-Basin Context: The Brantas River Basin, Indonesia—Trie M. Sunaryo	277
Part V. Summary	
Summary	307

INTRODUCTION

In many river basins, in addition to the impossibility of further increases in irrigated area, irrigation water is being diverted to other uses, especially during the dry season. Therefore, finding ways and means of improving the productivity of overall water resources within a given river basin has become a critical need for achieving sustainable improvements in irrigation performance. In most developing countries, the governments own and manage the water resources systems. The suboptimal performance of these publicly managed systems, particularly irrigation, has long been the subject for scrutiny by policy makers as well as donors. While acknowledging the existence of a strong technical-institutional linkage in water resources management, such studies have emphasized the need to invest sufficient time and resources in improving the institutional framework for integrated water resources management (IWRM). In January 2001, a workshop was held in Malang, Indonesia, examining issues of developing more effective water management institutions, to improve the productivity of water resources management.

The workshop was jointly organized by the International Water Management Institute (IWMI), the International Food Policy Research Institute (IFPRI) and Public Corporation of Indonesia, with the sponsorship of the Asian Development Bank (ADB). IWMI and IFPRI are two of the sixteen international research centers associated with the Consultative Group on International Agricultural Research (CGIAR). IWMI has its headquarters located in Colombo, Sri Lanka, and IFPRI is based in Washington, D.C. These centers have a common mission to contribute to food security and poverty eradication in developing countries through research, partnership, capacity building and policy support. The Jasa Tirta Public Corporation is a state-owned company, originally established through Government Regulation No. 5 of 1990, and later changed to Public Corporation I by Government Regulation No. 93 of 1999. The main tasks of this Public Corporation are to manage the water resources as well as operation and maintenance (O&M) of infrastructure in the Brantas river and its 39 tributaries.

The main objective of the 5-day workshop was to present and discuss research being conducted by IWMI and IFPRI in selected river basins in the Asian region with financial support from the ADB through its regional technical assistance mechanism (RETA). The studies conducted by the two centers share some common goals, and encompass work plans and methodologies that are highly complementary and mutually supportive.

The overall goal of the IWMI regional study, RETA No. 5812, "Developing Effective Water Management Institutions," is to improve the management of scarce water supplies available for agriculture, within and responsive to a framework for IWRM in a river basin context. Its specific objective is to develop and initiate the implementation of policies and institutional strengthening programs aimed at realizing the overall goal. This 3-year study, initiated in 1999, is in line with ADB's recent initiatives for assisting its developing member countries to establish their effective water management policies and institutions. The core activity of IWMI's regional study is a set of in-depth institutional and performance assessments on selected river basins in five of ADB's developing member countries: People's Republic of China, Indonesia, Nepal, Philippines and Sri Lanka.

To supplement these five-country studies, case studies were conducted in three additional river basins. Two of these are in developed countries: Murray-Darling in Australia

and Omonogawa in Japan. The main objective of the two case studies on developed-country river basins is to identify key elements of successful water resources management that may be relevant as lessons for water resources management in developing countries. The third river-basin case study, in the Brantas basin in Indonesia, was conducted in cooperation with Jasa Tirta. Its objective was to assess how an effective institutional framework and basin organization have been developed and installed to cover multiple uses of water in a large river basin in a developing country.

The IFPRI study, RETA No. 5866, “Irrigation Investment, Fiscal Policy, and Water Resource Allocation in Indonesia and Vietnam,” has two major objectives. One is to improve IWRM at the river basin level through an analysis of water allocation mechanisms and institutional structures and of the impacts of investments in irrigation and water resources development, reform of pricing and taxation policies, and improvement in water allocation mechanisms. The other major objective is aimed at sustainable irrigation sector development through an assessment of the impacts of agricultural taxation, water pricing and public expenditures on irrigation and water resources.

The core of IFPRI’s regional study is the development of river basin models for the Dong Nai river basin in Vietnam and the Brantas river basin in Indonesia, supported by an analysis of the effects of national fiscal and investment policies on water resources planning. The river basin models will assess the interactions between water allocation, farmer-input choice, agricultural productivity, nonagricultural water demand and degradation of resources, in order to estimate the social and economic gains from alternative water-allocation policies and river-basin investments.

To take advantage of the complementarity between these two regional studies, IWMI and IFPRI decided to conduct a joint workshop in the site common to both studies, the Brantas river basin in Indonesia. This basin also demonstrates the potential of a multipurpose river basin organization, the Jasa Tirta Public Corporation. The workshop brought together the national collaborators from the two study projects and emerging research results from the studies. Although the IFPRI study began a year later than the IWMI study, progress reports on the river-basin modeling and national policy analyses for Indonesia and Vietnam were presented at the workshop.

Over 80 persons attended the workshop. Senior policy staff and researchers came from 10 participating and nonparticipating developing member countries of the studies (Cambodia, China, Indonesia, Lao PDR, Malaysia, Nepal, Philippines, Thailand, Sri Lanka, and Vietnam). Participants included international experts and the staff from IWMI, IFPRI, and ADB, who are associated with this study and the subject of IWRM. Representatives of the Global Water Partnership also attended the workshop.

The first part of these proceedings presents the methodological framework and comparative findings from the IWMI Regional Study. Individual papers on each of the five countries make up the second part. The third part presents two papers on the IFPRI Study of Irrigation Investment, Fiscal Policy and Water-Resource Allocation in Indonesia and Vietnam, describing the modeling framework being used and initial information on the two basins under study. Papers in the following part identify lessons from the three additional basin studies, in Japan’s Omonogawa basin, the Murray-Darling basin in Australia and the Brantas basin in Indonesia. The final chapter summarizes activities and conclusions of the workshop.

Part I.
**Five-Country Regional Study—Framework
and Comparative Analysis**

CHAPTER 1

A Framework for Institutional Analysis for Water-Resources Management in a River-Basin Context

D. J. Bandaragoda¹

Introduction

The background to this framework is a 3-year regional technical assistance study that IWMI launched in 1999, with financial support from the Asian Development Bank (ADB). The study is being conducted in collaboration with local research institutes and implementing agencies in five developing member countries (DMCs) of the ADB: People's Republic of China (PRC), Indonesia, Nepal, Philippines, and Sri Lanka. The overall purpose of the study is to improve the management of scarce water supplies for agriculture in the participating DMCs, within and responsive to a framework for IWRM.

The specific objectives of the study are to assess the existing physical, social and institutional situation associated with water resources within selected river basins in the five DMCs and, based on that assessment, to develop and initiate the implementation of policies and institutional-strengthening programs that will lead to improved management of water resources used in agriculture. Details of the study design and expected outcomes are given in the section under "On-Site Gains and Off-Site Implications" of this framework.

The study is implemented in a collaborative mode. The collaborating research institutes and operating agencies in each country play an important role, not only in the successful completion of study activities, but also in developing increased awareness about the institutional changes that are needed and the lessons from more developed countries that can be applied to solve their institutional problems to achieve improved water management. Within this scope, the study was designed to have five main activities:

1. The development of a conceptual framework for analysis of policies, institutional arrangements, functions and resource mobilization related to agricultural water management in the wider context of IWRM.
2. Case studies in at least two developed countries to identify key elements of successful water resources management and provide lessons for transfer to the DMCs.

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3. In-depth institutional assessments and performance studies in five participating DMCs to assess the strengths and weaknesses in policies and institutions responsible for agricultural water management, identifying the major issues facing the countries and the opportunities to meet the emerging challenges.
4. Preparation of action plans and processes in each participating DMC for implementation of institutional, policy and strategic improvements, based on the findings of the in-depth assessments.
5. Support for implementation of action plans for policy and institutional reform in the participating DMCs.

This paper starts with an outline of the definitions of some key terms, which are often interpreted in different ways at different times, and proceeds to provide a brief explanation as to why a river-basin context is used as the unit of analysis. Considering the close interlinkages between physical, socioeconomic and institutional subsystems of a river basin, the paper refers to an integrated framework involving five study components and discusses three “pillars” of institutional analysis. Finally, the paper provides a number of methodological steps to arrive at possible institutional changes that are needed.

What are “Institutions” and “Organizations”?

Institutions and organizations are part of our daily life, and the two terms are so common in usage that we tend to take them for granted without realizing that they could have various distinct meanings. In analyzing institutional arrangements in this study, a clear understanding of the term “institutions” and how it is related to the term “organizations” is critically important, as many different meanings have been given to this term, depending on where, by whom and for what purpose it is used. A clarification of the two terms and their interaction is given below.

“Institutions” Defined

Consider the following list: caste system, marriage, executive presidency, contract, the military, school, hospital, trade union, labor laws, The World Bank, exchange control, World Trade Organization, General Agreement on Trade and Tariffs (GATT), IWMI, Mahaweli Authority Act, and the Mahaweli (River Basin) Authority of Sri Lanka. One common characteristic of the meanings conveyed by all of these words is that they all serve to shape human interactions. They can all be referred to as institutions but, clearly, only some of them are organizations.

In general sociology, an institution is “an organized, established, procedure” (Jepperson 1991). These procedures are represented as constituent rules of society, or “rules of the game.” The primacy of institutions in sociology was seen when Durkheim called sociology the “science of institutions.” A commentator on Weber suggested that “the theory of institutions is the sociological counterpart of the theory of competition in economics” (Lachmann 1971, 68). The notion that an institution is a social order or pattern that has attained a certain state or property implies that institutions serve the purpose of shaping and stabilizing human actions.

Institutional economics adopts a similar interpretation in which “institutions” are defined as basically “the rules of the game in a society, or more formally, the humanly devised constraints that shape human action” (North 1990, 3). The institutions set the ground rules for resources use and establish the incentives, information and compulsions that guide economic outcomes.

Institutions can be both formal and informal. Apart from written laws, rules and procedures, informally established procedures, norms, practices, and patterns of behavior form part of the institutional framework. After years of tradition, informal practices also become “rules” in their own right when they are accepted by the society. These formal and informal institutions define and fashion the behavioral roles of individuals and groups in a given context of human interaction, aiming at a specified set of objectives. The key characteristics of institutions are that “they are patterns of norms and behaviors which persist because they are valued and useful” (Merrey 1996).

The emphasis on rules of human conduct in the definition given to “institutions” finds an analogy in the set of rules and conventions governing any competitive sport, such as a game of football. Basically the rules give a structure to the game and provide a basis as to how the game is to be played. The rules also include provisions for rule enforcement—penalties or sanctions for violations and, sometimes, rewards for compliance.

The rules also specify the layout of the playing field, the positions of various players and the structure of the team. In this sense, the “institutions” cover both the organization of the team of players and how the game should be played.

How management performance is linked to institutions and organization is depicted in figure 1. Institutions take a variety of forms, including:

- policies and objectives,
- laws, rules, and regulations,
- organizations, their bylaws, and core values,
- operational plans and procedures,
- incentive mechanisms,
- accountability mechanisms, and
- norms, traditions, practices, and customs.

“Organizations” Defined

Organizations are defined as “networks of behavioral roles arranged into hierarchies to elicit desired individual behavior and coordinated actions obeying a certain system of rules and procedures” (Cernea 1987). A similar definition describes organizations as “structures of recognized and accepted roles” (Merrey 1996, 8). This hierarchical arrangement is popularly referred to as the “organizational structure.” Organizations are groups of individuals with defined roles and bound by some common purpose and some rules and procedures to achieve set objectives. Like institutions, organizations also shape human action.

Figure 1. *Nested institutions and management performance.*



Source: Adapted from Small and Svendsen 1990.

North (1990, 73) defines organizations as “purposive entities designed by their creators to maximize wealth, income, or other objectives defined by the opportunities afforded by the institutional structure of the society.” An example is the Mahaweli Authority of Sri Lanka (MASL), which was created by the government that came to power in 1977. The purpose was to harness water and land resources in the Mahaweli river basin for food production and employment generation, two strong political objectives at that time. As its value and usefulness grew in the society, MASL gained acceptance and became an established organization.

For the purpose of our study, institutional analysis at this stage will focus on both the underlying rule systems and the organizations as agents of institutional change.² A broad interpretation of the institutional framework as given below will be the chosen approach for this purpose, which will facilitate this needed focus. To be able to focus on the suggested emphasis on institutional analysis, an important conceptual consideration is the interaction between institutions and organizations, a brief outline of which is presented below.

²A thorough organizational analysis to cover various water management agencies such as Irrigation Departments is beyond the scope of this framework. Such a task would involve an analysis of leadership, motivation among organizational members, their knowledge, skills and capacities, and their value systems and preferences. Most of these aspects are directly related to management functions, which can be addressed when various stakeholder groups consider action plans.

Need for Clarification

Even in its most popular usage, the term “institutions” seems to convey a narrow and, therefore, not entirely correct interpretation. In this erroneous interpretation commonly used by many, “institutions” are regarded only as “organizations”. The connotation becomes much more common in the use of the term “institution building” that, most often, refers to the building up of new organizations (parastatal bodies, additional units in existing agencies, farmer organizations, river basin organizations, etc.).

To avoid developing and installing nominal institutional change, it is necessary to understand the cohesiveness and the functioning of various elements of the existing institutional framework in the contexts under study. It is necessary to distinguish between organizations and their underlying institutions, so that a comprehensive analysis could be undertaken. If there are new performance objectives that relate to changed physical and socioeconomic circumstances, what would be required is a review and reform in both organizational structures and operational rules, evaluated in the context of the wider institutional environment.

Interpretation of “Institutions” Adapted for the Study

Based on the above-mentioned concepts and definitions, the interpretation that is suggested to be adopted for the purpose of this study is given as follows. The institutional framework for water resources management in a river basin context consists of established rules, norms, practices, and organizations that provide a structure to human actions related to water management. Notably, the established organizations are to be considered here as a subset of institutions. For practical purposes, the overall institutional framework is considered in three broad categories: policies, laws and administration, all of which are related in some way to water resources management in a river basin context.

1. Policies

- national policies
- local government policies
- organizational policies

2. Laws

- formal laws, rules and procedures
- informal rules, norms and practices
- internal rules of organizations

3. Administration

- organizations at policy level for resources management
- organizations at implementation level for delivery management

River Basin as Unit of Analysis

With the recognition of significant reuse of water, the river basin is increasingly acknowledged as the appropriate unit for the analysis, and management of water resources, especially as water availability at the basin level becomes the primary constraint to agriculture. Growing scarcity of good-quality water in most river basins results in intense inter-sectoral competition for water. The efficiency of irrigation water use can be seen in a more comprehensive manner if the allocation of water in a basin among various users is considered along with irrigation use. Similarly, a more comprehensive analysis requires the adverse effects of a rapid degradation of the environment and other ecological problems arising from severe competition for water to be studied along with the irrigation-induced environmental problems.

The neglect of such a wider consideration of the resources base has, up to now, clouded the inherent limitations of existing institutional arrangements to deal with irrigation systems. As countries experience growing water scarcity, water-sector institutions need to be reoriented to cater to the needs of changing supply-demand and quality-quantity relationships and the emerging realities (Saleth and Dinar 1999). It is inevitable that irrigated agriculture, the largest water user in many river basins, will be called upon to reassess its water requirements in view of the competition for water from other users.

Difficulties imposed by policy and institutional constraints at levels above farms and irrigation systems are attributable to the failure in realizing the full benefits from many reforms that have been attempted in irrigation management. There is now wide acceptance of the necessity to focus on higher-level institutions, generally at the basin level. In Asia, this view was reinforced at regional conferences sponsored by the ADB in 1996 (see Arriens et al. 1996).

On-Site Gains and Off-Site Implications

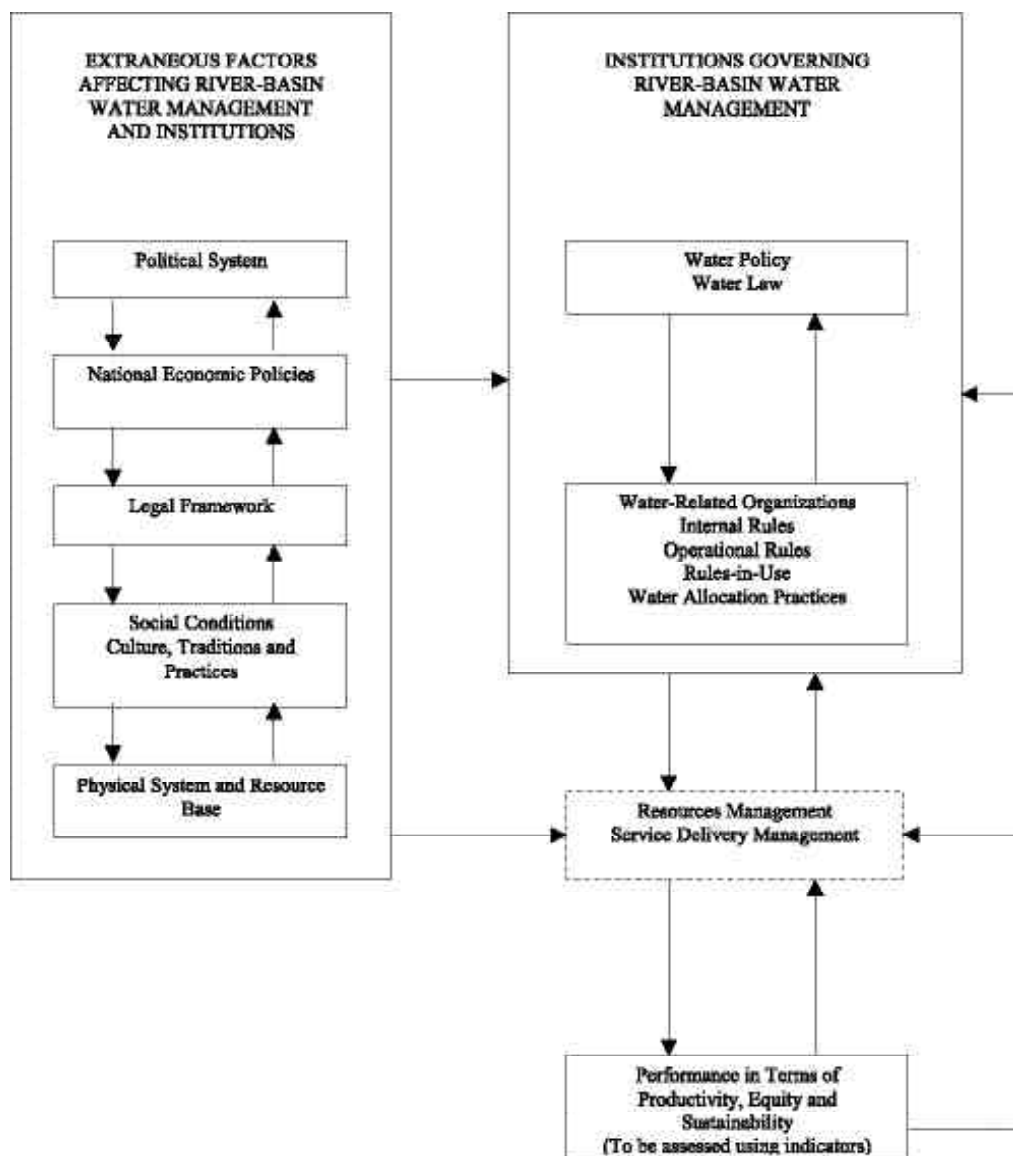
The river basin as the geographical unit in which analyses are conducted defines an area where various users of the basin's water interact, and where most of them live. A basin perspective helps include in the analysis the interactions among various types of water uses and users, and in the process, it helps in better understanding the physical, environmental, social and economic influences that impinge on the productivity of agricultural water management.

In a basin context, interrelated issues of both quantity and quality of surface water and groundwater, and the extraction, use and disposal of water resources can be more comprehensively analyzed. Participation of a larger number of stakeholders can be sought, and water resources planning can be more effectively carried out. The broader view through a river basin is able to capture dimensions that are not normally included in an irrigation system management approach, such as the causes (and not only the effects) of water scarcity, water quality, water-related disputes and inequitable water distribution and use.

An integrated approach to water resources management in a river basin would enhance both productivity and sustainability of natural resource use. Sustainability means that the concerns about resources use should transcend beyond short-term "on-site" gains, and should necessarily be on an environmentally sensitive use of resources including many possible "off-site" implications. For instance, in many irrigation systems, the act of water use is limited to achieving system objectives, such as obtaining highest crop yields, and is rarely concerned with downstream drainage problems or pollution caused by fertilizer and other chemical inputs.

The off-site influences on a water use system, as well as the off-site impacts arising from a water use system, can both be systematically studied to identify the factors that affect the performance of the water use system. Figure 2 shows the conceptual framework underlying the water-related institutions in a river basin.

Figure 2. Institutional environment of a river basin.



Study Design for Institutional Assessment

The main objective of the country-based studies is basically twofold. First, the field studies in the five countries are expected to identify the relationships between physical and socioeconomic characteristics of selected river basins³ and their existing institutional arrangements. Second, based on this diagnostic information, possible institutional changes are to be identified for improving the management of water available for agriculture in the context of IWRM in river basins.

Six key research questions are relevant in a search for appropriate institutional strategies in given contexts:

- What is the hydrological resource endowment of the river basin?
- Who are the present users of water, and what are the present patterns of water use differentiated by sector, public and private uses, gender and income level?
- What are the formal and informal institutional arrangements for sharing water between uses within the basin and what provisions (or potentials) exist for satisfying the unmet water needs of disadvantaged groups, such as women, children and the poor?
- How do the present formal and informal arrangements for allocating and managing water between uses affect equity and productivity of agricultural water use within the river basin?
- What is the nature of conflicts between uses and the means for conflict resolution within the basin?
- What can we say about the future trends and scenarios, with special reference to the future of irrigated agriculture and access to water resources by poor women and men?

Considering the river basin as the unit of analysis places the emphasis of research at a plane higher than that of the traditional focus on irrigation-system management and facilitates a shift in concerns towards overall water policy and IWRM. This stance helps capture the effects of growing inter-sectoral competition for increasingly scarce water resources.

The country studies aim to assess the degree of temporal and spatial scarcity of water and competition from all the water-use sectors, and actively participate in finding solutions to improve agricultural water management. The study design also enables the important research and policy considerations on water quality, resource depletion and degradation and the environment.

³Although a river basin is typically defined as the entire geographical area from which water drains to the point at which the river flows to a sink (i.e., sea), for purposes of this study, this definition was adapted to mean the entirety of such a river basin or a part of a basin (subbasin) defined by the location of its stakeholders who have an interest in one or more particular water-management problems and who have the ability to address them.

The collaborative study activities in the five selected countries are aimed at improving the management of their scarce water supplies for sustainable agriculture, within the constraints of competition for water by other sectors and environmental problems related to water use. The physical and social diagnostic analyses will help in both evaluating the existing institutional framework and formulating institutional change. The diagnostic analysis on irrigated agricultural performance will help the development and initiation of appropriate action plans to address the identified constraints in agricultural water management.

The five countries are in varying degrees of water-resources development and related institutional development. They are also at different levels of water management performances. The country studies will identify the distinct features in each of the selected water basins in the five countries, and assess the issues and constraints in the context of their respective national and regional water policies. These studies will also add to the institutional reform processes already launched in some of these countries, and will provide an impetus for reform in the others. The studies will also contribute to the ADB's initiatives in promoting national water policies.

Although the five study components are distinct, they are all related to socioeconomic relationships of the stakeholders associated with the basin's water resources. To this extent, the components are interrelated and are, in turn, linked to the final study goal of improving the productivity of agricultural water management in the basin (see figure 3).

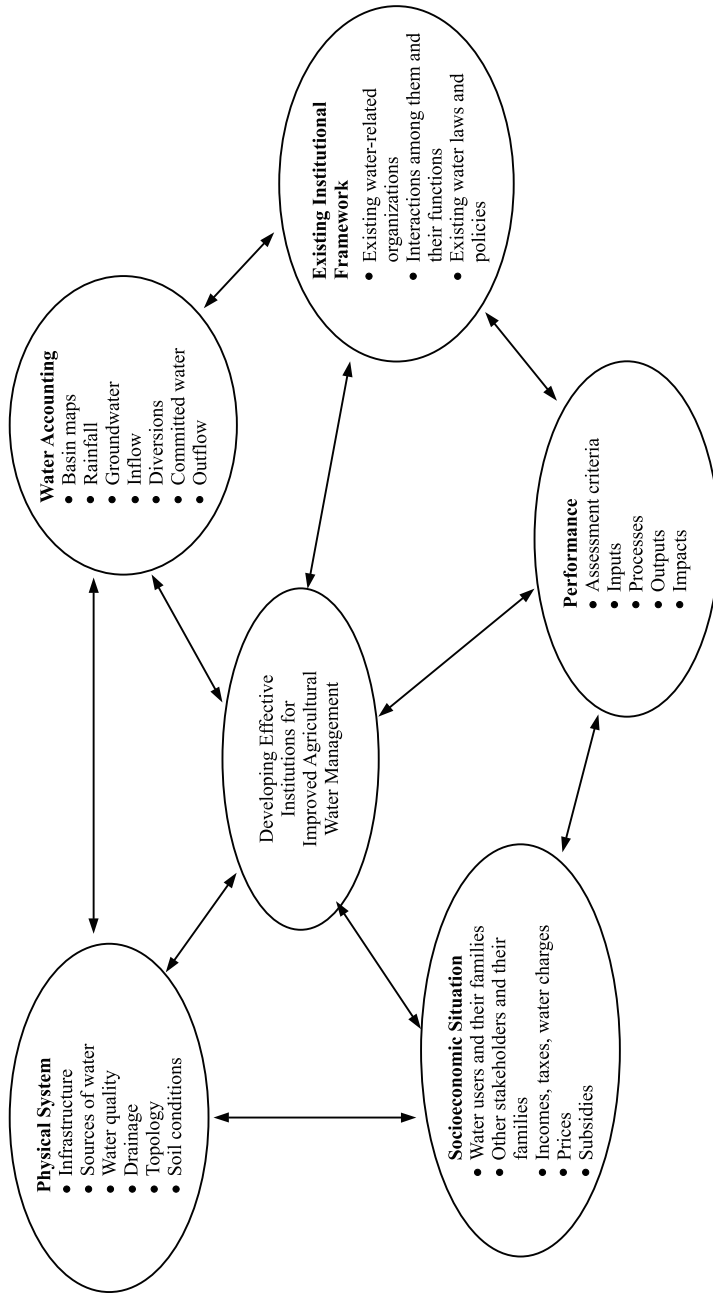
Physical System and Institutions

Presenting a river-basin perspective for water development, G. F. White (1957) noted that "if there is any conclusion that springs from a comparative study of river systems, it is that no two are the same."

The topology, soil conditions, climate and rainfall, geographical location, and natural vegetation all combine to distinguish one river basin from another. Closely related to these natural features is the man-made infrastructure for harnessing water resources from the river system to develop natural resources within the basin. In addition to the natural features of the basin, the characteristics of infrastructure, such as size and scale, technology, and purpose tend to determine the type and character of institutions established for water resources management. In effect, the physical system of the river basin mirrors the institutional arrangements.

A good illustration of this relationship is the canal irrigation system in the Indus basin and its institutional arrangement for water management. The flat terrain of the basin makes storage difficult and requires that the system is a run-of-river diversion in a contiguous canal system. At the tertiary level, there is continuous water flow along the watercourses and the structure at the head of the watercourse is designed to allow for automatic proportional distribution of water into the watercourses. This physical system is matched by a water allocation system in the form of a time-turn based rotation, popularly known as warabandi, which is self-policing and meant to share water scarcity equally among all the water users in the watercourse command area. Basically, the system is geared for minimum management and control, which also reflects the need to cater to a system of very long canals and a vast command area. Also, it reflects the social and economic characteristics of the water user community.

Figure 3. Study components aimed at developing institutions for improved agricultural water management in a river-basin context.



Water Accounting and Institutional Analysis

If a river basin is defined as the entire geographical area from which water drains to the point at which the river flows to a sink (lake or sea), then, the amount of water in a given river basin in typical years should be a constant. The only exception would be if there were man-made facilities for interbasin transfers of water. Historically, therefore, the variable phenomenon within a river basin is the water use through human interventions. As was mentioned earlier, as the population increases, and as the technology and social behavior change over time, the pattern of water use also changes. The main purpose of the water accounting activity is to assess this pattern of water use at a given point of time, and over a period of time. Water accounting is something more than calculating a water balance. Put simply, it is accounting for water resources in the river basin, to understand how much water is approximately received by the basin, and how, how much, and for what purposes this amount of water is used. The proportion of water that is (purposely) used for beneficial purposes directly corresponds to the intensity and efficacy of water management institutions, and the nature of this water use corresponds to the character and quality of the institutions.

Socioeconomic Situation and Institutions

As the population increases, interregional migration and rate of urbanization also tend to increase. In a consumer-oriented society, competitive demands for water for various purposes in a river basin (industries, drinking and domestic, and environmental protection) gradually increase. These increased demands are bound to clash with the traditional interests of agricultural water use and related institutions. The process of urbanization and modernization (development) accompanies new technologies and, in turn, they cause social change. Together, these socio-technical changes call for changes in the existing institutions.

A good example is how the traditional water allocation principle of “prior appropriation,” as in Colorado State in the US (Moore et al. 1994), has been threatened by the new demands for water, accompanied by some technical innovations. Remote data collection through telemetry networks and automated control systems provides managers with “real-time” information about water supply and demand and help them fine-tune their methods of using water efficiently. As part of this technological advancement, “demand-tailored” water deliveries are possible, and the result is a tendency towards developing new agreements to reapportion surplus water. At the same time, other water uses, such as power, municipal and industrial supply, flood control, navigation, fish and wildlife, and recreation press for their water rights through various lobbies and legal instruments. State laws are supplemented by Federal laws and Supreme Court decisions. For instance, the preservation of minimum streamflows is now part of the “public trust” doctrine of USA. The term “beneficial use” is being defined as “greatest good for the greatest number.” Another strange form of flexibility is emerging as a result of “parallelism and conflicts in laws.” The point is that a change from the traditional “first user, first right” to a new institutional framework is now possible because of innovative technological support to use water more efficiently, and the accompanying changes in social attitudes towards sharing of water.

The lesson that can be learnt from this experience is that there is a need to understand, in any context, the changes (or the potential for change) in terms of the technology of water management and the related social change that may have occurred in the recent past. This

understanding will help in determining the extent of change that can be incorporated into the existing institutional framework for water management.

Experience in the Omonogawa river basin in Japan provides another example of how new technology has combined with the existing institutional framework to solve a recurrent problem. Using the tradition of Land Improvement Districts, which was sufficiently adaptable, new technology was deployed to develop the basin with diverted water from the river through new canal systems. This basin development has played a significant role in reducing the frequency and the effect of droughts and floods in the area. Storage of diverted water serves to regulate flows and make water available on a more uniform basis throughout the basin. New technology has added automated control systems to the traditional LID procedures for better water resources management.

Performance Assessment and Institutional Analysis

The study component on performance assessment is designed to be limited to irrigated agriculture within the selected river basin. This decision was taken at the inception of the study, so that the available study resources would be best spent by focusing on the basin-wide influences on the major water use and the productivity of agricultural water management. Although this strategy agrees with the terms of reference of the study as well, the study is still designed to assess the need for coordination mechanisms in the institutional framework that would eventually contribute to improved productivity of agricultural water management. Once the current performance levels of irrigated agriculture are assessed (following the indicators given in the methodological guidelines), the influence of the existing institutional arrangements on the production processes is to be identified.

As explained in section under “Needs for Clarification” above, the study design considers that the institutional framework is a necessary condition for entrepreneurs or members of an organization to perform in the pursuit of their objectives, subject to leadership and coordination provided by management. In this document the main focus is on the institutional arrangements, and it stops short of proceeding to assess the efficiency of management functions. The main task at this stage of the study is to evaluate whether the existing institutional framework negatively constrains the performance of management tasks.

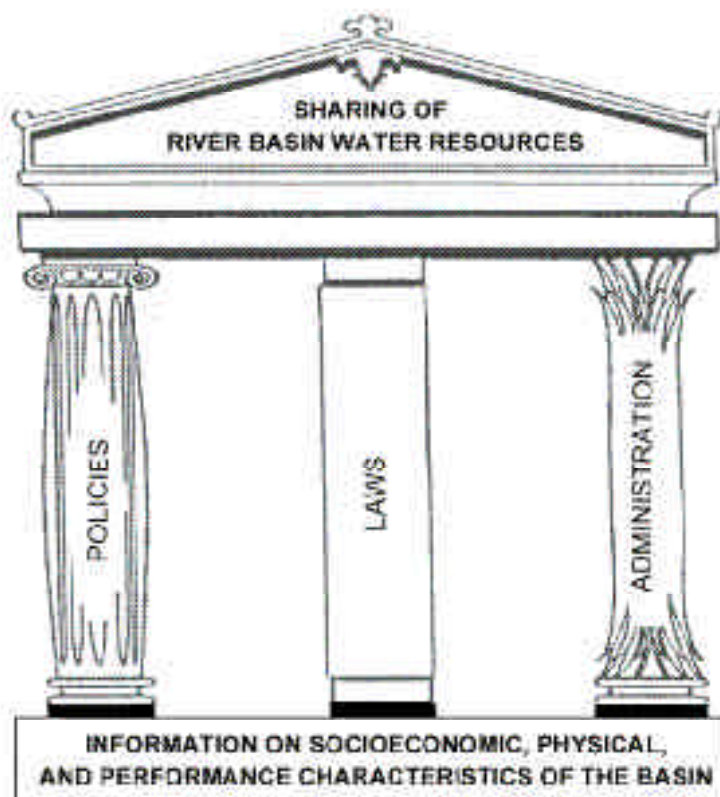
Classical Temple Metaphor of Institutional Analysis

The metaphor of the classical temple is an appropriate illustration of the combination of principles, processes and activities involved in this suggested method of institutional analysis based on the chosen definition of the institutional framework. Figure 4 depicts this metaphor as adapted from its use by Savenije and van der Zaag (1998). The framework rests on the foundation of diagnostic studies and supported by three pillars of key institutional areas.

Foundation: Diagnostic Study Components

The foundation for the analysis is the five study components conducted in each river basin. Although they are mostly in noninstitutional aspects of the basin, each component can be related to the institutional framework of the basin.

Figure 4. The classical temple metaphor indicating river-basin institutional development.



Three Pillars of Institutional Analysis

Following the definition adopted for this study, Policies and Administration are the three pillars of the institutional framework for IWRM in a river-basin context. They are very broad categories of institutional elements and each category can consist of a number of institutional elements.

The pillar of laws. The legal framework is a very complex set of enactments, subsidiary laws, rules, regulations, procedures, rights, customs and practices. They are also divided in terms of sources, such as national, local and village-level assemblies. There can be laws affecting water management and laws directly related to water management. The activity that may have been already accomplished during the diagnostic phase could be the inventorying of these legal elements. At this stage of the analysis, each element can be evaluated according to the procedure given below.

The pillar of policies. Policies are also determined by a number of actors at the national, local or organizational level. Usually, policies and laws are interlinked at the sources as well as at

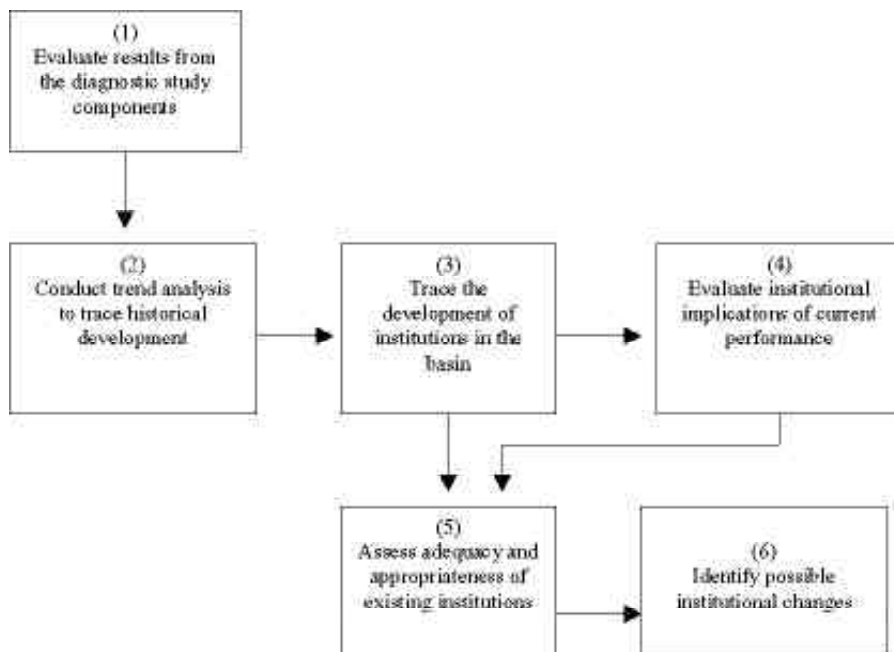
the implementation level. Some countries that have already established a water policy are in the process of formulating laws to implement the policy. In the analysis, the elements of this policy framework should be subjected to closer scrutiny.

The pillar of administration. Administration here means the organizations involved in water management and their internal rules. The organizations are necessary for two levels: resource management and delivery management. The evaluation of these organizational elements needs to be conducted in terms of procedures indicated in figure 5, to explore their effectiveness to undertake coordination among various water-use sectors in the river basin, data collection and processing for monitoring purposes, application of water rights, and enforcing various rules related to water management within the river basin.

Suggested Method for Institutional Analysis

The methodological steps that are suggested to be taken in analyzing institutions on the basis of study activities already undertaken are shown in figure 5, which gives a simple flow chart to depict the interrelationships among the steps.

Figure 5. Steps in institutional analysis.



Conclusion

Institutions are necessary for two distinct levels of management: higher-level resource management and lower-level delivery management. Although the set of institutions can collectively cover both levels, separate organizations are often useful for handling the two levels of management tasks.

While the institutional framework encompassing both these management levels needs to be analyzed, a state-of-the-art management strategy also needs to be developed, particularly as a guide to be followed during the action phase envisaged in this regional study. Strategic planning will form an essential preparatory task at the beginning of this action phase.

As river basin resources reach full commitment, the interactions at the basin level become critical. Consumption increases in one area must be offset by consumption decreases at another. Poorer quality effluent in an upstream area has direct impacts on downstream entitlements. Other issues—flood zoning, safety and operation of dams— must, of course, always be regulated and administered at the basin level. Thus the scope of management required is widening and the attention is moving progressively upwards, but the strength of higher-level institutions is probably declining precisely as this is happening. This institutional weakness needs to be remedied in a search for strategies in improving the productivity of agricultural water management.

As the largest user of water in most developing-country river basins, better agricultural water management will be the key factor in long-term sustainable water use in water-scarce river basins. As most basin areas and most stakeholders are linked with using water resources for agriculture, the minimum set of management tasks can be assessed more closely for agriculture production.

Each water basin is seen as unique in its features: physical, social, environmental and economic. Depending on the contextual factors, the minimum set of management tasks can also be ordered according to their importance. A composite performance indicator may be used to capture the relative importance of these various tasks, and of the different water uses within the basin.

The institutional analysis will finally be aimed at identifying effective institutional arrangements for agricultural water management at two levels in the context of IWRM in a river basin. At the macro level or basin (or subbasin) level, analysis will deal with institutional arrangements that concern inter-sectoral allocation of water, such as for irrigation, domestic water supply, hydropower, environmental purposes and other uses that depend on a common water source. The service-level analysis will focus on institutional issues relating to the multiple use of water within the irrigation service area. At this level, interest in other subsectors will only be to the extent that they affect agricultural water use either directly or indirectly. The water users' collective-action bodies will be part of this level of institutional development.

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Chapter 2

Linking Water Accounting Analysis to Institutions: Synthesis of Studies in Five Countries

R. Sakthivadivel and David Molden¹

Introduction

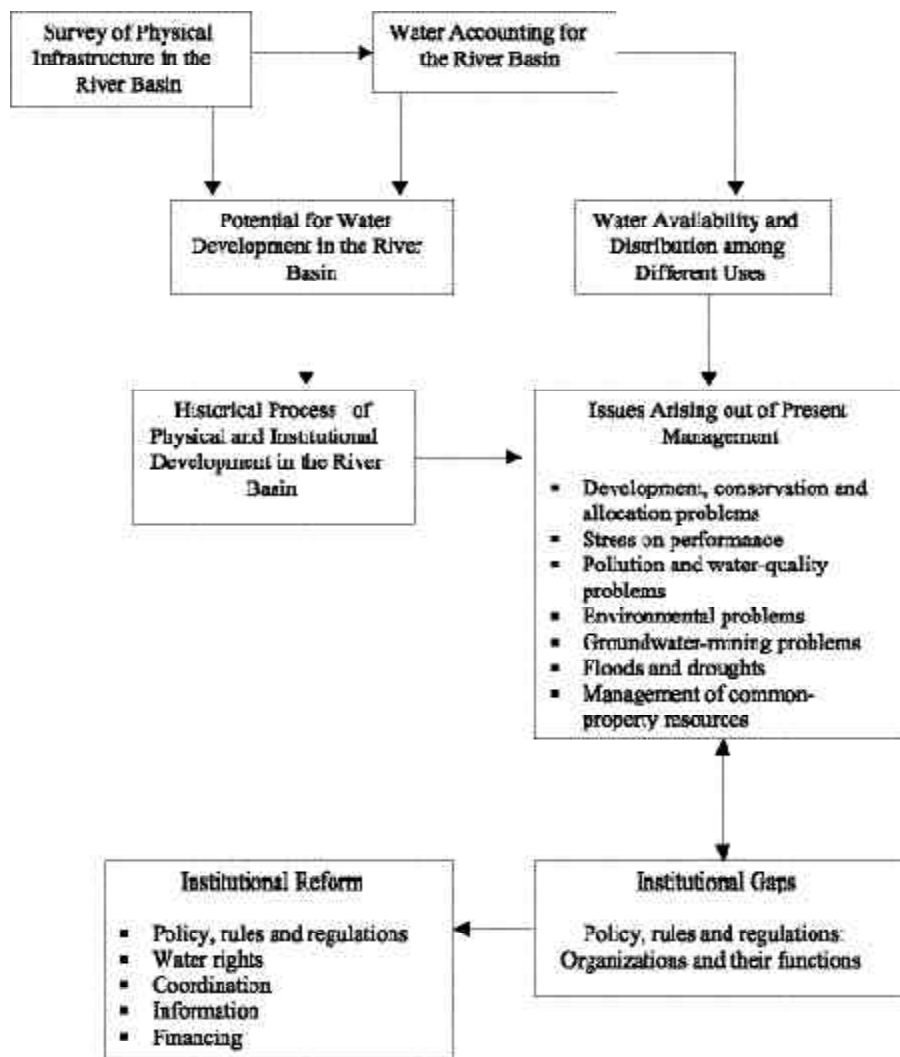
Four initial investigative studies—physical characteristics of river basins; water accounting; socioeconomic and stakeholder analysis; and performance assessment of irrigation systems studies—were identified and carried out. Based on these investigative studies from a basin perspective, a framework for institutional analysis was conceptualized. The framework is related to the existing situation as well as to the identified potential for improvement in agricultural water management, particularly in terms of the sociopolitical situation of the country concerned (figure 1). The four components help in linking the analysis both to the physical dimensions of the water resource—which are related to its location, type, quantity and quality—and to the nonphysical dimensions—which are related to its users, stakeholders and their interests, preferences and objectives. In addition, the basin-based diagnostic studies also link the analysis to the time dimension of the water resource, which are both the historicity and the sustainability, related to the use of water in the basin.

This paper deals with a comparative perspective of the salient hydrological features and water-resources endowment and use in the five basins selected for the study using a water accounting approach. The concept of water accounting developed by Molden (1997) and Molden and Sakthivadivel (1999) is simple and is based on a water balance approach, where the sum of inflows must equal the sum of outflows plus any change in storage. Water accounting classifies water balance components into water use categories and productivity of water uses. Inflows, outflows and water depletion into a domain are classified into various categories. Water accounting indicators are the output of this concept to describe the use, availability and productivity of water resources.

Water accounting and its analysis play a vital role in linking institutions to water resources development (WRD), conservation and utilization, and allocations. It identifies the available water, its potential development and its distribution among different uses within the basin. These aspects, together with historical development of water resources and related institutions,

¹Sakthivadivel is Principal Researcher and Molden is Leader, Comprehensive Assessment of Water Management in Agriculture, both of IWMI. Much of the information presented in this paper is drawn from the country reports submitted by the collaborating partners from the ADB-funded five-country study. The authors acknowledge the contribution made to this paper by the collaborating partners.

Figure 1. Framework for linking waters accounting with institutions.



allow us to elucidate issues arising from present institutional arrangements and management practices and enable identification of institutional gaps. This, in turn, leads us to formulate institutional reforms for effective river basin management.

Macro Context of the Five Countries

“There are marked variations in the water resources endowments and their utilization in the five countries selected for the study. In aggregate terms, Indonesia is well endowed with

availability of water at 10,500 m³/capita/year. But there are marked regional variations with less than 2,000 m³/capita/year in parts of Java to some 28,200 m³/capita/year in Irian Jaya. Philippines and Nepal also have abundant supplies of water at 4,700 and 10,000 m³/capita/year, respectively. Annual per capita water resources of Sri Lanka and China are 2,700 m³ and 2,200 m³, respectively, with the latter, especially its northern region, fast becoming one of the most water-scarce regions in the world.

“Agriculture remains a vital sector of the economy in the five countries selected for the study. However, in four countries—China, Indonesia, Philippines and Sri Lanka—the contribution of agriculture to the Gross Domestic Product (GDP) has declined vis-à-vis industry and the services sector, while in Nepal agriculture still remains the dominant sector and accounts for about 40 percent of the GDP.” (Samad, *this volume*) Yet, in all the countries, agriculture is the largest user of water, accounting for about 70 percent of withdrawals in China and over 90 percent in each of the other countries.

With the exception of the Philippines, the population in the selected countries is concentrated in rural areas. In the Philippines, it is relatively evenly distributed (48% in urban and 52% in rural areas). Data suggest that all countries are rapidly urbanizing. At the same time, the rate of industrial growth in the last decade has been more than double that of agricultural growth. These trends are likely to continue, with far-reaching consequences on the countries’ water resources, as more water is diverted from agriculture to other uses.

“Providing sufficient drinking water of good quality for the increasing populations is a high-priority policy item in all five countries. Other policy objectives vary from one country to another. In China, flood control, water pollution, water conservation and water saving in agriculture are major components of the government policy on WRD. Irrigation is considered vital for China’s food security but public funding for irrigation development is much less than investments in other areas of WRD. In all other countries, provision of irrigation facilities, especially for rice production, has been a dominant component of WRD along with other objectives such as hydropower generation, urban water supply and sanitation, and protection of the environment” (Samad, *this volume*).

Salient Features of the Five River Basins

The five river basins differ in terms of hydrology and level of development. The salient features of the basins are given in table 1.

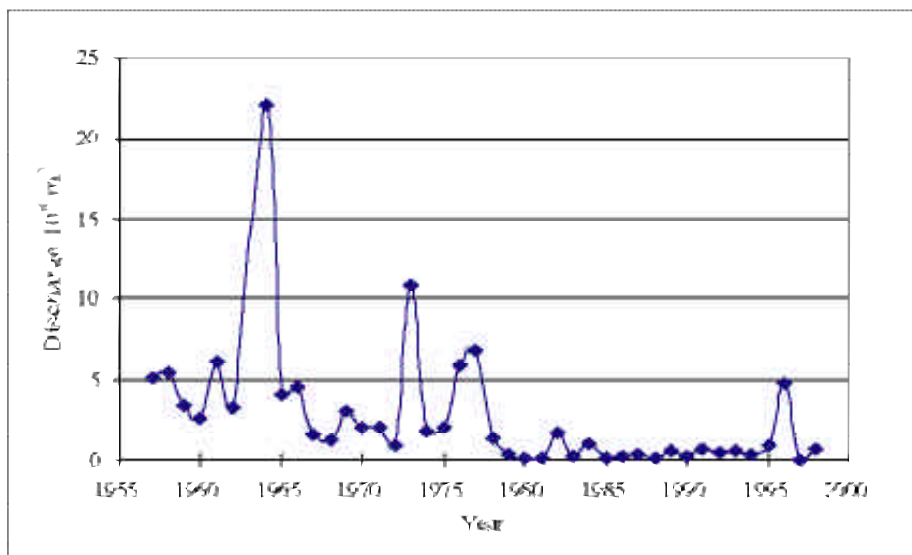
Fuyang River Basin in China

The Fuyang river basin (FRB) includes five prefectures, 43 counties, 345 cities, and 9,092 villages of southeast Hebei Province. The FRB is divided into 3 regions: Fuyang river mountain, Fuxi plain and Hufu region. This basin is classified as dry and subhumid. The annual mean precipitation is 569 mm and 80 percent of the rainfall occurs from June to September. The annual rainfall variation is high, 5 to 1. Temporal variation is also high (c.v. = 0.24) compared to spatial variation (c.v. = 0.07). The uneven temporal and spatial distributions of precipitation cause frequent floods and droughts in the basin, which are major disasters where agricultural production is concerned.

The recent growth of industry and living standard of local farmers have raised the share of water used in both industrial and other nonagricultural uses. In 1998, among the total withdrawals, 75 percent of water was allocated to agriculture, 15 percent for industry and 10 percent for domestic and other uses.

In the 1950s and 1960s, the Fuyang river was an important shipping channel for the Hebei Province. Since the 1970s, with increased water demand and decreased discharge, the shipping business has come to an end. Diversion weirs and other structures have been built across streams, reducing the utility of rivers for transportation. It can be seen from figure 2 that the outflow from the basin has dramatically decreased from the late 1970s. On average, the river has over 300 dry days annually.

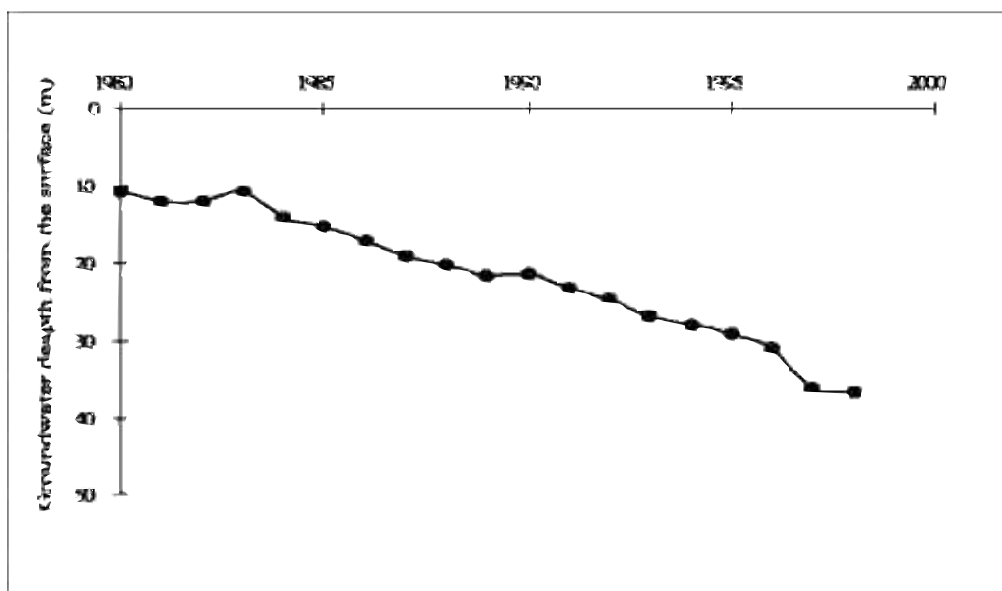
Figure 2. Variation of discharge measured at the Aixinzhuang hydrology station, 1957–1998.



Between the 1950s and the 1990s the withdrawal rate had not changed dramatically (from 8.2 billion m³/year to 9.3 billion m³/year). On the other hand, inflow and surface flow generated within the basin had decreased from 33.5 billion m³/year to 16.0 billion m³/year while, at the same time, consumptive use had increased considerably.

Groundwater is the most important water resource of the FRB. With the increased demand from industry, domestic use and agriculture the quantity of groundwater exploitation has increased quickly. At the same time, groundwater tables have dropped greatly due to the overexploitation in the last two decades. The shallow groundwater table dropped at 0.58 m/year in the 1980s and at 33 m/year in the 1990s. Similarly, the deep phreatic water table has also dropped at an increasing rate and the annual average decline is higher than that of the shallow water table (2.24 m/year). In 1995, the lowest groundwater table was 51 m, as shown in figure 3. The drop in groundwater tables has also resulted in groundwater pollution due to inflow from polluted streams and drainage channels. The falling groundwater table has also caused the settlement of the ground surface.

Figure 3. Variation of groundwater depth from the surface (1980–1998), Jiuzhou, Renxian County, the Hebei Province.



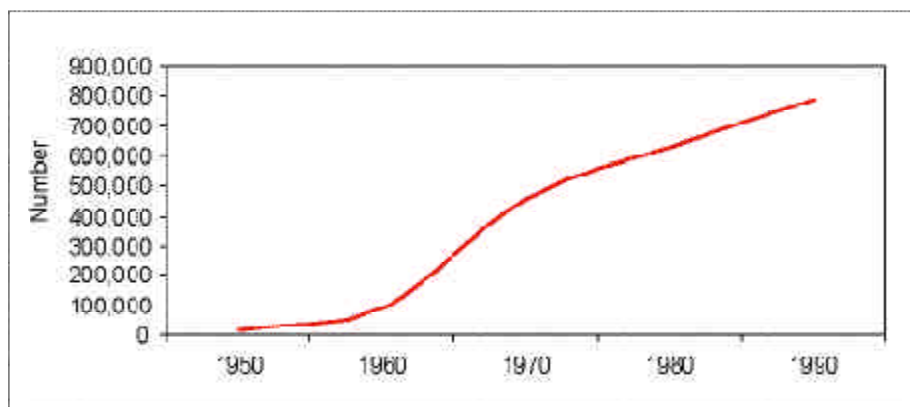
Industry and population growth lead to more and more serious water pollution, which further increases the scarcity of water in the FRB. With growing emissions and limited sewage disposal facilities, it is hard to meet the disposal demand. Within the total sewage emissions, nearly 70 percent comes from industry and 30 percent from domestic pollution. Due to limited sewage treatment facilities, only 52 percent of the sewage is treated, the other 48 percent being directly diverted into the river. In addition to the pollution of surface water, pollution of groundwater is also becoming very serious.

China's irrigated area quickly expanded from the 1950s to the 1970s. But after rural reform in the early 1980s, the growth of irrigated area has slowed greatly compared with earlier periods. In the FRB, the total irrigated area has expanded from 881,000 hectares in 1985 to 1,024,000 hectares in 1998. Unlike the generally increasing trend in irrigated area, the rain-fed area has continuously decreased since 1949 due to conversion of rain-fed areas into irrigated areas. In the Hebei Province, the cultivated area has decreased from 7,266,000 hectares in 1949 to 6,485,000 hectares in 1998, a decrease of more than 10 percent of cultivated area.

There has been a marked expansion in the number of tube wells. In the Hebei Province, there were no wells in 1950, but there were 731 wells in 1955, and the number has risen to 843,105, following the trend shown in figure 4.

Most large and medium reservoirs were established before the 1980s. In 1998, 80 percent of agricultural water supply came from shallow wells, 11 percent from diversion projects, 4 percent from water impounding projects and only 2 percent from turbine pumps. Most of the impounded water was diverted for drinking, industries and hydropower generation.

Figure 4. Development of wells in the Hebei Province.



The soil-erosion areas decreased from 842,000 hectares in 1985 to 564,000 hectares in 1998. On the other hand, saline-affected areas increased from 109,000 hectares to 127,000 hectares, and waterlogged areas from 182,000 hectares to 309,000 hectares.

The FRB is an important agricultural production region of the Hebei Province. The major crops of FRB include wheat, corn, vegetables, oil-bearing crops, cotton, soybean and fruits. It supports 15 million people on 1,239,000 hectares of cultivable area, 82 percent of which is cultivated. In 1998, the total sown area was 1,927,000 hectares. The cropping index of the province increased from 1.45 in 1993 to 1.55 in 1998.

Deduru Oya River Basin in Sri Lanka

The Deduru Oya river basin has a mean annual rainfall of 1,152 mm and there are three distinct agro-hydrological zones within the basin. Approximately the top one-third area of the basin receives over 1,250 mm of rainfall (P_{75}). Most of the middle reach has (75% probable annual rainfall, P_{75}) less than 900 mm and the tail reach has (P_{75}) less than 1,020 mm. The head and tail reaches receive fairly sufficient amounts of rainfall during both wet and dry seasons, while the middle reach receives sufficient rainfall only during the wet season. Historically, irrigation is practiced in the dry middle reach through innumerable small tank systems while run-of-river diversion schemes are used for irrigation in the upstream portion of the basin. After independence (1950s), two medium-sized storage reservoirs were constructed in the high-rainfall upstream portion of the basin. Subsequently, in the late seventies and eighties, many large-diameter agricultural wells have come into existence throughout the basin, mostly for irrigation during the dry season and for industrial purposes. Recently, a number of river lift irrigation schemes on either side of the river in the lower and middle reaches have started functioning.

During *maha* (rainy season) the river flows along its full length, discharging water to the sea. In *yala* (dry season), there is flow only in the head and tail reaches, while in the middle reach (for about 30 km), virtually no flow takes place since much of the river flow in the head reach is diverted for irrigation through run-of-river schemes and storage reservoirs. The flow

in the tail reach is due to the limited discharge from an intervening tributary joining the main stem of the river. The problem of no flow in the middle reach of the river has contributed to activities such as sand mining, brick making and pumping from riverbeds.

Urbanization at the head and tail ends of the basin is a special feature observed in the Deduru Oya river basin. This has contributed to pollution, causing negative impacts on water resources and the environment.

Population distribution plays a role in WRD. When we look at the distribution we see that the population density is low in the dry zone climatic conditions; we see that WRD is also low. These areas need special attention in river basin management because people in these areas are the most disadvantaged. These areas are characterized by poverty, water scarcity and dependency on paddy cultivation, based on small tanks, low productivity and lack of alternative employment opportunities.

The growth rate of the population is an important indicator of the availability and development of water resources. The high population density in places like Bingiriya may be due to migration of people looking for employment opportunities in industries and agricultural activities, as this area seems to be more prosperous than others.

Paddy and coconut are the major crops cultivated in the river basin. Coconut cultivation is the major perennial crop but it does not pose a threat for degradation of natural resources. Instead, it is arguably environmentally friendly, conserving soil and water. Paddy cultivation is the major livelihood activity of people living in the dry zone. However, paddy cultivation is gradually declining due to many problems faced by farmers, especially those who cultivate under minor irrigation schemes. The major problem they face is water scarcity due to low rainfall, silting of tank beds, lack of proper irrigation structures, reduced inflow to the tanks, pollution and other factors. Moreover, paddy cultivation is no longer profitable. These minor irrigation systems need to be protected from excessive sedimentation to maintain storage and the groundwater regime.

The situation in major irrigation schemes is different. A typical problem of major schemes is mostly the poor system management with symptoms including head-tail problems and poor maintenance, which ultimately contribute to poor productivity. Therefore, attempts in major irrigation schemes should be directed to institutional improvement for better system management.

The cultivation of other field crops (OFCs) such as vegetables is a major livelihood activity of people in the tail end of the river basin, especially along the river. Farmers who cultivate OFCs face serious problems similar to those associated with paddy cultivation under minor irrigation systems, due to salinity intrusion and inadequate water supply.

The industries associated with the river and reserved areas adjacent to the river, such as sand mining, brick making and tile making, and shrimp farming and processing pose severe threats to the river and its immediate ecosystem. Sand mining is the major cause of environmental problems in the Deduru Oya river basin. The damage to the river due to human actions is alarmingly high due to the readily available water supply and uncontrolled development by encroachers in the government-controlled river reservations.

Crop performance in the basin is affected mainly by problems associated with inadequacy of water and inefficient water management. However, the degradation of the river is much more serious than the problems in the areas away from the river. Therefore, proper management of the river and its ecosystem should receive top priority. The issues of water management in the basin can be broadly classified into four categories:

1. In the head end of the basin, adequacy of water is not a major problem. Issues such as better water management to improve the productivity of water assume significance.
2. In the middle portion of the basin where tanks and agricultural wells are predominant, inadequacy of water, especially during the dry season, and very poor performance of irrigated agriculture have led many inhabitants to live below the poverty line.
3. In the tail end of the system, inadequate flow in the river during the dry season, coupled with industrial development, such as shrimp farming, has created environmental problems, such as destruction of mangroves, intrusion of seawater, groundwater contamination and scarcity of drinking water.
4. The uneven flow and inequitable distribution of water in the river have caused scouring and deposition, and degradation of the river and river reservations.

East Rapti River Basin in Nepal

About 81 percent of Nepal's population is involved in agriculture, which contributes around 40 percent of the GDP. The irrigated agricultural area in the country is rising. The goal of WRD in the country is to tap and utilize water resources for social benefits. Beneficiary participation is a major thrust to achieve these goals. Developing the huge water resources potential of Nepal will not only meet the country's energy demand but also greatly help develop agriculture and industry, facilitate socioeconomic development and contribute to poverty alleviation. It is recognized that water is Nepal's key strategic national resource with potential to be a catalyst for development and economic growth of the country. Thus far WRD, especially in such areas as irrigation, hydropower, drinking water supply and sanitation, is far below the potential.

The east Rapti river basin (ERB) is a part of the Chitwan valley within the inner terrain of Nepal, with a drainage area of 3,120 km². Sixty percent of the basin is covered by forest. The average annual rainfall is 1,937 mm while the average annual potential evapotranspiration for the basin is 1,460 mm. The basin comes under the subtropical climatic zone and lies within two districts of Nepal: Makawanpur and Chitwan.

The population density of the basin as of 1998 was 212/km². Eighty percent of the population is involved in agriculture. The farm size per household is small (0.9 ha). Major crops grown in this basin are wheat, rice and maize. Their average yields are 1.85 t/ha, 2.5 t/ha, and 1.98 t/ha, respectively.

A major attraction of the basin is the national park in the tail region of the basin, covering a sizable area and constituting an important tourist attraction in Nepal. Providing reliable and adequate water supply to the Chitwan national park is one of the important aspects of water management in the basin.

The inflow to the basin comes from three sources: rainfall, diversion from the Kulekhani reservoir and lift from the Narayani river to feed to the Narayani lift irrigation system. Rainfall is concentrated during the 6-month monsoonal period from the middle of May to the end of October. July and August are the rainiest months, receiving nearly half the annual rainfall. Rainfall during the dry period is only 7 percent of the annual rainfall.

The long-term average monthly discharges at the confluence are shown in figure 6. The water accounting exercise of the ERB indicates:

- It is an open basin; only 53 percent of water is depleted. The remaining 47 percent of utilizable outflow moves out of the basin.
- Only 6 percent of the available water is process-consumed. The forests occupying 60 percent of the basin area consume a large portion of water. Non-beneficial depletion is only 5 percent.
- Agricultural water productivity is only US\$0.09/m³ of water consumed. Yields of cereals and oil-seed crops are low. There is a great potential to increase the water productivity of irrigated crops.
- Industrial and drinking water use is minimal and is mostly from groundwater.
- Groundwater use is presently very low. There is great potential to use groundwater conjunctively with surface water.
- Presently, the water requirement for the Chitwan park is not determined. Because of this any development plan put forward by other implementing agencies for developing the upstream areas gets bogged down in view of environmental objections. There is no organization existing at present in the basin to take a holistic view of water use within the basin and the impact of the upstream use on the downstream park.
- Many development plans for the east Rapti basin concentrate only on using the river flow. The river flow during the dry season originates from the groundwater aquifers as base flow. It should be possible to utilize this groundwater directly.

Irrigation systems categorized according to the management entities are called agency-managed, farmer-managed and jointly managed systems. The entire operation and maintenance (O&M) and other irrigation management responsibilities in the case of farmer-managed irrigation systems (FMIS) and fully turned-over systems lie within the WUAs. In the case of jointly managed systems, such responsibilities are mutually agreed upon and tasks are carried out accordingly. The focus of the Irrigation Department appears to be on rehabilitating the existing systems and developing joint management, with part of the system turned over to WUAs. In government-assisted systems, typical problems are inadequate collection of service fees and irregular maintenance, and, therefore, a need for rehabilitation after a few years. The question is how to break this vicious circle.

In this basin, there is great potential for groundwater development but organizations related to both surface water and groundwater act as different entities. Further studies are needed to explore the following:

- What kind of institutional change should be put in place to expedite the conjunctive uses of rainwater, surface water and groundwater, and increase productivity?

- What potential exists for smallholder irrigation systems to use low-cost and affordable technologies, such as drip, sprinkler, treadle pumps and low-horsepower pumps?
- What is the impact of groundwater use on the base flow of the river?

A number of organizations at the central government level are involved in the development and use of water within the basin. These are the National Planning Commission (NPS), Water and Energy Commission Secretariat (WECS), Ministry of Population and Environment (MPE), Groundwater Resources Development Board (GWRDB), Department of Hydrology and Meteorology (DHM), Nepal Electricity Authority (NEA), Nepal Water Supply Corporation (NWSC), Department of Water Supply and Sewerage (DWSS) and Department of Irrigation (DOI). A coordinated strategic approach to use the water more effectively is yet to emerge. Water management is still based on administrative boundaries rather than on hydrologic boundaries.

As long as sufficient water is available, the use of administrative units for water management at the sectoral level is not a big impediment; however, if there are upstream or downstream off-site impacts, then hydrologic boundaries and basin-level institutions become important. The east Rapti basin does not have institutions to solve problems, such as water requirements for the Chitwan park and the 36 village development councils in the buffer zone of the national park.

Singkarak-Ombilin Basin in Indonesia

The Singkarak-Ombilin river basin is located in the highland of West Sumatra Province and covers 2,210 km², with the Singkarak subbasin covering half of the area. The two subbasins are connected by the Singkarak lake. For the present study the Singkarak-Ombilin river basin, with an exit point at the Tanjung Ampalu river gauging station, was selected.

The Ombilin river is the only outlet of the Singkarak lake. Its discharge prior to the generation of the Singkarak Hydroelectric Power Project (HEPP) ranged from 14 m³/s to 120 m³/s with an average of 53 m³/s. After constructing the Singkarak HEPP the outflow to the Ombilin river is regulated at 2 m³/s to 6 m³/s.

Precipitation is the main inflow to the basin and, in the long term, there is a decreasing trend. Available water is mainly consumed by agricultural crops and natural forests. Only 25–37 percent of the gross inflow is used for process consumption due to the low cropping intensity of OFCs and shifting cultivation activities with slash-and-burn clearing techniques. During 1985–1998, the available water was not used to the fullest extent during wet and normal years, and the range of the total water depleted from available water is 35–81 percent.

The Singkarak-Ombilin basin is an open basin, which may become closed when the hydropower plant operates at its maximum discharge of 77 m³/s. Furthermore, under those operating conditions, the outflow from the Singkarak lake to the Ombilin river would be lower than the committed flow of 2–6 m³/s. The changed flows have already affected irrigated agriculture in the Ombilin basin. The conventional method of irrigation by using bamboo waterwheels for lifting water from the river to rice fields on the Ombilin river meadows may not be feasible anymore, and a new technology with low O&M cost and continuous flow should

be studied. The area below the Singkarak lake but above the Selo river is most affected by the decreased outflow from the Singkarak lake.

Rice production of the entire basin has been increasing at an average rate of 7,509 tons/year (3% of annual production). However, rice productivity at 0.94 kg/m³ of consumed water remained constant during this period and the increase in overall production is a result of increasing cropping intensity. The overall cropping intensity increased at 5.4 percent per year and most of it (5%) is due to rice cultivation.

Availability of water in this basin is highly affected by the amount of water diverted from the basin into another basin (transbasin diversion). The changes in land use from year to year have not resulted in major changes in depletion of water. In keeping pace with the expansion of industrial activities within and around the basin, water tends to be allocated for industrial uses such as for hydropower, thermal power plants and coal mining instead of for agriculture. This has a great impact on farmers and communities with low incomes from agriculture. Water rights, water allocation and reallocation rules should be studied comprehensively, since water allocation and transbasin diversion based on private-sector development often ignores the needs of the poor people.

Upper Pampanga River Basin in the Philippines

The Upper Pampanga river basin (UPRB) located in Central Luzon, the Philippines has a total drainage area of 374,250 hectares. Within the basin, the Upper Pampanga Integrated Irrigation System (UPRIIS), which became operational in 1975, is designed to irrigate 102,500 hectares. In addition to UPRIIS, there are communal irrigation systems and rain-fed areas contributing to the overall rice production within the basin.

Agriculture has been the dominant user of water but because of the growing population, domestic water supply, coupled with industrial, commercial, recreational and environmental requirements, is fast catching up. Given the beneficial water demand for the present and future, the outflow from the basin, which is still substantial, will be the focal point of interest.

According to the rainfall pattern in the basin, there are two distinct seasons—wet and dry. The dry season lasts from November through April while the rainy season lasts from May to October. On average, there are 22 annual weather disturbances (tropical depressions, storms and typhoons) in the Philippines, causing floods due to inadequate storage in the river basin.

The average rainfall of the basin is 1,881 millimeters with a coefficient of variation of 12 percent. Except during the El Niño rains, the annual rainfall does not vary by more than 15 percent from the mean annual rainfall. More than 92 percent of rainfall occurs during the wet season and, therefore, there is a pronounced need for irrigation, especially during the dry season.

Realizing the need to harvest the excess rainfall runoff, the government has embarked on constructing a small water impoundment within the basin, with capacities to supply irrigation water to 50 to 100 hectares of riceland. Small farm reservoirs ranging from 500 m³ to 2,000 m³ in capacity are also being built for small rice farms outside the service area of UPRIIS.

Rice is the major crop during the wet season, followed by rice and upland crops during the dry season. Onion, tomato and garlic are some of the popular crops grown in UPRIIS. The estimated long-term consumptive water use has a mean value of 2,537 mm with a standard deviation of 60 mm.

Underneath the flood plains of the basin lies a vast groundwater reservoir. Aquifers with shallow to medium water depth are common as evidenced by tube wells installed as deep as 12 m within the area.

Yields in traditional grains like rice and corn improved steadily but not dramatically from the period 1946–50 (1.11 tons/ha for rice and 0.61 tons/ha for corn) to the period 1991–96 (2.85 tons/ha rice and 1.46 t/ha for corn). The population growth rate (2.32%) outpaced the growth rate in agriculture (0.72%) from 1994 to 1996. In 1997, the livelihood of 63 percent of the population depended on agriculture.

The area devoted to agriculture is decreasing due to the pressures of urbanization and industrialization, which continue to hamper production efforts. Therefore, the need to optimize available land for agriculture is imperative, which is only possible if water is available. The UPRB provides a stable food requirement of 25–30 percent of the total population of the Philippines.

The average annual discharge moving out of the basin is roughly 4,000 million m³. The water available in the basin is sufficient for potential use for the foreseeable future. Multiple use of irrigation water by cities and industries does not significantly reduce the amount of water for agriculture but it pollutes the water to a great extent.

Scarcity of irrigation water occurs at the tail end of irrigation systems. Dwindling water supplies for domestic uses occurs particularly in areas where water is taken from springs. In populated areas where domestic and industrial water is drawn from groundwater aquifers, the drawdown is felt in nearby farming communities, where water yield in wells tends to decrease.

Due to multiple use of water, the quality of surface water is beginning to deteriorate in terms of physical, chemical and biological characteristics. Solid waste, particularly polyethylene plastic materials and rubber from cottage industries, clogs waterways and irrigation channels. The absence and inadequate capacities of sewage treatment plants in cities and municipalities result in the draining of wastewater and raw sewage into rivers and creeks.

Future Trends in Irrigated Agriculture

A new multipurpose reservoir (Casecnan Project) would provide irrigation facilities to an additional area of 30,000 hectares. This will bring 92 percent of the cultivable area (140,000 hectares) of the basin under irrigation. The remaining 11,200 hectares will be under rain-fed cultivation, where a limited amount of groundwater irrigation can be attempted.

Presently, the irrigation intensity is only 150 percent. With the construction of the Casecnan multiple purpose irrigation and power project, the irrigation intensity can be increased to 180 percent through better control of water supply. Maintenance is a major problem in this system. Heavy investment is required to rehabilitate the system and turn it over to Irrigators' Associations.

One way of conserving water is to better utilize rainwater through in-situ conservation in fields. Construction of the Casecnan multipurpose project will materially improve the availability of water and reliability of its supply. More water-storage facilities and water conservation measures are needed to optimize the utilization of the uncommitted portion of the available water (2,500 million m³).

Comparative Analysis of Five Basins

Physical and Hydrological Features

The basins selected for the study vary over a wide spectrum of climatic and water availability conditions (table 1).

The FRB has the largest drainage area, approximately ten times larger than the smallest, the Singkarak-Ombilin basin. The other four basins have more or less similar extents of drainage area, varying from 2,000 km² to 4,000 km². The average annual rainfall varies over a wide range, from 570 mm in the FRB to 2,025 mm in the Singkarak-Ombilin. The other three basins lie in between. Per capita water availability varies from 868 m³/year (FRB) to 9,034 m³/year (east Rapti).

The FRB is a closed basin while the Singkarak-Ombilin and UPRB are open basins. In open basins, more water could be developed and beneficially depleted upstream without diminishing existing uses: in other words, the opportunity cost of additional depletion is zero. A closing basin has no more remaining available water flowing out of the basin during part of the year, typically a dry season. In a completely closed basin, all water is committed to environmental and process uses. The east Rapti is seasonally water-scarce while the Deduru Oya is both spatially and seasonally water-scarce. The population density per km² is highest in the FRB (686/km²) and lowest in east Rapti (212/km²). The urban population is highest (36%) in Pampanga and lowest in the Deduru Oya (10%). The percentage of the population engaged in agriculture is highest in east Rapti (79%) and lowest in the Upper Pampanga (22%).

The type of irrigation practiced varies widely. In the Singkarak-Ombilin basin only surface irrigation takes place, with river lift pumps and waterwheels. In Deduru Oya, most of the area is irrigated by surface gravity from small tanks and medium reservoirs, with some areas irrigated by dug wells and river-lift pumps. In east Rapti, most surface irrigation is by river-diversion schemes, aided by a limited number of shallow tube wells. In the Upper Pampanga, irrigation is mainly from a large reservoir, supported by communal irrigation schemes and shallow tube wells. In the FRB, most irrigation is from shallow and deep tube wells, coupled with supply from large and small reservoirs as well as from diversion schemes. The net area irrigated as a percentage of basin area is highest in the FRB (45%) and lowest in east Rapti (12.8%). Annual cropping intensity varies from 200 percent in Singkarak-Ombilin to 133 percent in Deduru Oya.

Domestic and industrial water supplies are mainly from the Singkarak and Ombilin rivers in Indonesia, while they originate mainly from groundwater in east Rapti in Nepal and in Upper Pampanga in the Philippines. In the Deduru Oya and the FRB, both surface water and groundwater are used. East Rapti and Deduru Oya have no power plants while FRB in China has 14 power plants. In all basins except FRB, rice is the main crop while in FRB, wheat and corn are the main crops. Per hectare yield is highest in FRB and lowest in east Rapti and Deduru Oya.

Table 1. Salient characteristics of the river basins selected for study.

Basin Characteristics	Fuyang	Singkarak-Ombilin Subbasin	East Rapti	Upper Pampanga	Deduru Oya
Country	Peoples Republic of China	Indonesia	Nepal	Philippines	Sri Lanka
Catchment area (sq. km)	22,814	2,210	3,135	3,742	2,623
Location : Province	Hebei	West Sumatra	Not applicable	Nueva Ecija	North Western
District/s	Shijiazhang, Handan, Xingtai	Solok, Tanah Datar and Sawah Lunto Sijunjung	Makawanpur Chitwan	Bulacan Pampanga	Kurunegala Puttalam
No. of urban centers	345	4	3	3	2
No. of villages	9,092	400	Not known	325	2,663
Average annual rainfall: Normal year	570 mm	2,025 mm	3,576 mm	1,994 mm	1,494 mm
Dry year	200-300 mm	1,163 mm	1,778 mm	1,100 mm	1,152 mm
Per capita water availability (m ³)	868		9,034	3,630	1,046
Facilities /Assets					
No. of irrigation schemes (surface irrigation)	3 (major) and a number of small storage systems	None (Ombilin Subbasin)	214	37	3, 4, 3,596 major, medium and minor systems respectively
No. of lift irrigation units (groundwater & river lift)	185,527 (groundwater)	14 pump and 184 water wheel (Ombilin subbasin)	Shallow tube wells = 589; Dug wells = 1,809; treadle pumps = 47	9	shallow wells = 2,450
Domestic water supply schemes	41	2 (Ombilin subbasin)	45	17	37 pipe-borne 1,199 tube wells
No. of hydropower plants	14	1 Hydroelectric, 4 micro hydroelectric power plants	None	2	None
Land use and agriculture					
Cultivated area (ha)	1,239,000	130,291	85,578	254,490	201,585
Grassland/Savannah (ha)	-	11,234	10,500	4,117	55
Forestland (ha)	119,000	45,498	120,959	37,425	8,035
Area covered with water bodies (ha)	223,800	1,956	17,275	9,600	1,410
Surface irrigated area (ha)	150,000	32,180	32,388	98,222	47,150
Groundwater irrigated area (ha)	875,000	-	7,743	25,135	1,515
Main irrigated crops	wheat, corn, cotton, rape seed	rice, mungbean, groundnut	rice, maize, wheat	rice, vegetables, corn, onion	rice, chili, pulses, vegetables
Annual cropping intensity (%)	155	rice irrigation=200 other field crops=38	274 = irrigation from main river 257 = irrigation from tributary	156 = surface irrigation 200 = groundwater irrigation	133-165 = surface irrigation 180-300 = groundwater irrigation
Irrigated area (%)	45	14.8	12.8	33	18.5

Water Accounting Indicators

A number of performance indicators described by Molden and Sakthivadivel (1999) were calculated for the five basins. Out of these, four important indicators have been selected for comparison and are discussed here (table 2).

Table 2. Water accounting indicators for a typical normal year.

Indicator	Basin				
	East Rapti	Singkarak-Ombilin	UPRB	Fuyang	Deduru Oya
DF_{gross}	0.34	0.41	0.51	1.08	0.85
$DF_{available}$	0.39	0.50	0.63	0.98	0.85
$PF_{available}$	0.05	0.17	0.38	0.74	0.50
$PF_{depleted}$	0.12	0.35	0.58	0.75	0.58

Note:

DF_{gross} = Depleted/Gross inflow.

$DF_{available}$ = Depleted/Available water.

$PF_{available}$ = Water consumed for intended purposes/Available water.

$PF_{depleted}$ = Water consumed for intended purposes/Depleted water.

The first indicator, depleted fraction with respect to gross inflow (DF_{gross}), indicates how much water entering the basin is depleted. Depleted water includes water evaporated by soil and open bodies of water, transpired by beneficial and non-beneficial vegetation, process consumed and water entering into sinks. Gross inflow is the total amount of water flowing into the water balance domain from precipitation and surface and subsurface sources. The higher the DF_{gross} , the more the depletion of water. A value more than 1 indicates that depletion exceeds gross inflow and mining of groundwater is taking place. It can be seen from table 2 that Fuyang is depleting more than what it receives (an unstable situation), that in east Rapti only 34 percent of inflow is depleted and that in the rest 66 percent of gross inflow leaves the basin. Next to Fuyang, Deduru Oya depletes the largest proportion of the gross inflow entering the basin.

The second indicator, depleted fraction with respect to available water ($DF_{available}$), gives an indication of how much water is still available for further use. Available water is the net inflow (gross inflow adjusted for any changes in storage, e.g., groundwater withdrawal as in Fuyang), minus both the amount of water set aside for committed uses and the nonutilizable uncommitted outflow. Committed uses include that part of outflow from the water balance domain that is committed to other uses such as downstream environmental requirements or downstream water rights. Thus available water includes process and non-process depletion plus uncommitted water. The variation of this indicator is similar to that of DF_{gross} . $DF_{available}$ can be interpreted as scope for further development. In other words, 98 percent of the available water is utilized in the Fuyang basin while only 39 percent of available water is used in east Rapti. Chances for further development exist in east Rapti, while that alternative is minimal in Fuyang. Increasing agricultural water productivity should be attempted through other means.

The third indicator, process fraction of available water, $PF_{\text{available}}$, is the amount of process depletion divided by the amount of available water. $PF_{\text{available}}$ indicates how much of the available water is consumed for intended purposes such as for irrigation, drinking, and industries. This indicator varies from 5 percent in east Rapti to 74 percent in Fuyang.

The fourth indicator, process fraction of depleted water, PF_{depleted} , is the amount of process depletion divided by total depletion. PF_{depleted} indicates how much of the depleted water is process consumed (used for intended purposes). The pattern of variation of this indicator is similar to that of $PF_{\text{available}}$.

Current Water Management Issues

Table 3 lists some important water management issues arising from water availability (adequacy, spatial/temporal distribution, surface water and groundwater), present use, competition among and between sectors and pollution aspects. A study of these current issues will lead us to identify emerging issues and related industrial aspects. The emerging issues are listed in table 4.

Linking Water Accounting to Institutions

An effective institutional arrangement is a key requirement for a high performing water resources systems. What constitutes an effective institutional arrangement? We argue that there is no single best institutional model to satisfy all types of river basin systems, as institutional requirements vary depending on the stages of development of basins. In fact, institutions evolve depending on the water resources issues that the basin faces and need to be solved. The hypothesis presented in this paper is that depending on the issues faced by a river basin, institutions must adapt to tackle those changes. Therefore, effective institutions are not static systems but must be adaptive and dynamic to tackle the current and foreseeable issues that the basin is likely to face.

Three broad stages of development are identified: infrastructure development, utilization and allocation (figure 5). We use a water accounting methodology to illustrate these stages of development. We argue that, over a period of time, institutions must change their focus from development of infrastructure, to better utilizing and conserving water resources during the utilization stage, and lastly to improving allocation and regulation of water resources within a basin context. In the initial stages of development, the institution may serve a single purpose and has limited functionality. As the basin develops, they either expand their functions, or other institutions may evolve to fulfill management requirements. These concepts will be illustrated in the five case studies.

In the development stage of infrastructure, 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 increasing supplies. Institutions typically emerge to serve a single function, mainly oriented to the construction of infrastructure.

In the utilization stage, a significant development of infrastructure has taken place. There are opportunities for further development; however, the cost-effective goals are to make the best use of the already developed facilities. Water conservation and saving, improved

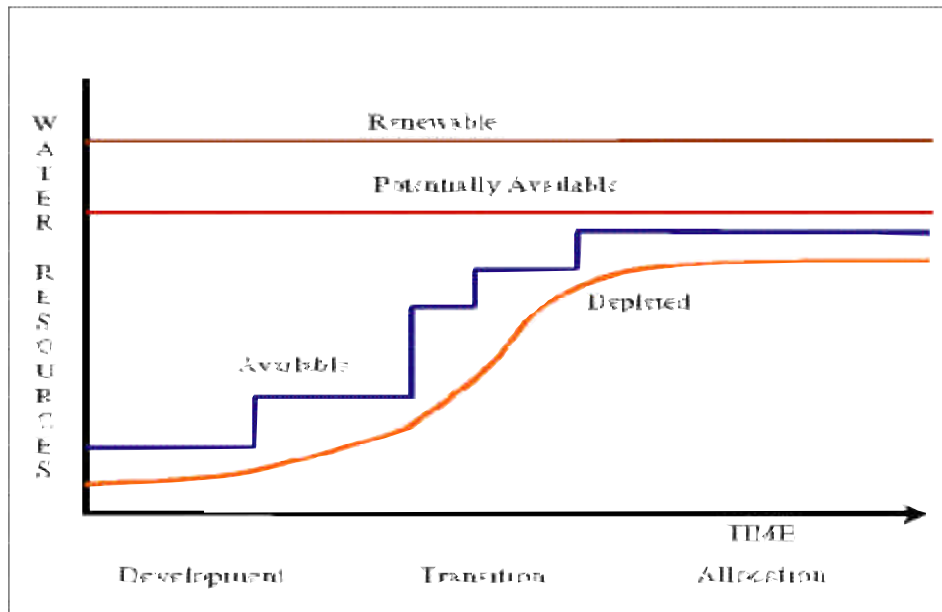
Table 3. Some important current water-management issues.

Issues	Basin				
	Fuyang	Dedura Oya	East Rapti	Singkarak-Ombilin	Upper Pampang
Water scarcity	Acute (quantity-wise).	During dry season scarcity in the middle reach (spatially and temporally).	Scarcity during the dry season (spatial).	Scarcity in terms of depth of flow.	Scarcity during dry season and flooding during wet season.
Inter-sectoral competition	Very high. Agriculture worst affected.	Competition between drinking water and agriculture	Competition between environment and irrigation.	Competition between hydropower and irrigation (trans-basin diversion)	Competition between industry, drinking and agriculture (especially groundwater).
Environmental issues	Groundwater decline; degradation of the quality of surface water and groundwater; untreated sewage into rivers.	Seawater intrusion, sand-mining, destruction of mangroves by shrimp farming; waste from hospital and rice mill; wastewater pollution, siltation of tanks.	Ecological health of flora and fauna affected; wildlife migration and industrial pollution; watershed degradation, O&M.	Surface water treatment cost increased; watershed degradation, lake sedimentation.	Rubber factory, duck and fish rearing and small-scale industrial pollution.
Water resources development/conservation /allocation	Water conservation and increasing productivity are increasingly adopted.	Potential for water resources development exists. Performance of water allocation and irrigation system low.	Potential for conjunctive use of groundwater at low cost exists; very low use of surface water and groundwater.	Allocation of basin water and participation of stakeholders important.	Efforts are expended to conserve surface water and rainwater. Better irrigation management.
River flow and reservoir status	Flow over the years decreased rapidly; reservoir levels are decreasing.	River management is poor. Siltation of tanks has reduced the capacity.	No storage structure along the river; run-of-river schemes; quite large variation in river flow.	Trans-basin diversion; lake level decreasing; depth of flow in the river is low.	Flooding and drought occur alternately; huge uncommitted outflow.
Groundwater status	Large-scale extraction of groundwater. Water table declining fast; groundwater contamination.	Very limited groundwater; quality of groundwater bad at middle and tail reaches.	Very limited groundwater is used; good quality groundwater available.	Not much groundwater is in use.	Groundwater use is on the increase; competition for groundwater exists.

Table 4. Emerging issues.

Issues	Basin				
	Zuytdig	Dadum Oya	East Rapd	Singharab-Ombilin	Upper Pampanga
<i>Basic Level Issues:</i>					
Need for reliable data and information management		X	X	X	X
Inadequate or absent basin-level planning procedures		X	X	X	X
Absence of well-defined water rights and allocation principles		X	X	X	X
Absence of short-term measures					
Lack of information and pollution control both surface water and groundwater	X		X	X	
Absence of institutional mechanisms to integrate present and use of surface water and groundwater resources	X	X	X	X	X
<i>Low priority Sector Level Issues:</i>					
Water inadequacy during dry season	X	X	X		X
Load and differences		X			X
Groundwater decline	X				
Low productivity		X	X		
Inadequate water control		X			X
Waterlogging and flooding					X

Figure 5. Phases of river basin development.



management of water deliveries, and maintenance and management of already-built structures are important objectives. In this phase, managing the supply of water to various uses is a primary concern. Pollution and water scarcity are localized issues, but they begin to emerge as major issues. Institutions are primarily concerned with sectoral issues, such as managing irrigation water or managing supplies of drinking water. In many situations, environmental issues exist but they are not given proper recognition.

In the allocation stage, closure is approached and depletion approaches the potential available water, with 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-value uses. Managing demand becomes increasingly critical. Construction of infrastructure is limited to those that aid regulation and control. Institutional issues concern allocation, conflict resolution, regulation, pollution prevention and environmental preservation. Several important management and regulatory functions gain prominence, including inter-sectoral allocation. Coordination becomes important, involving significant transaction costs. To effectively carry out these functions, either a single entity emerges, or several interlinked organizations may manage these functions. Interlinked organizations may be seen in the case of the Brantas Basin in Indonesia and the South Platte River Basin in Colorado, USA. Institutional concerns differ depending on the stage of development. These concerns may exist during all stages but their importance or emphasis may change over time as the basin develops, as illustrated in table 5.

Table 5. Concerns at different stages of development.

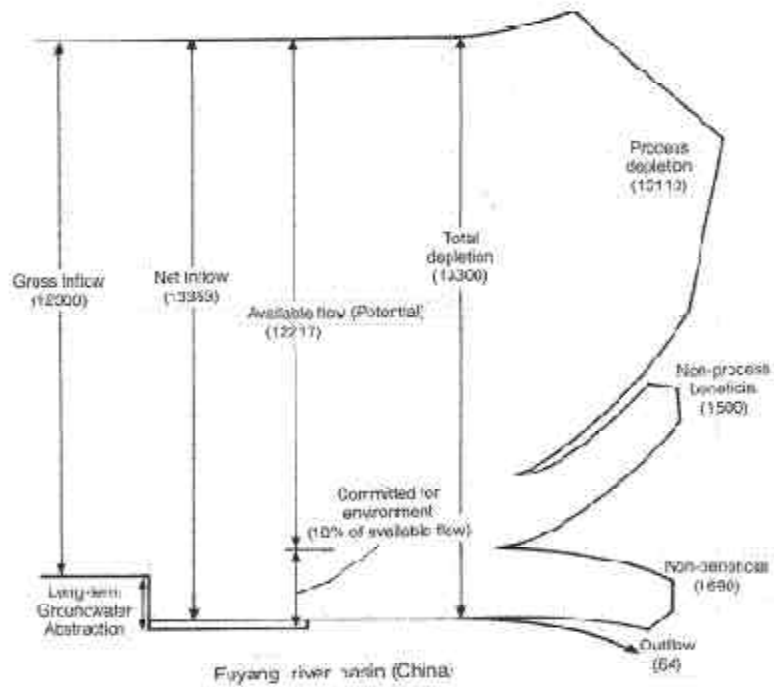
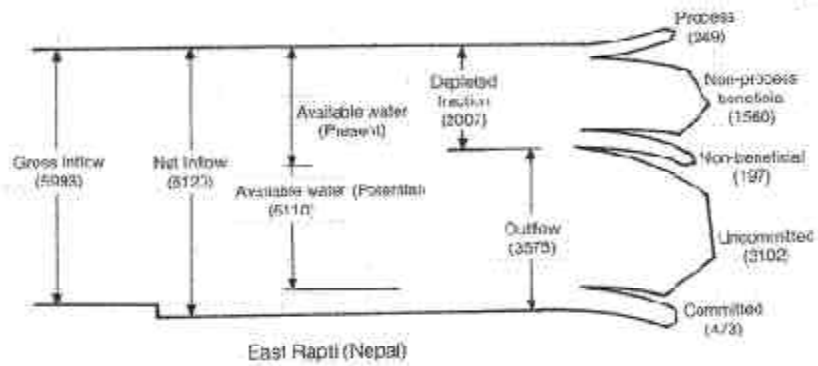
Development	Utilization	Allocation
Construction	Improving O&M services for better water use	Shifting to higher-value uses
Managing supply distribution	Investing in O & M and managing through both supply distribution and demand management	Managing demand
Low value of water	Increasing value of water	High value of water
Large structures	Modernization and rehabilitation, recycling of return flow, water harvesting	Measurement and regulation
Utilizing groundwater	Conjunctive management	Regulating groundwater
Diffusing pollution	Emerging pollution/salinity	Cleaning up and preventing pollution
Fewer water conflicts	Conflicts within systems	Conflicts between and among systems
Economic water scarcity	Localized water scarcity, river encroachment	Physical water scarcity
Water data not so important	System water delivery data important	Data on basin-water accounting important
Stakeholders excluded in decision making : poor water-related services	Management transfer in irrigation systems, involving stakeholders in decision making	Service orientation in water distribution
Developing new water resources with less emphasis on environmental needs	Agricultural, domestic and industrial pollution, off-site effects, waterlogging, drying of wetlands	Allocating water to environment
Problem of poverty: poor excluded from development	Poor people not involved in decision making	Pro-poor interventions: poor are the main beneficiaries do not push them out

Examples

River basin water accounting provides a clue as to where to focus efforts in institutional transformation to use the basin water efficiently, produce more per drop and sustain the productivity and environment of the system. The water accounting finger diagrams for two typical cases (east Rapti and Fuyang) are shown in figure 6.

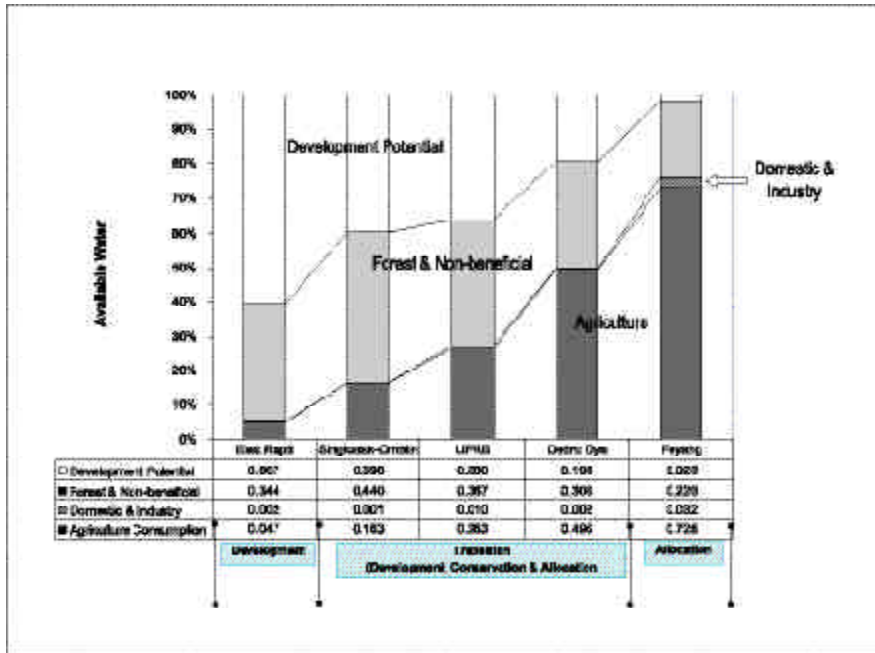
In the case of ERB, the problem is not one of water availability but exploiting and utilizing groundwater resources in addition to efficient use of available water (both surface water and groundwater). At the level of the irrigation sector, there is an urgent need to tap the potential of groundwater and use it efficiently to produce more. The emphasis at the level of the irrigation system must go to improving operation, maintenance and management of the system, better fee collection, and improving productivity and profitability of the farmers. At the basin level, there is a need to allocate the water for different purposes taking into account the on-site and off-site impact of water use. Industrial pollution is also on the increase. Intense competition for river water during the dry season among wildlife sanctuaries, tourist requirements,

Figure 6. Water accounting finger diagrams.



All units in 10^6 m^3

Figure 7. Basin water use and development potential.



maintaining the ecological health of the system, and supplying water for irrigation for settlers evacuated from the wildlife sanctuary area need immediate attention. Increasing the agricultural productivity of water through conjunctive use of surface water and groundwater is also an important issue.

In the case of the Singkarak-Ombilin basin, availability of water appears to be sufficient for all uses in the foreseeable future. But development is taking place through private-sector initiatives without due regard to the existing uses such as agriculture through water wheels. Stakeholder participation is minimal in basin planning. Hydroelectric development and coal mining have introduced adverse impacts on paddy irrigation and on the quality of drinking water supplies. Watershed degradation and siltation of lakes and water bodies are a major issue. Agricultural productivity is stagnating. This basin, which was once purely devoted to agriculture, has fast transformed into a basin of large scale industrial activities without due regard to the existing use of water and its technology.

This basin is in a transitional stage from infrastructure-development to utilization; it is transforming from irrigated agriculture to industrial development. This basin development also clearly indicates how the poor are pushed out from using traditional water wheels, and how industrial requirements such as power production are taking over.

UPRB is a water-surplus basin with substantial utilizable outflow from the basin during the wet season. The WRD through reservoir construction, water harvesting and effective use of rainfall is an important activity. The basin has good groundwater potential. Development and use of groundwater in conjunction with surface water constitute another area necessary to increase productivity of irrigated agriculture. Competition for groundwater between drinking and agriculture is on the increase, as is water pollution. Head-tail differences in water availability in irrigation systems are a major determinant for agricultural productivity. It is the one basin where paddy yield has stagnated or declined during the last 10 years. Flooding, waterlogging and drainage problems are important issues in this basin. Maintenance of already developed infrastructure and learning more effective water utilization are important.

In the case of Deduru Oya, the problem is one of maldistribution of water supply in space and time. Unfortunately, in this basin, there is very little capacity to store groundwater and use it during dry season. Although there is an adequate supply at the basin level, at local levels there is inadequate water supply for use. Even at the sectoral level, water use is not very efficient. One of the basic problems that farmers face in this basin is inadequate management of the rivers and reservation areas along the river. Although the government agents of the districts should manage these resources (river and river ecosystem), their efforts are not sufficient and, therefore, there is misuse (pollution, sand mining, intrusion of seawater, shrimp farming, river lifts, and brick making). Therefore, there is a clear need to strengthen the management of these resources and to develop a strategy to overcome the spatial and temporal variation in the availability of water supply in the basin.

The FRB in China is a closed basin. Sectoral development and use of water are very high. However, intensive sectoral use of water has led to overdraft of groundwater, falling water tables, and pollution of surface water and subsurface groundwater. The major problem appears to be not at the sectoral level but at the basin level. Although the sectoral-level agencies realize the importance of pollution of surface water and groundwater depletion, there are no effective mechanisms as yet to deal with these issues. The immediate necessity is to arrest overextraction of groundwater and stabilize agricultural production. Integrating the surface water and groundwater use and increasing the water productivity should be attempted through demand management. Real water saving is limited in the basin and this should be achieved through reducing pollution. Water conservation through reduction of pollution, pollution mitigation and improving land and water productivity are the major issues in the basin.

Concluding Remarks

The water accounting methodology, coupled with the conceptual framework suggested in the paper, provides a good starting point for analyzing institutional transformation of river basins. As a river basin progresses from an “open” to a “closed” basin, three stages of development are identified: infrastructure development, utilization, and allocation and regulatory. There is no single “best” institutional model for river-basin management. Rather, institutional requirements differ with different stages of development and the issues currently faced and to be faced in the near future.

In many instances, institutional transformation is thought about and put in place to tackle a whole range of issues: pollution, poverty, allocation, regulation and construction. Depending on the stages of development of a river basin, some of these issues are not major concerns, and hence institutions concerning these issues become dormant and obsolete. It may be inappropriate to force premature development of institutions. Institutions for the management of water resources must adapt to meet different challenges as patterns of water use change. A key feature of an effective institutional design is the ability to adapt to changing needs.

There are nascent basin issues such as industrial and domestic pollution, and competition for water during the dry season. One important basin issue to resolve is the water need for environmental and ecological purposes such as for tourists, wildlife, and wetlands. The relationship between ecological services and additional withdrawals is not known. Efforts for water development may be withheld because of this constraint.

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CHAPTER 3

Socioeconomic Conditions in the Five River Basins

Madar Samad¹

Introduction

This document provides a synthesis of the salient socioeconomic features of the five basins selected for the study: east Rapti (Nepal), Inderagiri-Ombilin (Indonesia), Upper Pampanga (the Philippines), Deduru Oya (Sri Lanka), and Fuyang (North China). The analysis is based on the reports of the socioeconomic investigations carried out by the respective national research teams. The aim of the socioeconomic studies is to develop a deeper understanding of the socioeconomic conditions in a river basin in order to devise institutional options that would cater to the specific needs of the community and the society at large. Detailed information is given in the respective country reports.²

Historically, river basins have been the scene of the development and progress of human societies. There is clear evidence that the momentous change of human life style from a mostly nomadic way of life to sedentary farming that occurred several thousand years ago took place in narrow river valleys. The second major turning point in human history also occurred along riverbanks, this time along rivers of northern England, which powered the early factories that set off the industrial revolution. Over the years, rivers and their hinterlands have been the centers of intense human actions that have had profound impacts on the river basin as an ecosystem and human society.

The paper begins with an overview of the macroeconomic context, focusing specifically on the key objectives of the national water sector policy. The next section summarizes the key physical characteristics of the basins. The sections that follow deal with some key aspects of the socioeconomic situation prevailing in the respective basins.

Macroeconomic Context

There are marked variations in the water resource endowments and their utilization in the five countries selected for the study. In aggregate terms, Indonesia is well endowed with water, with an annual per capita water supply of 14,000 m³. But there are marked regional variations,

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²Perera et al. 2000; Ghimire et al. 2000; Center for Chinese Agricultural Policy 2000; Ifdal and Helmi, 2000; Orden et al. 2000.

with less than 2,000 m³/capita/year in parts of Java to some 28,200 m³/capita/year in Irian Jaya. The Philippines, with 12,000 m³ and Nepal with 10,000 m³ also have abundant water supplies. Annual per capita water resources of Sri Lanka and China are 2,400 and 2,200 m³, respectively, with the latter, especially its northern region, fast becoming one of the most water-scarce regions in the world.

Agriculture remains a vital sector of the economy in the five countries selected for the study. It is the largest user of water, accounting for about 70 percent of withdrawals in China and over 90 percent in each of the other countries. However, in four countries, China, Indonesia, Philippines, and Sri Lanka, the contribution of agriculture to the Gross Domestic Product (GDP) has declined vis-à-vis industry and the services sector. In Nepal, it remains the dominant sector and accounts for about 40 percent of the GDP.

Providing sufficient good quality drinking water for the increasing populations is a high priority policy item in all five countries. Other policy objectives vary from one country to another. In China, flood control, water pollution and water conservation are major components of government policy on water resources development (WRD). Irrigation is considered vital for China's food security but public funding for irrigation development is much less than investments in other areas of WRD. In all other countries, provision of irrigation facilities, especially for rice production, has been a dominant component of WRD along with other objectives such as hydropower generation, urban water supply, sanitation, protection of the environment, and controlling water pollution. In the irrigated sector, transferring operation and maintenance (O&M) responsibilities to irrigators is an established policy in all five countries. In more recent times, river basin management within the framework of integrated management of water resources is a dominant theme in national policy discussions.

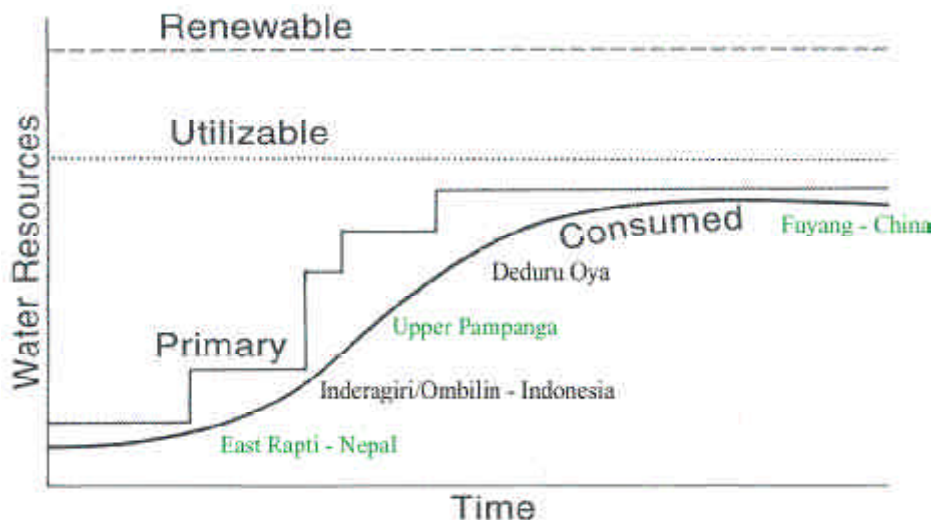
The indications are that WRD in the five countries, which for most of the twentieth century focused on irrigation development, is being refocused to achieve a broader set of objectives. There is greater emphasis on efficiency in allocation and management of the resource, equity considerations and environmental sustainability. There is a greater recognition of the need for institutional reforms in the water sector, user participation in water management, clearer definition of property rights and a greater appreciation of the growing scarcity of water.

Physical Characteristics of the Basins

Each of the five river basins selected for the study typifies a specific stage in the development of river basins (figure 1). At one end of the scale is the east Rapti river basin in Nepal, an open basin, relatively underdeveloped but well endowed with water resources. Per capita water availability is estimated at about 9,000 m³. At the other extreme is the Fuyang river basin in China, which is a closed basin. With an annual per capita water availability of 868 m³, it is one of the most water-short regions in North China.³ The other three basins fit in between these two extremes as indicated in figure 1, and display varying stages of development and levels of water scarcity.

³A more recent estimate suggests that per capita water availability is less than 400 m³ (Wang and Huang 2001).

Figure 1. Hypothetical development stages of a river basin.



Note: Prepared by M. Samad, IWMI, Colombo, Sri Lanka.

The Upper Pampanga basin is relatively well endowed with water, with per capita water availability exceeding 3,500 m³. The Deduru Oya basin in Sri Lanka, with an annual per capita water supply of 1,046 m³, is seasonally water scarce, especially during the peak of the dry season when there is hardly any flow in the rivers. It is also spatially water scarce, especially in the midstream region of the basin, which is predominantly in the drier region of the basin.

East Rapti in Nepal, with an annual per capita water supply of 9,034 m³, is comparatively well endowed but there is a significant reduction in river flow in the dry season. An added feature of this basin is the need to commit water for environmental purposes (for a national park) and also the need to take into account transnational water transfers. The Ombilin subbasin located in the upper reaches of the Kuantan-Inderagiri river basin in West Sumatra, Indonesia is an “open basin.” However, there is intense inter-sectoral competition for water and a high incidence of water-related conflicts.

Demographic Characteristics

Population Distribution and Employment

Table 1 gives the salient demographic features of the basin. The populations in all five basins are concentrated in rural areas. The Fuyang river basin is the most densely populated basin and east Rapti the least. In the Deduru Oya basin, there is a heavier concentration of population in the head and tail areas that are more urbanized than the middle region of the basin. High population growth has been reported in east Rapti and Upper Pampanga.⁴ In Deduru Oya, there is an overall decline in the population growth rates but there is evidence of an increase

Table 1. Salient demographic features of the selected river basins.

Characteristics	Fuyang (China)	Inderagiri -Ombilin (Indonesia)	Upper Pampanga (Philippines)	East Rapti (Nepal)	Deduru Oya (Sri Lanka)
Total population (million)	15.6	0.7	1.5	0.6	1.0
Population density (persons/km ²)	686	396	450	212	378
No. of urban centers	4	4	3	3	22
No. of villages	9,092	400	325	na	2,807
Urban population (%)	28	na	36	25	10
Rural population (%)	72	na	64	75	90
Per capita availability of water (m ³)	868	na	3,630	9,034	1,046
Urban households having piped water (%)	97	na	27	36	21
Rural households having piped water (%)	77	na	na	na	09
Proportion employed in agriculture (%)	67	59	61	79	40
Proportion of population living below national poverty line (%)	6	na	39	42	60

in population in the more urbanized area suggesting an increase in rural-urban migration.⁵ Population growth, especially growth in the urban population, will result in an increase in the demand for domestic water supply.

In all locations, statistics on employment specific to the basin are not available. Yet, employment data from the various administrative areas that fall within the basin indicate that, overall, agriculture is the major source of employment of the inhabitants of the respective basins. The proportion of the population dependent on agriculture varies from 40 percent in Deduru Oya to 79 percent in east Rapti.

Incidence of Poverty

The least incidence of poverty is in the Fuyang basin with only 6 percent of the population living below the official poverty line. In three other locations the incidence of poverty is high: Pampanga, 39 percent; east Rapti, 42 percent; and Deduru Oya, 60 percent. Detailed information on poverty is given only in the Sri Lankan and the Nepalese case studies.

In the Deduru Oya basin, pockets of poverty have been reported from the principal urban center (Kurunegala). The other location where poverty is more pronounced is in the midstream area of the basin situated in the drier region, where there is acute scarcity of water, especially in the dry season. In the latter case, poverty is attributed to low agricultural productivity levels due to the scarcity of water.

In east Rapti, poverty is more pronounced in the rural areas than in the urban centers. Besides location effects, there are also strong caste and ethnic dimensions to the poverty problem. Certain groups identified as “primitive” and leading mostly a nomadic life are among the worst affected. The incidence of poverty is reportedly high among the ethnically disadvantaged groups, especially among fisher communities. This is primarily due to decreasing

⁴2.7% and 2.9% per annum in the two districts in east Rapti (Ghimire et al. 2000) and 2.9% per annum in Upper Pampanga (Orden et al. 2000).

⁵Comparable data on population growth rates for the Fuyang basin and Ombilin are not available.

fish population in the river due to overfishing and also due to water quality problems from the discharge of industrial effluents into the river.

Key Aspects of Irrigated Agriculture in the Basins

Agriculture is the main user of water in all five basins. In the Fuyang basin, groundwater schemes are predominant with some 185,527 schemes irrigating some 874,000 hectares of land or 85 percent of the total irrigated land area in the basin. There is evidence of declining groundwater levels due to overexploitation.

Irrigation in the Ombilin basin is mostly by water lifted from the river with waterwheels. Due to changed river flows, the number of waterwheels has come down from 366 in 1996 to 184 at present. The indications are that more waterwheels will go out of operation in the coming years.

Surface irrigation schemes dominate the basins in the other three locations. In the Deduru Oya basin, aside from three major schemes, there are some 3,600 minor irrigation schemes (with command areas of less than 80 hectares). These schemes are spread throughout the basin and their hydrological endowments vary substantially. Table 2 summarizes key features of the agriculture sector in the basins. The paragraphs that follow highlight some of the key issues in the irrigation sector in the respective basins.

Deduru Oya

A unique feature of the Deduru Oya basin is water scarcity in the midstream region. This area has the highest concentration of small tank schemes in the entire basin. Water scarcity has seriously affected irrigated agriculture in the small tank schemes in this area. Rice is the main crop cultivated under irrigation in both the wet and dry season. In some of the water-scarce areas non-rice crops are grown in the dry season.

In recent years, there has been an increase in groundwater abstraction using diesel/petrol-powered pump sets. These are primarily for nonagricultural purposes such as brick making. In some places, water pumps are being extensively used to lift water directly from the river for irrigation. Rice and other field crops (OFCs) are the main crops grown by river-lift irrigation in the head and mid regions of the basin. In the tail-end areas vegetable cultivation is the dominant activity.

Farmers identified sedimentation and silting of tank beds, reduction of inflow into the tanks due to blocking of natural watercourses by encroachers, and unplanned development activities in the tank catchments as some of the major hazards in the basin. Unregulated sand mining carried out on a large scale was reported as the major cause of environmental degradation in the Deduru Oya basin. It is the biggest commercial activity in the basin. Excessive sand mining has resulted in the intrusion of seawater, loss of natural ponds along the river, reduction in the groundwater level and disturbance of the stability of the bridges across the river.

East Rapti

Agriculture is the major source of livelihood of the population in the basin. Of the total economically active population of Makawanpur district, 82.7 percent, i.e., slightly more than

Table 2. The agriculture sector in the five river basins.

Characteristics	Fuyang (China)	Ombilin (Indonesia)	East Rapti (Nepal)	Upper Pampanga (Philippines)	Deduru Oya (Sri Lanka)
No. of surface irrigation schemes	3	184 (river lift)	214	37	3,600
No. of groundwater irrigation schemes	185,527	14	2,445	0	2,453
Surface irrigated area (ha)	150,000	32,180	32,388	98,222	47,150
Groundwater irrigated area (ha)	875,000	-	7,743	25,135	1,515
Main irrigated crops	Wheat, corn, cotton, rape seed	Rice, mung bean, groundnut	Rice, maize, wheat	Rice, vegetables, corn, onion	Rice, chilli, vegetables
Annual cropping intensity (%)	155	na	na	156-Surface water 200-Groundwater	133-165-Surface water 180-300-Groundwater
Comparison of current crop yields with yield 10 years ago	Decline in yield of all major crops	No change in yield of major crops	No change in yield of major crops	Drop in rice yield by 14-21%	Current yields of major crops are higher
Reasons for yield change	Water scarcity, institutional constraints	Not relevant	Not relevant	Climatic changes, pest outbreak	Improved agronomy; Better prices
Responsibility for O&M of groundwater schemes	Individual farmer		WUAs		Smaller schemes-WUAs; Larger schemes WUAs and Irrigation Agency
Responsibility for O&M of surface irrigation scheme	Local government authority	River lift schemes; water wheels; Individual owners	WUAs and Irrigation Agency	Irrigation Associations (WUAs) and Irrigation Agency	Individual owners
Multiple use of irrigation water	Yes	Yes	Yes	Yes	Yes

the national figure, are involved in agriculture. In Chitwan, 75 percent of the population are engaged in agriculture. It is estimated that about 26 percent of the total land area in the basin is used for agriculture. Of the total area cultivated some 18 percent is in the river valleys and inner plains. These are the major irrigated farming areas in the basin. The cropping intensity (CI) of these areas is between 200 and 300 percent. Cropping patterns in such areas with year-round irrigation facilities are paddy-fallow-paddy, paddy-wheat-paddy, paddy-wheat-fallow, paddy-legumes-paddy, and paddy-legumes-fallow. However, in areas with seasonal irrigation facilities the cropping intensity approaches 200 percent. The cropping pattern in such areas is paddy-wheat, paddy-legume, paddy-maize, maize-oilseeds, maize-maize, paddy-vegetables, maize-vegetables, etc. Livestock (improved breeds of buffaloes and cows, and poultry farming) is also very popular in the plain areas. Agriculture in the hilly part of the basin is largely rain-fed. The dominant cropping patterns in these hilly areas are maize-millet, potato-millet, maize-potato-fallow, and maize-fallow.

Agriculture in the basin is essentially a smallholder activity. The area of each holding of nearly 75 percent of the holdings is less than 1 hectare. Land distribution in the basin is highly skewed. About 46 percent of the households own only 16 percent of the total available cultivable land. In contrast, some 6 percent of the households own approximately 26 percent of the total cultivable land.

A significant development over the last few years is the proliferation of groundwater development particularly in the plains. A major reason for the rapid spread of groundwater development is the subsidy amounting to 60 percent of the cost for the establishment of tube wells. More recently, the government has suspended the subsidy program. This has slowed down the establishment of tube wells.

Fuyang Basin

Fuyang is one of the most water-short basins in North China. The availability of per capita water resources is less than 400 m³. Agriculture is the largest user of water, but the share of water used in agriculture has been declining over time, from 81 percent in 1993 to 75 percent in 1998. This is primarily due to the growing domestic demand. Industrial water demand during the same period has increased by only 1 percent.

The total design area under surface irrigation is about 430,000 hectares. In the 1990s, the actual area irrigated was only 41 per cent of the designed irrigated area. Most of the surface irrigation schemes are managed by government agencies, though a contract management scheme has been implemented in some periods. With the decline in the supply of surface water and the increasing water demand for agricultural, domestic and industrial uses, exploitation of groundwater has increased rapidly. Investment in groundwater irrigation was mainly financed by the local villages and townships, with varying extents in government financial subsidies. Prior to the implementation of the household production responsibility system (HRS) initiated in the late 1970s, investment in groundwater was by local government agencies with financial assistance from the government. Farmers contributed family labor for constructing groundwater irrigation schemes. These schemes were under collective ownership. With the implementation of HRS, investment in groundwater was primarily by private individuals.

There is evidence that groundwater tables (both shallow and deep) have fallen by more than 1 m annually in the past two decades. Urbanization, industrialization and population growth have also led to the increasing pollution of groundwater and surface water that, in turn, has further aggravated the water-scarcity problems in the basin.

The main crops under irrigation include wheat, corn, cotton and rice, along with some millet, soybean, peanut and horticultural crops. With the modernization of agriculture since the 1950s, crop yields have increased. Yield of grain crops has doubled. At the same time, yield of ginned cotton has increased threefold.

Ombilin River Basin

The major use of water varies among the three major rivers and lakes that constitute the basin. Water from the Ombilin river is used for irrigation, industry, power generation and domestic purposes. Irrigation and domestic uses are the dominant uses of water in the other two basins.

The development of the Singkarak Hydroelectric Power Plant has significantly reduced the outflow of water from the Singkarak lake to the Ombilin river, affecting the quantity of water flowing in the Ombilin river. This reduced water flow has adversely affected farmers

who rely on the river for irrigation water. Pump irrigation has been adopted by a very limited number of farmers in the last decade.

Marked seasonal fluctuations in the river flow are a major feature of the Ombilin river. For the owners and operators of water wheels, fluctuations in the water discharge of this river have caused several problems in system O&M. The inadequacy and unreliability of irrigation water have adversely affected agricultural production in the basin. Rice yield has declined from an average of 4.2 tons/ha earlier to 3.1 tons/ha in 1999.

Deterioration of water quality is an emerging problem. This is particularly due to the discharge of effluence from a coal plant. This is causing serious health problems to people living downstream who depend on the river for water for domestic needs. Furthermore, the fish population in the river has declined because water quality in the river is unsuitable for some species of fish. This situation has affected the livelihood of these households whose cash income is dependent on fishing.

Competition for Water

Two major nonagricultural uses of water are industry and agriculture. With increasing water scarcity there is a growing inter-sectoral competition for water. The scarcity is highest in the Fuyang basin in North China. But even in the water-abundant east Rapti basin, there is location-specific competition, such as between the water needs for agriculture and environment, recreation and transnational commitments.

In Deduru Oya, the competition for water is within the irrigation sector. Plans to construct major irrigation schemes and haphazard rehabilitation of small irrigation schemes would also have negative impacts on downstream water users and small tank schemes. Industrial demands are not expected to be significant in the near future. However, government proposals to use groundwater and stream water for domestic water supply (drinking, bathing, washing, etc.) for the growing urban and rural populations would lead to competition and water scarcity.

In the Ombilin subbasin, inter-sectoral competition is less intense at present. The most serious problem is the competition between water for hydropower generation and rice production that uses water wheels for irrigation. The economic benefits from hydropower far exceed the returns from rice farming, making it hard to justify priority allocation for the latter.

In the Upper Pampanga, water for domestic and industrial uses is mainly drawn from groundwater. At this stage, however, considering the vast reserve of groundwater in the basin, which is being replenished by rainfall every year, competition from other users vis-à-vis irrigation does not affect agricultural water use. Moreover, results of a field-level study in the UPRIS area indicate that except for fish ponds, other enterprises like duck and poultry farms consume very minimal amounts of water.

Major Socioeconomic Issues in the Basins

Each of the river basins shows variable levels of socioeconomic development. This section summarizes the salient social and economic issues in the five basins.

Deduru Oya

Deduru Oya is unique in the sense that the wetter parts of the basin are at located at the head reach and the tail end of the river, whereas the midstream area is very dry. The main urban centers in the basin are located in the head and tail areas. These centers have high population density. The urban areas are predominantly service centers. Industrial development is low and industrial pollution is not a major issue at present. Drainage problems and use of the river for domestic waste disposal as it flows through the towns pose serious environmental threats to water resources in the town area.

There is a high incidence of poverty in the basin especially amongst the farming population. The main reason for this is water scarcity and dependency on based paddy cultivation based on small tanks, low productivity, and lack of alternative employment opportunities. Agriculture is the main source of employment in the basin. The majority of the people depend on coconut cultivation as it provides some regular income.

Paddy cultivation is the major livelihood activity of the people living in the part of the basin lying in the dry zone region. Paddy cultivation is gradually declining, especially that cultivated under minor irrigation schemes. The major problem the farmers in this region face is water scarcity due to low rainfall, silting of tank beds, lack of proper irrigation structure, reduced inflow and pollution of water. The cultivation of vegetables and OFCs is a major source of income for the people residing downstream of the river basin. Salinity buildup, due to intrusion of saltwater, is a serious problem for farmers engaged in vegetable cultivation. Salinity control is urgently needed to continue these activities on a long-term basis without damaging the environment.

The potential for the development of animal husbandry in the river basin is very high. The coconut lands available in some areas provide the necessary environment for livestock. The Provincial Department of Animal Production and Health is committed to the promotion of this sector. But some institutional and management improvements and resources are required for further development.

The industries in the river basin are mostly associated with the two main agricultural products, coconut and paddy. These industries do not pose serious environmental threats if they are implemented properly. Sand mining is the major cause of environmental problems. This is an activity carried out with the blessing of politically powerful people. Immediate attention of the relevant authorities is required to regulate this activity through proper institutional arrangements.

Community-based organizations in the river basin were found to be very weak. The farmer organizations face serious problems due to lack of assistance from the relevant agencies. Though the relevant agencies have capability in institution building, they lack interest due to various sociopolitical reasons.

East Rapti

East Rapti is relatively well endowed with water. It is an open basin and is relatively underdeveloped. Two administrative districts cover the entire basin: Makawanpur and Chitwan, with population densities of 128 and 160 persons/km², respectively. Chitwan is rapidly urbanizing compared to the Makawanpur district, largely due to the Chitwan national park, which is a major tourist attraction. Migration of hill people to the plains and also rural people

to the urban areas exerts high pressure on the natural resources. The increasing incidence of landslides and floods in the Rapti river and its tributaries due to natural and man-made causes is one of the major environmental problems in the basin.

There is a high incidence of poverty in the basin. It is estimated that around 50 percent of the population in the basin are below the official poverty line. Poverty is more pronounced in the rural than in the urban areas and is concentrated more in the hills than in the plains. Ethnically disadvantaged groups constitute about 18 percent of the population within the entire basin. Such groups inhabit the hills. A major social problem in the basin is the erosion of the traditional fishing rights of ethnically disadvantaged groups, thereby marginalizing them even further. There is also evidence of wide disparities in incomes and access to resources.

The major institutional problem in the basin is the lack of coordination among the stakeholders such as irrigators, domestic water users, foresters, industries, park and people. Uncoordinated interventions in the water-resources sector by government agencies, national and international NGOs and other stakeholders not only duplicate efforts but also add to unnecessarily large costs.

Fuyang

With the intense competition in water use among various sectors at the basin level, more and more surface water is being transferred out of the agriculture sector. Agriculture is becoming increasingly dependent on groundwater. Overabstraction of groundwater has been steadily lowering the groundwater table. With the groundwater table dropping, there has been an increase in the cost of groundwater abstraction. At the same time, grain prices have more or less stagnated, and costs of agricultural inputs have risen, thereby resulting in a reduction in farm incomes.

A noteworthy development in the basin is the change in property rights, especially in groundwater. Collective property rights are being replaced by individual property rights. There has been a notable shift from cultivating grain crops to high-value cash crops, such as vegetables. In addition, dryland agriculture will be adopted by more and more farmers and drought-resistant varieties will become popular. The institutional challenge in the basin is to devise appropriate strategies for demand management and to increase the productivity of water.

Ombilin

The major problems in the basin are the decrease in the river discharge and deterioration in water quality. The decreased discharge of the main Ombilin river has resulted in problems of water quality because of the high inflow from the Selo river where the quality of water is very low. In addition to this, the discharge of industrial effluent disposed from the coal mining company has affected the downstream water quality. This has resulted in serious health problems among downstream water users. There has been a decline in the total irrigated area and, in some cases, cropping intensity and yield of irrigated agriculture have declined markedly.

Upper Pampanga

Estimates of the water balance indicate that there is a good deal of uncommitted water running to the sea and there are plans to extend the downstream irrigated area. Despite the seemingly ample supply of water, there is a great deal of year-to-year variability in wet-season yields. The 1999 survey of 102 farms in the wet season also shows that yields were lower and much

more variable among farms in certain locations (districts II and III) compared to districts I and IV. One can see that the area irrigated in the dry season has dropped very sharply. The tail end of the scheme has been affected more than the head end. From a management point of view it is far easier to cut off the tail of the scheme than to try to allocate a limited supply of water across the whole scheme. Yields are consistently higher and somewhat less variable from year to year in the dry season than in the wet season. The high cost of fuel and insufficient groundwater discourage the use of pumps.

Farmers in the Upper Pampanga River Integrated System (UPRIIS) experience a great deal of year-to-year variability in production (and income from rice) in the wet season due to weather, and in the dry season due to weather-related uncertainties in deliveries from UPRIIS. The degree of variability depends very much on where the farm is located in the system.

Increased population pressure on land and other resources, including water, is likely to affect the river basin. There is increased water demand for domestic and industrial uses due to increased population and urbanization. Increases in population density could decrease the degree of social interaction or may diminish the effectiveness of water user associations and other collective efforts in water resources management in the basin.

In recent years, the use of pumps has expanded. More than 20 percent of the farmers surveyed had acquired pumps, most of these in the last 5 years although this may be biased upward due to a bias in the sample. However, high fuel costs and insufficient groundwater have slowed down the proliferation of pump irrigation.

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Part II
Five-Country Regional Study—Country Cases

CHAPTER 4

Diagnosis of the East Rapti River Basin of Nepal

Keshav Raj Adhikari¹

Introduction

Much research has been done and valuable recommendations made to increase the effectiveness of farmer-managed irrigation systems (FMIS) in Nepal (Gill 1996). However, an integrated approach emphasizes that development policy should not merely work on issues of one sector and resource scarcity but shift attention to multiple sectors and access to resources.

Despite continued government efforts to curb poverty, 42 percent of the population in Nepal still suffer from poverty (Vaidya 1999). There have been many debates and criticisms about the government's welfare interventions in this mountainous country (Jodha 1995; Bandyopadhyay and Gyawali 1994; Giri 1992). In the case of utilization of water resources, state-led development activities have demonstrated a bias in irrigation and rural water supply that ignored or bypassed village communities (Bandyopadhyay and Gyawali 1994; ERL 1988). The cumulative effects of the past efforts can also be illustrated by the national statistics of increased food deficit during 1989–97 that are attributed to decreased agricultural productivity (MDD 1998[xx This is not referenced]). As the conventional development approaches could not meet the expectation placed on them to sustain agricultural productivity and to keep up natural resources systems, a shift in the development paradigm to newer concepts has now begun to gain momentum.

Some of the implications of the above debates and conclusions might have been very instrumental for the government to emphasize in the Ninth Five-Year Plan (1997–2002) for the development of a policy on overall water resources. The baseline document of the Ninth Five-Year Plan puts forth the necessity of discouraging earlier sectoral- or subsectoral-biased policies and developing an overall water resources policy that will emphasize managing the growing inter-sectoral competition over water use (National Planning Commission [NPC] 1997)

Embracing the idea of a basin approach to water resources management and to contribute to the national objective of poverty alleviation, the Water Management Study Program (WMSP) at the Institute of Agriculture and Animal Sciences (IAAS), Tribhuvan University, Rampur, Chitwan, Nepal collaborated with the International Water Management Institute (IWMI), Sri Lanka and the Department of Irrigation, Kathmandu, Nepal for a series of studies on a) the performance assessment of irrigation systems, b) socioeconomic and stakeholder analysis, c) institutional analysis, and d) water accounting of the east Rapti river basin of Nepal for developing effective water management institutions.

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This paper attempts to summarize findings from these studies. The focus is on diagnosis and development of insights within and across the sectoral use and management of water resources, considering the river basin as the unit of analysis. The basin concept is a key to identifying a range of existing or potential natural processes and human activities, especially water use and to promoting development objectives by securing a higher degree of coordination among various stakeholders and related regulatory agencies (IWMI 1999).

The paper has been organized into nine sections. The first section is the introduction while the second section presents the physical characteristics of the basin. The third section discusses important demographic features including ethnicity, pattern of employment, urban versus rural population, growth trends, and poverty. Agriculture being the major basis of livelihood with the basin population, a more detailed discussion is provided in the fourth section focusing particularly on irrigated agriculture. Increasing nonagricultural use of water as identified by the study is presented in the fifth section. An overview of land and water rights is provided in the sixth section. Section seven describes one of the major themes of the paper that links water resources endowment with use patterns by multiple sectors and emerging issues, looking at “stakeholder perceptions.” Section eight illustrates the existing institutional structure including the role of multilevel government agencies, constraints, and factors that affect their role in water resource management. The last section concludes the paper with major issues and policy recommendations for improved management and development of water resources in the basin.

Physical Characteristics of the Basin

Situated in the central development region of Nepal, the east Rapti river basin lies between the latitude 27° 26' and 27°54' N and longitudes 84°10' and 85°12' E. It is surrounded by Gorkha, Dhading and Kathmandu districts in the north, the Rautahat, Bara and Parsa districts as well as part of northern India in the south and the Nawalparasi district in the west. Of the total basin area of 3,222 km², Chitwan and Makwanpur districts occupy about 58 and 42 percent of the basin area, respectively. Similarly, 82 percent of the Chitwan district and 55 percent of the Makwanpur district are in the drainage area of the basin (Adhikari 2000).

Topography and Soils

The east Rapti river originates in the southern part of Middle mountain (in the Lesser Himalaya) about 25 km southwest of Kathmandu. A sharp gradient in elevation between the origin of the river (1,500 m asl) and the point where it moves out of the basin (140 m asl) contributes to the diverse biophysical environment. The river abruptly descends from the Middle mountain to the enclosed valley of Siwalik and Churia hills, where the valley floors of Makwanpur and Chitwan districts occupy a large part of the basin. The Siwalik hills form a front of Himalayan origin bounded with the Middle mountain range by a distinctive fault zone referred to as the Main Boundary Thrust and comprising thick sedimentary formations of the Tertiary Age. The Chitwan valley is a tectonic depression of widely undulated Siwalik Groups and has been buried beneath thick alluvial deposits (Nippon Koei 1986).

Moderately, steeply, and very steeply sloping hilly and mountainous terrain are laid over slopes of less than 10° to more than 30°. Diversified landforms and soil types as well as dissected hilly terrain slopes and mosaics of alluvial plains, have been formed by the action of the river and gravity. Due to great diversity in climate and topography, an array of soil types is found in the basin, ranging from sandy or cobbly and sandy and loamy skeletal in the sloping areas to the coarse and fine loamy soils in the plains. The depth to water table varies and seasonal ranges of depth to water table also vary from less than 2 m to more than 15 m. A large part of the Middle mountain drains well, whereas drainage in Siwalik is highly variable and is subject to river flooding near the Rapti river and in areas of natural depressions (LRMP 1986). Where settlements occur, they reflect areas with stable soils and consistent year-round water supply. The soils on many slopes are too shallow to terrace, even though gradients may be gentle. In general, most of the soils of Chitwan valley are young without much differentiation into horizons. Proper management and adequate inputs including irrigation water can make the valley soils highly productive (Khatri-Chhetri et al. 1987).

Land-Use and Climate

The dominant land use and land cover, as shown in figures 1 and 2, comprise mixes of warm temperate, subtropical hardwood and coniferous trees (62.25%), followed by lowland agriculture (18.31%), upland agriculture (8.42%), shrubland (3.67%), grassland (3.61%) and others including urban settlements, swamps, rocky outcrops, and sandy and gravel river banks (3.74%) (Adhikari 2000). Since countrywide land resource maps were developed only once in 1986, a trend analysis of land-use change in the basin was not possible, so land-use data given in this paper represent a one-time piece of information.

The basin has a predominantly monsoonal climate. Because of the great variations in elevation, climates that contribute to the water resources of the basin are characterized by warm temperate (1,000–2,000 m elevation and 15–20 °C mean annual air temperature) in the Middle mountain regions particularly in the upstream part of the river, and subtropical (<1,000m elevation and 20–25 °C mean annual air temperature) climate downstream (LRMP 1986). April and May are the hottest months and the average maximum temperature is 35 °C whereas December and January are the coldest months. Minimum temperature rarely falls below 5° C in most years. The average relative humidity is about 75 percent and varies from 50 percent in the dry season to 90 percent in the rainy season. The average velocity of the wind is 1.6 km/hr. or 0.4 m/sec. in the plain area.

The use of Class-A pan gave an estimate of the annual evaporation to be about 1,470 mm with a daily average of 1.5 mm/day from December to 6.7 mm/day in May. Long-term rainfall data from the four agro-metereological stations have been obtained. Although it may be small, the variation in annual average rainfall across four stations gives a comparative idea of upstream versus downstream rainfall patterns (table 1). Rainfall records in 1970–88 at the Rampur agro-metereological station indicated that more than 75 percent of the annual rainfall occurred from June through September (Shukla et.al 1993) and more than 90 percent of the annual rainfall occurred from May through October (Nippon Koei 1986). Similarly, the basin-level picture of rainfall distribution is that it is concentrated during the 6-month monsoonal period from the middle of May to the end of October. July and August receive the heaviest downpour and account for nearly half the annual rainfall.

Figure 1. Land-use distribution in the basin.

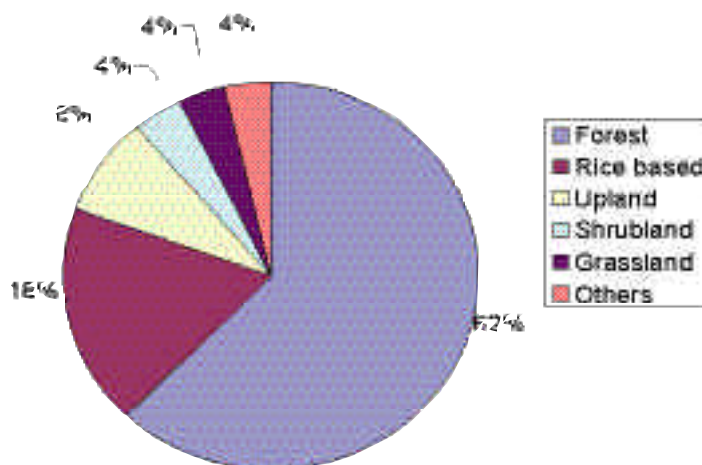


Table 1. Long-term rainfall patterns in the basin.

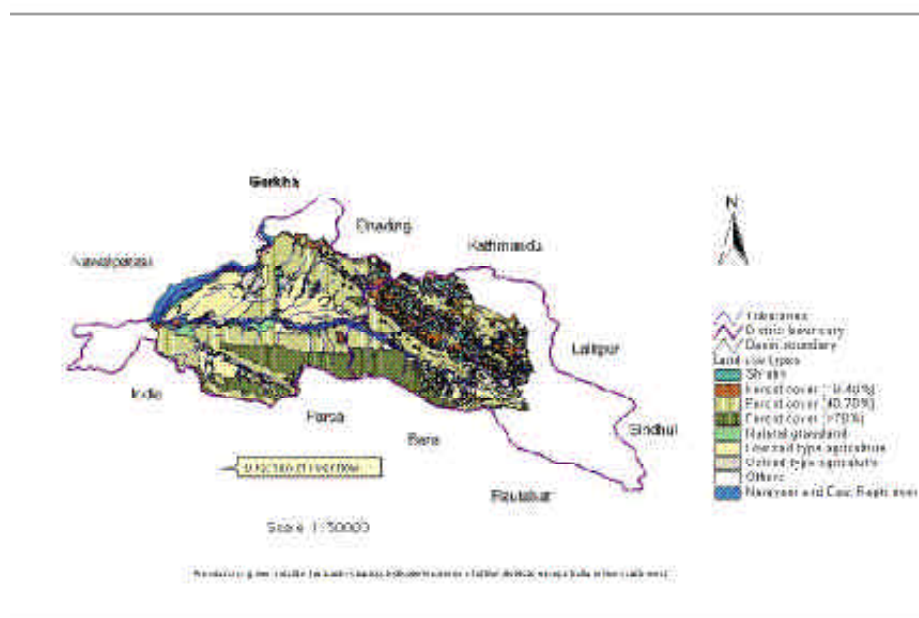
Agro-Meteorological Stations	Average Annual Rainfall (mm)	
	Upstream	Downstream
Chisapanigadhi ^a	2,182	-
Hetauda ^a	2,233	-
Jhuwani ^a	-	1,866
Rampur ^b	-	2,000

^aNippon Koei 1986. ^bShukla et al. 1993.

Hydrology of the Rapti River System

The river course is 122 km long and flows westward to join the bigger snow-fed Narayani river. In the Chitwan valley, it flows about 70 km meandering through the alluvial deposits and gathering many tributaries from the north (Nippon Koei 1986). Most of the tributaries originating in the Churia hillside in the south are ephemeral compared to the tributaries originating in the Siwalik and Middle mountainside in the north. Kali, Rani, Samari, Karr, Manahari, Lothar, Kair, Khageri, Budhi Rapti and Riu Khola form the major tributaries of the river. The total length of the main river including all tributaries is 399 km (RTDB/IAAS/IWMI 2000). Figure 2 shows spatial distribution of land use land cover and river networks in the basin.

Figure 2. Land use and land cover in the east Rapti river basin as of 1978–1979.



Based on rainfall data for 21 years (1976–96), annual rainfall inflow varied between 2,482 mm in a wet year and 1,450 mm in a dry year, with average rainfall of 1,937 mm. The analysis of 21 years of rainfall data indicated a perceptible spatial trend from upstream to downstream and very little temporal trend. Rajaiya, one of six stations, was used to derive discharge data for water accounting. The long-term discharge record of the east Rapti river at Rajaiya hydrostation indicated that about 85 percent of the total rainfall occurred from June to October (RTDB/IAAS/IWMI 2000).

Water accounting was computed for three typical years (table 2). Net inflow of water in the basin for normal (1979), dry (1992) and above-normal (1978) years were found to be 6,120, 4,564 and 7,171 $\text{m}^3 \times 10^6$, respectively. Net outflows for these years were computed to be 3,576 and 3,848 $\text{m}^3 \times 10^6$, respectively.² The general conclusion that can be arrived at from the data is that it is an “open basin” where only 53 percent of available water is depleted in a dry year and the remaining 47 percent of utilizable flow exits from the basin. Only 6 percent of available

²The negative sign in the table indicates addition of water to storage to supplement the deficit of previous normal year. As defined by Sakthivadivel and Molden, IWMI scientists, storage change is the difference between storage at the beginning of the year and at the end of the year. Since data is not available to compute surface and soil moisture storage at the beginning and end of the year, it is assumed that the storage at the beginning of a year is at full potential level (100%) of storage if the previous year is an above normal year, at 75% of its potential storage if the previous year is a normal year, and at 25% of its potential if the previous year is a dry year.

Table 2. Water accounting results for wet, normal and dry years.

Components	Wet Year (Above Normal) (1978)	Normal Year (1979)	Dry Year (1992)
Gross inflow into the basin	7297	5,993	4,564
Groundwater storage change	-126.03	126.03	0
Net inflow into the basin	7,171	6,120	4,564
Depletion: Process depletion	284	249	234
- Non-process, beneficial	1,933	1,561	1,533
- Non-process, Non-beneficial	242	197	198
Outflow (runoff)	3,848	3,576	2,201
Deep percolation	863	537	400

Source: RTDB/IAAS/IWMI 2000.

Volumes are in million m³.

water is process-consumed. Forests, covering more than 60 percent of the area, consume the bulk of available water. Non-beneficial consumption is only 5 percent. Agricultural water productivity is very low (US\$0.09/m³ at the conversion rate of US\$1=NRs 70) indicating great scope to enhance water productivity. Although data are scanty, industrial and domestic use is mostly from groundwater and the amount is small. As a significant fraction of utilizable water moves out of the basin during the year, great potential exists to harness this flow for increased water productivity within the basin. Flow dynamics representing wet, normal and dry years in the basin are illustrated using finger diagrams in figures 3, 4 and 5.

Water-Control Infrastructure

The east Rapti river serves as a prime source of livelihoods for scattered settlements in both the Makwanpur upstream and the Chitwan valley downstream. The river has experienced recurrent high flood amplitude in the past, contributed by a large number of ephemeral tributaries originating in mountains upstream. Soil erosion and landslides are prominent upstream and floods downstream. Appropriate water control structures are necessary to safeguard communities, infrastructure, croplands, flora and fauna against unexpected floods as well as for the development of water resources in the basin.

The latest massive flood in the river was recorded in July of 1993, which took lives and property of many, particularly in the Chitwan valley. This was when the east Rapti Irrigation Project (ERIP), Irrigation Sector Program of HMG/Nepal was preparing to construct a huge diversion weir in the river. Local people and environmentalists had raised issues of negative impact of the diversion weir on flora, fauna, Royal Chitwan National Park and on locally made irrigation infrastructure downstream. As a result, in lieu of a weir, a continuous embankment was built along the bank of the Rapti river.

The construction of an 18-km long flood embankment extending from Lothar to Kumroj was completed in February 1996 with a loan assistance of NRs 272.72 million from the ADB. Besides rehabilitation and improvement work for irrigation, the ERIP also erected 50 spurs around Sauraha and some in bridge sites at Lothar to protect the banks from river cutting. Spurs at both sites incurred a total cost of NRs 8.56 million (ERIP 1998). Before ERIP intervention, permanent (8%), semipermanent (46%) and brushwood (46%) diversion structures were observed in 88 FMIS (Shukla et.al. 1993) in the east Chitwan valley. To date, ERIP has been the largest project in the area to support water control structures. In some irrigation canals water regulators were established to control flood and silt load.

Demographic Features

Basic Characteristics of the Population

Thirty-two Village Development Committees (VDCs) out of 36 VDCs of the Chitwan district and 23 out of 43 VDCs of the Makwanpur district lie within the physical boundaries of the basin. In Nepal, VDC refers to the lowest administrative unit of the government. The total population of the basin as a whole is 536,031. Data on basin population by sex was not available. However, as the basin includes 79 percent of the total population of both districts, the population of the districts, about 50 percent each for female and male, might represent the basin.

Population distribution by district and basin. Table 3 indicates that, as of 1993, a larger proportion of the basin population resides in Chitwan (63%) than in Makwanpur (37%). The basin total represents 2.9 percent of the national population and 79 percent of the combined population of both districts for the respective year, whereas the combined population of both districts represents 3.66 percent of the national population. Since there are 75 districts in the country, this population value indicates a high density and appears to be above the national average.

Table 3. Population distribution by district and basin.

Districts	Basin-Wise (%)	Basin Total	% of District in the Basin	District Total
Chitwan	63	336,934	93	361,892
Makwanpur	37	199,097	63	314,599
Total	100	536,031	-	676,491

Source: CBS 1993.

Population distribution by ethnicity within the basin. Diverse ethnic groups with distinct costumes, cultural and occupational values and traditions exist in the basin. The population of Bramhin and Chhetri is the largest (38%), followed by Mongols (29%), Tharu (8%), Indigenous (7%), Lower cast (7%), Bote (1%), and Others (4%). The massive scale of their migration from surrounding hills within the last four decades might have contributed to the large population of Bramhin and Chhetri in the basin.

Population distribution by employment pattern within the basin. Most of the population (both male and female) in the basin are employed in farm work and businesses, followed by services, and the least in technical or professional jobs (table 4). However, the lower proportion of women in services and professional jobs and their higher contribution to farm work than their male counterparts indicate social inequity related to access to resources and opportunities prevailing in the basin.

Table 4. Employment patterns (%) by sex within the basin.

	Technical/ Professional	Services	Sales	Farm Work	Others
Male	2.9	12.8	5.3	67.1	11.9
Female	0.8	7.2	2.6	87	2.4
Total	2	10	4	76	8

Distribution of Population

Population distribution by rural and urban areas within the basin. In this paper, municipalities are considered as urban centers. There are two municipalities, Bharatpur and Ratnanagar, in the Chitwan part of the basin, and one municipality, Hetauda, in the Makwanpur part of the basin. Most of the people reside in the rural areas of the basin in both districts (table 5).

Table 5. Population distribution (%) by rural and urban areas within the basin.

	Rural	Urban	Total Population in the Basin
Chitwan	76	24	336,934
Makwanpur	73	27	199,097
Basin	75	25	536,031

Population density and literacy. The annual population growth rates in Chitwan and Makwanpur districts are 2.92 and 2.68 percent, respectively, as against the national average of 2.38 (CBS 1999). Population density was consistently higher in Chitwan than in Makwanpur over 30 years between 1971–2001 (table 6).

Table 6. Trend of population density per km² in the basin districts.

District	Year			
	1971	1981	1991	2001 ^a
Chitwan	83	117	160	211
Makwanpur	68	100	130	167

Source: CBS 1981, 1991 and 1999. ^a Predicted population.

With some variations, literacy rate of 6-year olds and above increased by 19 percent in the Chitwan district and by 14 percent in the Makwanpur district between 1981 and 1991 (table 7). Within the basin, hill people appear to have a lower literacy rate than the people in the plain and valley areas. As table 8 shows, women in the hilly areas appear to have much less access (19%) to education (table 9) than women in the plain areas (81%).

Table 7. Trend in literacy rate (%) by basin districts.

District	1981	1991	Change
Chitwan	34	53	19
Makwanpur	24	38	14

Source: CBS 1991 and 1999.

Table 8. Distribution of literate population by sex and region within the basin.

Gender	Region		Total
	Hill	Plain	
Male	34,840	95,368	130,208
	(27%)	(73%)	(61%)
Female	15,884	68,065	83,949
	(19%)	(81%)	(39%)

Source: CBS 1993.

Population Growth Trends in the Basin Districts

As the population census in Nepal is taken once every 10 years following the administrative and district boundaries, data on the basin-level population were not available. Therefore, district-level data were used in this paper because most (79%) of the districts' population resides within the basin. Table 9 indicates that the total population of both districts rose from 1981 to 1991, though the rate of increase was slowing.

Table 9. Population trends in the basin districts.

Year	Chitwan		Makwanpur		Total	% Change
	Number	%change	Number	%change		
1961	69,000	-	-	-	69,000	-
1971	184,000	167	163,766	-	347,766	-
1981	259,000	41	243,411	49	502,411	44
1991	355,000	37	314,599	29	669,599	33
2001 ^a	467,809	32	405,952	29	873,761	30
2011 ^a	596,494	28	510,785	26	1,107,279	27

Source: CBS 1993 and 1999. ^a Predicted population.

Other criteria like migration, age structure and birth rate also bear equal significance in analyzing the demography. These data are available for only for the Chitwan part of the basin. Although data on migration exist at the level of a much broader development region (DR), which comprises a number of districts, it might still offer some indications given the lack of other data. It is interesting to note that the central DR, of which Chitwan forms a part, exhibited net positive migration (male 97,429, female 87,991) for 1981–1991 compared with net negative migration (male -24568, female -22834) between 1971 and 1981 (CBS 1991).

For the Chitwan part of the basin, excluding the Bharatpur municipality, the GIS unit of the National Planning Commission (1997) reported that in-migrated households exceeded (843) than out-migrated ones (791) during 1991–1996. This indicated a significantly dynamic rural migration pattern in this district. Analysis of the rural population structure by age revealed that the population of 10-year olds or those below had the largest proportion (29%), followed by the population of those between 11 to 19 years (22%), 20 to 29 years (18%), 30 to 39 years (12%), 40 to 49 years (8%), 50 to 59 years (5%), and 60 or above (5%). The population in the age category 10 years or less also reflects, although indirectly, relatively high birth rates or better nutritional status in the district or both.

Poverty

The term “poverty” is a buzzword for many in these days. The dictionary meaning of poverty is “state of being poor,” “inferiority,” “deprivation,” “disadvantaged,” “inadequacy,” or “lack of access to resources or benefits” and so forth. It appears that its meaning is broad, but many of us understand or use it frequently in a narrow monetary sense. Can we apply these broader meanings in a water resource use and development context? Certainly, the basin

population is rich in culture, tradition, ethnicity, coexistence, natural resources including biodiversity, as well as land and water resources. Then, what is critical for the basin population in relation to poverty? This section provides some information related to what we understand by poverty in the context of Nepal and in the basin.

National and regional poverty. Based on income, individuals with annual income levels below Rp 3,900 in the hill and Rp 2,500 in the *terai* (plains) are considered as poor in Nepal's 1995 Plan. No reference is made in the plan as to how this monetary value is related to international poverty standards (APP 1995). The calculations by the National Planning Commission indicate that the relative concentration of poor people in Nepal is higher in the hills than in plains (Vaidya 1999). Referring to the Agricultural Census of 1991, Vaidya says that if measured by landholding sizes, acute poverty is found more in the plains than in the hills. However, regardless of region, poverty in Nepal is recognized as an agricultural phenomenon. The current food-deficit situation and the scarcity of employment have aggravated poverty in Nepal.

District-level poverty. The International Center for Integrated Mountain Development (1997) used 39 key indicators to rank districts on the basis of a composite index of development. Differential access to resources, employment and facilities, child deprivation, gender discrimination, disadvantaged groups and food production were the key indicators used for ranking districts (worst, intermediate, best) on a poverty and deprivation scale. Chitwan was ranked as one of the best and Makwanpur as one of the intermediate poverty districts according to this scale.

Distribution of poverty within the basin districts. Poverty of different magnitude and nature prevails both in the plains and the hills of the basin. According to both the National Planning Commission and the International Center for Integrated Mountain Development criteria, poverty is concentrated more in the hills than in the plains of the basin. The aggregate population of disadvantaged ethnic groups like Chepang, Magar, Kami, Kumal, Damai, Sarki and Danuwar communities is 17.8 percent within the entire basin, clustered in the hills. The Bote, a traditionally specialized fishing community, which is also one of the disadvantaged groups, lives downstream along the east Rapti river. This group comprises another cluster of 2,173 people in the plains of the Chitwan part of the basin. The man-land ratio of this community is 14 times smaller than that of the upper caste Brahmin community (Poudel 2000). All these communities, including the Bote, belong to lower castes in the traditional society of Nepal. They do not generally expect to progress or fare well in their traditionally and culturally established specific professions. They think that their professions are not rewarding anymore in terms of money in the face of a competitive world. Neither do they have access to adequate education and alternate employment opportunities. Despite government efforts to curb poverty through a host of approaches, such as participatory social activities, fund raising, and saving and credit in the village, their family size still remains larger than those of the relatively upper caste. This further aggravates the poverty by pushing family separation and land fragmentation.

Poverty is also more concentrated in rural areas in the basin. This finding is supported by Silwal (1997) who explains that 66 percent of the population in the National Park Buffer Zone³ is below the poverty line, 50 percent of which faces food deficit in most years. In addition to the communities mentioned above, the Tharu and Darai, both indigenous to the basin valley, also form a poverty concentration in the Buffer Zone.

The Agriculture Sector

Importance of Agriculture in the Basin

Agriculture has been the predominant occupation of the majority in the basin. Although current statistics should be significantly different due to population explosion and development activities, back in 1978–79, the area under agriculture (rice-based lowland and upland) was calculated to be 27 percent (figure 1), the second largest land-use type after natural forest (62%). As of 1992, the agricultural sector alone provided employment to 76 percent of the basin population (table 5). More females (87%) were found engaged in agriculture than males (67%).

The basin comprises both hills and valley systems with unique biophysical environments suited to diverse agriculture and allied enterprises. Until the early 50s, large parts of the valley were under dense forest. A small number of scattered communities of Tharu and Darai in the valley floor as well as Chepang and Magar in the slopping hills were the indigenous people. Those in the valley floor lived on traditional wetland rice cultivation, animal rearing and fishing while those in the sloping hills survived on collecting wild food and fishing. Still another sector of society, Bramhan, Chhetri, and people of other castes, lived higher up in the hills and mountains. They cultivated uplands for crops like maize and millet and grew irrigated rice by making bench terraces where they could tap water from the nearby ravines.

When the government opened the Chitwan valley in early 50s for planned settlement for those who suffered from landslide and flooding in the hills, people migrated into the valley on a massive scale from the surrounding hills. That is the major reason why population increased by 167% in Chitwan between 1961 and 1971 (table 7). The government cleared a significant forest area for resettlement under the Rapti Valley Multiple Development Project. The valley now experiences diverse and intensive agricultural systems by communities of mixed culture, tradition, norms and values.

Rice, wheat, maize, and oilseeds are the major crops of the basin. Besides traditional crops, commercial vegetables are emerging as a cash crop, particularly in the valley floor. Since basin-level data were not available, a combination of trends of area and production of major crops of both districts (1980/81–1997/98) is presented in figure 6. Data that were published in 1981, 1991 and 1999 by the Central Bureau of Statistics/HMGN were used for this presentation.

³The Buffer Zone refers to the belt of the National Park area along the sides of east Rapti river where wild animals from the sanctuary, by their movement, affect the adjoining agricultural land uses of the surrounding farm families and vice versa. Park and People, a UNDP-supported international NGO and several others are working in this area in close association with the local communities and government line agencies towards achieving a balance between forest and riverine ecology of the basin with the rural community.

Figure 6. Area and production of major crops in the basin districts (combined) between 1980/81 and 1997/98.

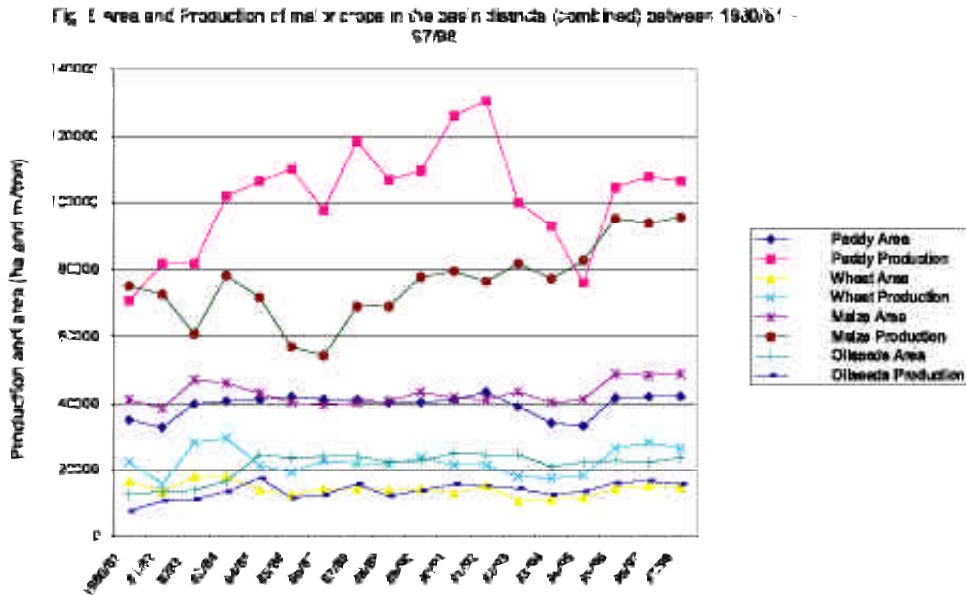


Figure 6 indicates that paddy and maize are the leading crops supplying the increasing food requirements of the district population. With stagnant area, paddy production increased from the year 1980/81 to 1991/1992, but it decreased afterwards. Maize production, although low during 1984–86, has shown a steadily rising trend thereafter. No significant increase in area and production in wheat and oilseeds was observed. In view of the ever-increasing population (table 7) and with the majority of the population still engaged in agriculture, the question of food security appears more challenging.

Irrigated Farming Systems in the Basin

FMIS and government policy. Initiation of some of the farmer-managed irrigation systems (FMIS) in Nepal dates back to at least 1750 (Pradhan 1986). Irrespective of size, 178 and 156 irrigation systems in the Chitwan and Makwanpur districts, respectively, have been recorded (Adhikari et al. 2000). In the present context, they include farmer-developed and farmer-managed as well as government-developed and jointly managed irrigation systems. In the case of FMIS, farmers have developed local institutions to enable the collective management of water for agricultural production. Based on water source, landholding pattern, terrain types and management complexities, Narayini Lift (8,600 ha), Khageri (3,900 ha), Pithuwa (1,600 ha) and Rapti-Pratappur (1,005 ha) in the Chitwan district can be considered as large irrigation systems. Each system in the Makwanpur district is smaller than 500 hectares. This indicates that except in a few cases, almost all irrigation systems in the basin are small.

The government's effort in irrigation to improve food security in the country dates back to the early 1950s. The irrigation policy publicized in 1992 emphasized users' participation at all stages of project implementation including decision making and cost-sharing for developing the needed infrastructure. The policy puts forward the vision of implementing joint management for systems larger than 500 hectares in the hills and 2,000 hectares in the plains. Systems smaller than these sizes would be completely turned over to the users.

Access to irrigation. Today, the development of irrigation systems concentrates more in the valleys than in the hills. Rice, being the staple food crop, receives top priority so long as constraints of topography and water acquisition do not exist. District-level information related to irrigated area and access of households to irrigation resources is given in table 10.

Table 10. Access to irrigation by holdings.

	Chitwan	Makwanpur	Combined
Total cultivated area (ha)	42,814	31,547	74,361
Irrigated area (%)	57	18.9	41
No. of total holdings (No.)	53428	48676	102,104
Reporting access of holdings to irrigation (%)	63.6	32.8	49

Source: CBS 1993.

Irrigated area and access to irrigation in Chitwan are much more than in the Makwanpur district. However, aggregation of district data reveals that 49 percent of households have access to irrigation and 41 percent of the agricultural area is irrigated.

Water management in irrigation systems. Water User associations (WUAs), formal or informal, are responsible for carrying out operation and maintenance (O&M) activities related to acquisition, control, distribution and use of water for irrigation. Farmers contribute substantial levels of labor resources for repair and maintenance of the systems. With some deviations from one system to another, awareness of a sense of ownership and incentives has been the prime driving force to create institutions, for resource mobilization, record keeping, sanctioning, water fee collection, and account auditing, for achieving distribution and production equity among farmers in the basin.

Crop Production and Cropping Patterns

Cropping patterns. Rice, wheat, maize, mustard, lentil and potato are the major crops grown in the basin. Depending on water availability, terrain types and level of management, these crops are grown in different types of rotations. Table 11 provides all possible combinations of crops in a cropping sequence under three water adequacy regimes. This information is based on the WMSP survey of 88 FMIS from the East Chitwan valley in 1993. Current dominant cropping patterns reported for the Makwanpur district are given in table 12.

Table 11. Cropping sequences.

Perennial Water Source	
Water adequate	Water limited
Spring paddy–Monsoonal paddy–winter maize	Monsoonal paddy–mustard–spring maize
Spring paddy–Monsoonal paddy–winter wheat	Monsoonal paddy–lentil–spring maize
Spring paddy–Monsoon paddy–mustard	Monsoonal paddy–mustard+lentil–spring maize
Spring paddy–Monsoonal paddy–lentil	Monsoonal paddy–mustard+lentil–fallow
Spring paddy–Monsoonal paddy–mustard+lentil	Monsoonal paddy–wheat–fallow
Spring paddy–Monsoonal paddy/lentil	Monsoonal paddy–winter maize–summer maize
	monsoonal paddy–fallow–spring maize
	Monsoonal paddy–potato+wheat/
sConditionSpring maize	Monsoonal paddy–fallow–fallow
	Monsoonal paddy/lentil–fallow
Seasonal Water Source	
Water deficit	
Spring paddy and spring maize–Monsoonal paddy–lentil	
Spring paddy and spring maize–Monsoonal paddy–mustard	
Spring paddy and spring maize–Monsoonal paddy–winter maize	
Spring paddy and spring maize–Monsoonal paddy–wheat	
Spring paddy and spring maize–Monsoonal paddy–mustard+lentil	
Spring paddy and spring maize–Monsoonal paddy/lentil	

Table 12. Cropping pattern reported in the Makwanpur district.

Spring paddy–Monsoonal paddy–wheat/maize
 Spring paddy–Monsoonal paddy–mustard/lentil/fallow
 Spring maize–Monsoonal paddy–wheat/potato/linseed
 Spring fallow–Monsoonal paddy–wheat
 Spring fallow–Monsoonal paddy–wheat/maize

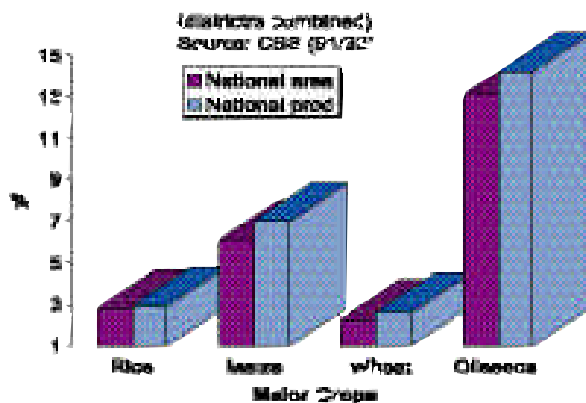
The above cropping patterns suggest that regardless of reliability of water availability in terms of timeliness and the needs of farmers, cropping intensity tends to approach 300 percent. However, the major cropping patterns under adequate, limited and deficit water conditions are spring paddy–monsoonal paddy–mustard; spring paddy and spring maize–monsoonal paddy–mustard; and spring maize–monsoonal paddy–mustard, respectively. The recent Makwanpur survey suggested additional cropping patterns like spring paddy–monsoonal paddy followed by wheat during winter in water adequate systems; and monsoonal paddy–winter wheat/maize/fallow followed by paddy/maize/fallow in water limited and deficit systems or deficit parts within the systems.

Contribution to national agricultural production. Figure 7 reveals that oilseeds contribute the most to the national agricultural production, followed by maize, rice, and wheat. It is interesting to note that the contribution is more in terms of production than in terms of crop area. This does not mean that rice is of lesser value. Crops other than rice are practiced both in uplands and lowlands and contribute to more production. Rice is restricted mostly to wet or irrigated area only.

Performance of Irrigated Agriculture

Overall basin-level performance of irrigation systems. Descriptive statistics of 37 systems were obtained for their overall performance in the basin (table 13). With a mean value of 264 percent, cropping intensity varied from 142 to 300 percent. Yields of spring rice and monsoonal rice varied between 2 t/ha and 5 t/ha. However, mean yield of the spring rice (3.52 t/ha) was slightly more than that of monsoonal rice (3.41 t/ha). Given the same level of water supply and input use, spring rice performs better than monsoonal rice because of cool nights, hot days and low winds favorable for net carbon assimilation during the spring season (Mallik 1981/82). Yield variation and production risk was observed more in winter crops (wheat, lentil and mustard) than in spring and monsoonal crops in the basin.

Figure 7. Contribution to national area and production.



Yield comparison with national average. Out of 37 systems, monsoonal rice yield in 35 systems was found to be above the national average. Because the mean yield of spring rice was higher than monsoonal rice in the basin (table 13), it is obvious that the yield of the former also exceeds the national average. The majority of systems (10 in 13) produced wheat yields above the national average. The opposite was the case with maize yield. In 12 out of 17 systems yields were lower than the national average.

The generally held notion is that maize is sensitive to excess soil wetness and that poor drainage could hamper its yield. However, looking at the data related to the water supply situation in these twelve systems, it was found that many of them fell in the tributary-fed water-deficit category (table 14), which implied a situation where systems had little or no water to irrigate a maize crop during the spring/dry season. This indicates that the cause of lower maize yields, among others, has been shortage of water for irrigation.

Table 13. Descriptive statistics, whole basin.

Indicators	N	Min.	Max.	Mean	Std. Deviation
Cropping intensity (%)	37	142	300	264.05	30.81
Monsoonal rice yield (t/ha)	37	2	5	3.42	0.65
Wheat yield (t/ha)	13	1	6	2.46	1.33
Lentil yield (t/ha)	21	0.1	1	0.5	0.21
Mustard yield (t/ha)	10	0.18	0.85	0.43	0.23
Spring rice yield (t/ha)	23	2	5	3.52	0.85
Spring maize yield (t/ha)	17	0.3	2	1.22	0.55

Mustard and lentil were combined as one category of oilseeds and pulses so as to make their productivity values comparable with national crop categories and values. Yields ranged from 0.2 t/ha to 1.2 t/ha with the majority producing below 1.0 t/ha. The higher proportion of east Rapti river-fed systems contributed to such lower yields. Out of fourteen systems observed, eleven had yields below the national average. This corresponds to the farmers' experiences that oilseed and pulses have been declining over time in this valley probably due to the intensified cropping systems, imbalanced fertilizer use and changed weather conditions.

Table 14. Water availability in selected irrigation systems.

Water availability	Rapti systems	Tributary systems
		(No. of irrigation systems)
Adequate*	19	0
Limited**	1	17

*As per farmers' need

**Below farmers' need

Performance by size of systems and source of water supply. The performance of 37 irrigation systems by their sizes and types of water supply (fed by main river versus tributaries) was assessed in terms of cropping intensity, gross margin, weighted mean of input cost, and gross value of outputs in major crops like rice, wheat, maize and oilseed.

Regression analysis revealed a nonsignificant or weak dependence of stated dependent variables on the variation in service area. However, yields and gross margin of monsoonal rice, as well as impact of level of fertilizer use (weighted mean of N, P and manure) were found significantly higher in systems that took water directly from the east Rapti river than those that took water from tributaries (table 15).

Table 15. Mean comparison of system performance by type of water source.

Indicators	Mean		Mean		Difference	t-statistic
	Off the river	N	Tributary	N		
Monsoonal rice, yield (t/ha)	3.74	20	3.19	17	0.55	2.88*
Gross margin, rice (Rs/ha)	20,123	20	15,181	17	4,942	1.79*
Nitrogen (kg/ha)	56.2	20	38.4	17	17.8	3.59*
Phosphorus (kg/ha)	20.3	20	12.7	15	7.6	2.2*
Animal manure (kg/ha)	1,474	20	1,055	17	419	2.0*
Input cost (NRs)/ha/yr.	17,121	20	14,498	17	2,623	2.39*

N=No. of observations.

*=Significant at 0.05 confidence level.

Farm Incomes

Farm income from sources other than crop production was not available. To manage the uncertainty, some indicators of farm income have been used to gain an insight at the basin as well as the household level. First, since farm income has a positive correlation with crop productivity, figure 6 presents a trend between 1980/81 and 1997/98. However, except for rice and maize, the production of wheat and oilseeds has remained stagnant in these basin districts. This indicates that there has not been an appreciable increase in basin-level farm income due to agriculture. The high dependence of farm income on crop productivity is explained by the fact that most people of the basin (75% of the population) are engaged in agriculture and are also supported by off-farm employment.

Second, data analysis from a survey of 814 households in the basin valley representing 37 irrigation systems indicates that there is a strong correlation ($r=0.83$) between size of landholding and off-farm employment. The reason might be that most of the larger landholders, irrespective of their family size, have a tendency to lease out land to smallholders. By so doing, the larger landholders can look for easy and clean jobs that utilize time saved from leasing out the land. Another underlying reason for leasing out is that under the current status of resources and technology available to the farmers, agriculture (especially raising field crops) does not seem to be a lucrative business. On the other hand, smallholders, who are mostly poor, must dig the soil for a living and also seek wage earnings.

The average number of off-farm employment per household is 4.1. The average family size is 7.4 and the ratio of average family size per household to average off-farm employment per household is approximately 2:1. On the other hand, 75 percent of the household population is composed of small holders (<1 ha) (table 16). By relating the r-value with the percentage of smallholders and percentage of the total population engaged in agriculture, it can be concluded that the major source of household income is through agricultural production. In many households surveyed, it was observed that livestock and poultry have, to a certain extent, contributed to sustain the rural economy. According to a sample survey in irrigation systems with interventions in East Chitwan, the Project Completion Report of ERIP (1998) reported that income from livestock is nearly equal to 18 percent of income from crop sales.

Third, at the individual system or user level, gross margins from different crops grown in the Panchkanya irrigation system, Chitwan were also obtained through field survey by Ghimire et al. (1999). In this survey, data from 27 households surveyed from head, middle and tail reaches of the system were averaged. Margins from rice, maize, oilseeds and wheat were calculated to be NRs 24,695, NRs 5,117, NRs 3,167, and NRs 1,580 per hectare, respectively.

In 72 agency-intervened FMIS from the East Chitwan valley, the Project Completion Report (1998) of the east Rapti Irrigation Project (ERIP) indicated that average annual income per household was NRs 49,272 with a surplus of NRs 15,421. The major sources of income were crop sales (NRs 12,976) followed by off-farm activities (NRs 114,222) and livestock (NRs 2,304) and other sources (NRs 41,181). This computation was based on sample households that represented farmers from the service areas of irrigation systems that were assisted by ERIP for infrastructural improvement. Although the ERIP report does not mention sources of off-farm income activities, our study in the same basin indicated that 33 percent of men and 13 percent

Table 16. Household and land distribution pattern in the basin districts.

Class of Land Size	No. of Households	Households (%)
<1ha ⁴	76,938	75
1 to 2ha	18,137	18
>2ha	6,266	6
Landless ⁵	763	1
Total	102,104	100

Source: CBS 1991.

⁴Smallholders are those who generally hold less than one hectare of cultivable land. This does not apply to urban areas. But in rural areas like the Chitwan valley, a household made up of a medium-sized family can make just a simple living and support schooling of children by cultivating one or nearly one hectare of land. Without supplemental irrigation these smallholders are always at risk of crop failure from flood, drought or disease, thus contributing to poverty.

⁵Landless households are understood to be those who may own a house, or run a trade or business, but do not possess land for cultivation. This may result either from flood or land fragmentation. Since landholding is related to farm income, holdings that lack other dependable income sources may contribute to poverty.

of women are involved in off-farm activities that include technical/professional, sales, labor, contractors, pension, own bus/truck/tractor, and the services.

Gross margin of paddy crop including its input cost computed for comparing the effect of variation in source of water supply (table 17) should be the most reliable indicator for understanding income from the main crop in the valley, as the data were collected from a large number of households surveyed.

Table 17. Mean comparison of system performance by type of water source.

Indicators	Mean		Mean		Difference	t-stat
	Off the river	N	Tributary	N		
Monsoonal rice, yield (t/ha)	3.74	20	3.19	17	0.55	2.88*
Gross margin, rice (Rs/ha)	20,123	20	15,181	17	4,942	1.79*
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Input cost (NRs/ha/yr.)	17,121	20	14,498	17	2,623	2.39*

N=No. of observations;

*=Significant at 0.05 confidence level

Nonagricultural Use of Water

Domestic and Municipal Supply

This sector uses both surface water and groundwater sources. A groundwater survey indicated that, at different times, the farmers in the ERIP area had, at different times before the ERIP was started, constructed about 400 shallow tube wells or open wells (ERIP 1998). The District Water Supply Office at Bharatpur, Chitwan developed 17 medium-sized and 20 small water supply schemes in the plains and surrounding hills to provide access to safe drinking water for a population of 143,657, corresponding to 40 percent of the district population. Drinking water facilities in the hills are targeted to most of the poverty-stricken communities. However, the current achievement still falls short of the initial agency target of providing clean water to 65 percent of the district population in Chitwan (personal communication with the agency authority). In the case of Makwanpur, there are 71 schemes out of which 21 lie within the basin. Altogether, 43 percent of the district population in Makwanpur now has access to safe drinking water (personal communication with DWSO authority 2000). After the completion of project work, the O&M of some of the schemes have been handed over to the beneficiaries.

Generally, the water supply schemes in Nepal are constructed assuming an effective production period of less than 20 years. A field survey of Pithuwa and Bhandara water supply schemes in Chitwan showed that high cost of repair and maintenance has been a problem for users. Problems included faulty design and inappropriate diversion siting, as well as unauthorized water extraction by a community of migrants for use in kitchen gardens. Usually, the users demand relaxation of water service fee for periods when no water was supplied.

Because of inadequate monitoring and record keeping of water availability, this demand has become unsuccessful. Furthermore, faulty diversion structures, from which a reliable supply cannot be expected, have forced the users to switch to alternative sources, such as dug wells, at their own cost.

With a very few exceptions, no conflicts are found between drinking water supply and irrigation in the basin. One example of conflict was related to drinking water of the Pithuwa Village Development Committee (VDC) and the irrigation water for neighboring Chainpur VDC. Both use the same source of water, the Kair stream. Both want water supply according to their own convenience. Since drinking water is more critical than irrigation and due to high water demand during the daytime, the conflict was resolved by a mutual written agreement whereby Chainpur would divert water only at night for irrigation, so that the high demand for drinking water of the Pithuwa residents is met during the daytime.

Industrial Use

In our industrial survey, we found 71 and 68 industries in the Chitwan and Makwanpur districts, respectively. Most of the industries are relatively more dispersed in Chitwan, whereas they are more clustered in Makwanpur. In Chitwan, groundwater is the sole source of water that is managed and regulated by individual industries. In Makwanpur surface water (Karra stream) is the major source of water, which is supplemented by groundwater during the dry season. The Industrial District is the authority to manage water production and distribution in Makwanpur. The consumption rate of water in the Industrial District has been calculated to be 358,232,149 liters/day. In terms of quantity, it seems that industries have used water that other sectors had used minimally or not used at all. Industrial use of water has not adversely affected the irrigation-water sector or the drinking-water sector. With caution, it can be said that no noticeable water competition prevails in the basin between industrial and other sectors related to quantity, source and allocation of water. Every industry produces some kind of pollution. However, industrial effluents of some of the factories like textiles, leather, soap and cement, and feed industries located in the Hetauda Industrial District (HID) in Makwanpur were reported to have produced high water pollution (NPC and IUCN 1991). Since the east Rapti river flows via Hetauda towards the national park and Chitwan, the effluents of these industries have presumably polluted the river and have posed threats to those using this water downstream.

Environmental Use

Although the Ninth Five-Year Plan (1997–2002) has brought about an Environmental and Resource Conservation Act in Nepal, there is still room to doubt progress in formulating rules and defining accountability of government line agencies in the district to implement this act. This situation can lead district-level agencies to remain ineffective in terms of coordinating and ensuring participation in the management and development of natural resources. However, as encouraged by the act, a large number of local and international NGOs and local youths now appear to have participated in different spheres of environmental development and conservation activities.

Related to environmental water use in the basin, there is a paucity of published government data on the apportionment of total water into different sectoral uses. However, based on the recent water-accounting study, an attempt was made to quantify relative patterns of water uses by various sectors (RTDB/IAAS/IWMI 2000) (figure 8).

Since water keeps moving from one sector to another, any change in its level in one component brings corresponding changes in its amount in other related components. Considering this relationship, all sectors as shown in figure 8 form integral parts of the whole environment of the basin. The figure explains the difference in water use across the sectors as affected by annual variation of water in the basin. It is thus important to understand whether excess use in one component has produced any adverse effects on other, but equally important, sectors of the basin.

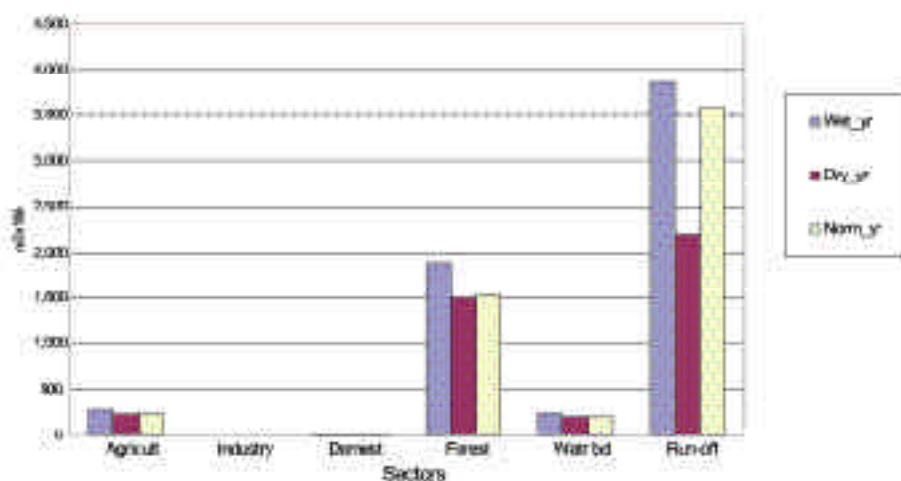
Land and Water Rights: An Overview

Recognized property rights to land and water, and related duties provide definitions as to who may control and use the property. Although patriarchal society, social customs and statutes are the three major factors that largely determine the property rights in Nepal on land and water resources, Pradhan (1989) states that traditionally, property rights had been well defined by social customs or by the community at large, rather than by statutes.

After marriage, women leave their homes to live with their husbands. Parental properties including land are therefore endowed to and shared equally among the male offsprings. However, female offsprings also hold statutory rights on the parental land, provided they remain unmarried and decide to stay single after the age of 35. Parents can also bequeath land to any or all daughters regardless of their marital status, although this practice is not very common. The daughters can acquire all parental property when there are no male siblings in the family. Caste and cultural traditions also affect the pattern of inheritance of property rights.

Water rights are also associated with land rights. In irrigated lands, this means that the right to use water is automatically transferred to the offsprings as landownership is inherited by virtue of statutory law as per the Legal Code of Nepal (1963). This is also the case when land buyers acquire landownership after purchase. A number of traditional water mills, locally

Figure 8. Multi-sectoral water use in the basin.



called *Ghatta*, exist in the upper reaches of some streams. However, water is sent back to the stream after its use by the Ghatta without adversely affecting the canal flow downstream. Because of the prior appropriation rights recognized by the Legal Code, irrigation water users cannot stop water use by the Ghatta. The users of the Ghatta are not required to own land. For purposes of irrigation, the Irrigation and Related Water Resource Act of 1967 recognizes rights of individuals, groups of individuals or the community to divert water from sources like streams, rivers or groundwater in such a way that the extraction does not adversely affect the functioning of government irrigation schemes or hydropower plants. The Water Resource Act of 1992 states that the ownership of all water sources of the kingdom will be vested in the state and people will have use rights so that the resource is utilized for creating national assets and contributes to revenue.

Irrigation being the major domain of beneficial process consumption of water in the basin, it is important to focus more on how property rights in water are practiced. The conventions for property rights in water include both principles by which water is allocated among farmers and the responsibilities that individuals have for maintenance of the system (Martin and Yoder 1988). Depending on the nature of the water source, there can be a series of diversion structures along the course of a given stream or river and irrigation systems with diversions next to each other may have conflicts over water acquisition and distribution. To minimize such conflicts, the Legal Code of Nepal 1963 clearly spells out that the diversion distance between two systems that are located close to one another should be kept at least 100 meters apart. Although local geomorphology controls the drainage behavior of stream flow to a great extent, the intent in the Code is, as far as practicable, to allow the downstream users equal access to water. It is forbidden to construct concrete diversions that can substantially harm the water rights and availability to other systems.

Water rights are also related to tenure. Different kinds of tenure arrangements operate in the basin including owner-operator, sharecropping, mortgage, lease and contract farming. Sharecropping is a quite common practice after owner-operators. All operators possess water rights as they are required to contribute resources in terms of kind, cash or labor for the acquisition, production, distribution and the use of water resources for irrigation. In the absence of male members, women can also represent the household in WUAs or assembly and related decision-making processes as de facto members (Ghimire et al. 2000).

Stakeholder Perceptions of Water Resource Development and Management in the Basin

Perceptions of Water Scarcity

The water accounting study indicates that the east Rapti river is an open basin as it drains a significant amount of the utilizable water flow (47%) out of the basin annually. On the other hand, out of the remaining 53 percent of depleted water only 6 percent is used for beneficial process consumption within the basin. A complementary study using a Key Informant Survey indicates that even in an open basin there exists great variation in the availability of agricultural water and dry-season scarcity because of diverse topography and highly skewed seasonality in the rainfall pattern. Significant spatio-temporal variations in water availability are forcing

some areas to look for alternative cropping patterns (see under subhead Crop Production and Cropping Patterns). Although rice has low water-use efficiency, irrespective of water adequacy it is cultivated as the main crop in large tracts of the basin for a variety of reasons. The main reasons are that it is considered as a staple and traditionally superior food crop. It fetches a good price and stores well. Also, rice straw serves as excellent animal fodder throughout the year. That is why everyone, including poor people, grows rice even under rain-fed conditions.

Despite many irrigation infrastructures, lack of dependable water sources and unreliable supply have, in many cases, resulted in failure of maize crops, particularly in dry areas during the spring season. However, due to low evapotranspiration requirements, winter crops, such as wheat, mustard, lentil and potato, grow fairly successfully even with a few light winter showers. As farmers put in substantial collective efforts to manage water for all possible crops in all seasons, they have experienced more water deficit in winter and spring season, particularly in dry areas that have no access to river water.

The drinking water sector appears to be relatively better served irrespective of location and season. Almost every household in the plains owns a low-cost open or dug well or a hand pump. For dry areas with deep water tables, there are community water supply schemes in place. The government agency for drinking water, and NGOs have made more efforts to build community water supply schemes in the hills, especially for poverty-stricken areas. The industrial sector uses a minimal amount of water as evidenced by figure 8 and no noticeable deficit or scarcity of water was observed in any industry during the survey. This sector is also not found to have any water competition with other sectors except in matters related to localized pollution by a few industries.

Perceptions of Issues on Water Quality

The basin receives water intercepted and conserved by the surrounding hills and mountains, whose ecosystem is dominated by forests (>60% basin area). Irrigators have considered such water as clear, and a boon for crop production due to its fertile nature. They also tap flash floods to feed into canals. Although flood events have become more destructive in the east Rapti river, one biologist at the Mahendra Trust for Nature Conservation, Sauraha, Chitwan emphasized the need for floods that sweep away old vegetation including grasses and allow growth of new vegetation necessary for wildlife. Government line agencies for water supply in both basin districts have considered water from the hills and mountains to be safe for drinking.

However, water-polluting industries such as textiles and leather, despite their wastewater treatment plants, were found to have polluted the river water upstream. Although the toxic effects were reported to be more of a confined and localized phenomenon, it seems logical to foresee that industrial effluents (toxic substances and heavy metals) might have affected the aquatic creatures downstream. So long as there is no monitoring of water pollution levels in the river it will be hard to know the magnitude of their effects on different flora and fauna. However, considering the high price of chemical fertilizers, the wastewater sludge if managed properly, could be an attractive supplement to the animal manure currently in use (MoFA et al. 1996).

Perception of Water-Related Conflicts and Conflict Resolution

In Nepal, people hold legitimate rights to develop, manage and use water for productive purposes. Those who invest in a water resource can stake a claim to it. For irrigation, the

users' collective decisions and actions define incentives in proportion to the level of contribution to irrigation development. Individuals in a group reach a set of agreements, forming working rules that define what is required, forbidden or permitted, and monitor closely what has been done. The rules are season- and location-specific as the canal flow changes temporally and spatially. Conflicts arise if rules are somehow altered or violated, which in turn may limit or expand one's claim. Intersystem conflicts are mainly attributed to the use of common sources, whereas intra-system conflicts mainly come from methods of water distribution, often during dry season or low-flow periods. External factors like high floods, associated with catchment degradation due to encroachment upstream, damage diversion structures, resulting in high repair and maintenance costs. While none of the users want to lose their claim on water, conflicts arise due to those who have sometimes not participated in, or paid cash or contributed the required labor for repair works. Floods that change stream courses have been a potential cause of conflicts. In some cases, intervention by an external agency has displaced the old structures and obstructed water distribution patterns among users. Although settled by the users themselves, more conflicts do occur due to competition for water in water-deficit areas.

Depending upon the nature and severity of conflict, a range of mechanisms is used to resolve conflicts. These include both formal and informal mechanisms. Many cases are resolved by simple informal negotiations or arbitration, while some have gone as far as hearings by the Supreme Court. Although informal mechanisms are most common, users approach legal and quasi-legal institutions when informal mechanisms fail to resolve conflicts adequately (Shukla et al. 1996). Different water rotation schedules, monitoring, and graduated sanction systems are used to minimize conflicts within the system.

No major conflicts are found between sectors in terms of quantity of water used in the basin, except between hotels in the National Park, Sauraha, Chitwan and between irrigation systems with diversions upstream of the Park. Hotel authorities claim that these systems divert substantial amounts of river water, hindering rafting and boating for tourists during the dry season. The irrigators' grievance is that they find their temporary diversions dismantled by hotel workers at night. Both parties fight for their own interests. The concern of the farmers is for their survival, as they have no alternate sources of irrigation in the area, whereas it is a matter of making business more profitable for the hotel people in the park. Obviously, the conflict is due to the absence of appropriate institutions to resolve such multi-sectoral water uses. It seems that existing use patterns of river water by the National Park and irrigators downstream, and the disposal of industrial effluents in the river upstream need to be assessed for appropriate mechanisms agreeable to all water use sectors in the region.

Perceptions of Current Institutional Arrangements for Water Allocation

Farmers themselves manage all irrigation systems except the Narayani Lift and Khageri irrigation systems, which are jointly managed by the government and users associations. Most of the irrigation systems acquire water from a series of head-works along the same streams. An arrangement for water allocation between these systems is based primarily on mutual consensus among upstream and downstream users when water becomes limiting, especially during the dry seasons. The tradition is that the downstream users approach the upstream users through functionaries to make an informal request for sharing water. Also, there are irrigation systems among which a formal legal right of access to water is also found. In some others, water is allocated proportionately into a number of shares depending upon the labor contribution and

farm-size to be irrigated. Contributions in terms of kind, cash, or labor are made to maintain the common intake and keep the canal structures functioning. All users must own or lease land for cultivation. Those individuals who demand more water for irrigating additional land areas are required to make proportionate contributions.

In the case of intra-system water allocation, boundary rules are used to define who the users are and who are not. Each farmer within the rule is allocated water, based on his or her labor contribution to O&M of the system. Stringent rules are implemented during water-deficit periods to ensure equity in allocation. Systems switch from continuous to rotational patterns of water distribution as canal supplies decrease. In most systems, opportunistic user behaviors such as shirking and water pilferage are controlled by rules for graduated sanctions.

One embankment (18-km long) and a number of spurs were built along the river course for flood protection in the downstream area. But no storage facility that can control or distribute the flow from the river to other places or sectors has been developed. No explicit allocation of uncontrolled river water is found among various sectors. As mentioned earlier, conflicts between tourism and irrigation sectors indicated that although the national government assigns high priority to tourism and national parks, exclusion of irrigation water use from the river appears impossible unless options are developed acceptable to both sectors. This raises the issue of little or no water allocation between sectors or protection of riparian property rights for water use.

The HID, located in the upstream area, supplies water to all industries except one. Using an intake channel, they extract water from both Karra stream and a well. Hetauda Textiles has its own well and only a minor part of the consumption is supplied by the HID. Water allocation and supply within industries are demand-based and does not seem to be a problem since revenue is collected from the use of power. At present, the wastewater from all industries is discharged practically untreated and eventually ends up in the river. Although textile factories drain wastewater at night, river water is still very polluted where it is used for various domestic purposes. This raises an issue of water quality in the river due to poor wastewater management.

Institutional Structure

Kinds and Levels of Institutions Involved

The Ministry of Water Resources (MoWR), Water Resources Development Council (WRDC) and National Planning Commission (NPC) are at the national policy level. The District Water Resources Committee (DWRC), District Irrigation Office, Irrigation and River Control Committee (IRCC), District Water Supply Office, and District Branches of National Irrigation Water User Federation (NIWUF) are at the district level; Municipalities, Village Development Committees (VDCs), resource users, both individuals and WUAs, industries as well as the Buffer Zone Development Council, National Park, and tourism are at the local level. Together, these are the principal actors related to development, management and utilization of the water resources in the basin districts.

Role of the Government Agencies

MoWR, WRDC, NPC and DWRC are the main agencies for overall interagency water resources coordination. The DWRC, as seen today, provides legitimate status to water users by

registering users groups, based on a recommendation by the VDC on whether the acquisition and use of water from a given source would create disputes with other user groups in the area. Such a licensing process gives the user groups water use rights. The National Code of Conduct (1963) has also legally recognized customary water-use rights. More recently, the Irrigation and River Control Committees (IRCCs) have been formed with the responsibility of taking preventive measures and protecting irrigation infrastructure against landslides and floods. The IRCCs of related districts can hold joint meetings if the problem is large and the river is designated as part of more than one district. The IRCCs also have to maintain coordination between irrigation- and agriculture-sector programs of the District Agricultural Development Office. The Chief District Officer is the chairperson of both the DWRC and the IRCC, while the Local Development Officer, a government nominee, and the Chief of the District Irrigation Office serve each as member secretary in the DWRC and IRCC, respectively.

The Water Resource Act of 1993 has set sectoral priorities for water use, in which drinking and domestic use receive top priority followed by irrigation, hydropower, industrial, navigational, recreational and other uses. Conflicts are resolved based on the importance and priorities stated above when multi-sectoral claimants are involved in water use for different purposes. However, conflicts between new versus old users for any specific purpose are resolved based, primarily, on customary rights. Within the irrigation sector, water users usually seek conflict resolution first by informal negotiations and arbitration. The VDC intervenes only when the contenders seek solution from a government-authorized agency at the village level. There have been a few cases in which the side that lost the case in the VDC has filed a petition with the Chief District Office and the District Courts to seek a favorable verdict. In some other instances, the Supreme Court has also intervened in the cases when the losing side appealed after being defeated in the Appellate Court.

As guided by the Irrigation Master Plan of 1988 and the revised water resource policy of 1997, the Department of Irrigation has so far been directing its investment mainly a) to turn over of its small irrigation projects to WUAs, b) to assist FMIS with irrigation management, and c) to irrigation management programs and some rehabilitation work on its large Terai projects. However, the newly emerged National Water Resource Strategy Formulation (WRSF 2000) of HMGN recommends that related policy and implementing government agencies be prepared for their new roles. According to WRSF recommendations, the government should move, among other things, towards necessary basin-wide interventions including flow-regulating reservoirs, interbasin transfers and demand-side management for sustainable development of water resources. It should consider river basins as a fundamental planning unit and adopt water balance simulation models through basin-wide database development and analysis, for appropriate decision making for the proper utilization of water resources in the future (WRSF 2000).

Institutional Constraints

So far, all the planning and implementation exercises have been carried out on a project basis. No formal institutions exist to manage the water resources from the basin perspective. This has led to an uncoordinated and unbalanced growth of the water sector with the existing institutional structure. Despite the legal provisions, the national government seems weak to translate many of its policies into effective implementation. The concept of long-term basin

water resources policy and regulations is not clearly spelled out for integrated development and management of the water resources that includes the involvement of all stakeholders.

While informal WUAs are required to register their associations mainly for external assistance, formalization of WUAs has not been tailored to provide support services. There is also a need to empower the WUAs so that viable local institutions are recognized and organizations assume legal authority, for example to sue a person for damages, for compensation or for resolving a conflict. In this line, unstable government policy, poor administration, inability to enforce rules as in the case of managing industrial effluents and contradictory Acts for sharing water with the multiple water users have been constraints. In the case of the irrigation sector, the users have not been able to realize the expected benefits as envisaged by the new working policy on the development and management of participatory irrigation.

Conclusions

A large number of organizations and levels are involved in the water sector in the basin. Although the resources are part of two districts, at present, none of the agencies are responsible for the basin-level work. However, concurrence of both districts and related offices is crucial for any policy, program and implementation, and stakeholder inclusion for development activities of the basin water resources. Therefore, it seems logical to seek a mechanism, for example a Basin Water Office or an authority that could facilitate coordination across sectors, districts and levels.

While it is an “open basin,” perceptions differ as spatio-temporal variation of water availability is a common phenomenon that significantly affects the agricultural productivity, as illustrated by comparing performances of river-fed and tributary-fed irrigation systems. FMIS have strong local institutions in place but for various reasons, infrastructural performance for effective water delivery is far below designed capacity. Learning from the past agency interventions, many of which ended up with perverse incentives, future assistance should focus on implementing a fully participatory approach (farmers as principal actors). It should work towards a policy of developing scarce zones so that more attention is paid to improve access to water resources in dry areas. Equally important is to increase outreach research for water productivity.

Forests act as a major source of rural livelihoods in the country and in the basin. There is an increasing trend towards private forests at the cost of national forests. The Decentralization Act, new forestry legislation (1983) and the 25-Year Forestry Master Plan (1986) provided legal foundation for handover of government forests to user groups. Despite the willingness of the users, community forestry programs in these districts have not progressed as expected. In principle, reinforcing community forestry would lead to forest conservation that, in turn, would help sustain water sources for drinking water, irrigation as well as to reduce downstream flooding.

Protection of wild life and environmental conservation of the National Park, a World Heritage Site in the downstream area, require safe and adequate water to be maintained in the river around the year. Low dry-season runoff combined with the conflicting interests between irrigators and tourism in the Park has affected both. While both stake claims over use of the river, an identification of water users and provision of alternative sources of irrigation water

through subsidized shallow tube wells appear imperative to reduce farmers' dependence on river water. Although against the country's 20-year Agricultural Perspective Plan, the government has stopped subsidizing shallow tube wells from 2000 onwards. From our extensive field observations, we now know that farmers have privately made many dug-wells and shallow tube wells as a means to deal with dry spells. The water accounting study of the basin identifies great prospects for exploiting shallow aquifers for irrigation without adversely affecting the nonrenewable aquifers. The question then turns to learn why shallow tube wells/dug-wells are proliferating at private individual scale and why the government efforts have failed.

While increasing population will put more pressure on river water in the foreseeable future, it appears inevitable to review, establish and implement appropriate policy and programs related to issues on water rights and somehow develop mechanisms for allocating reasonable shares of flow to various sectors. In terms of pollution, Makwanpur and Chitwan are among the industrial hot-spot districts. Keeping in view the adverse impact on river ecosystems, as well as on the National Park and people downstream, monitoring and low-cost pollution control programs must be promoted. The government should establish pollution-control standards, provide industries with necessary support for technical assistance, training and subsidies, and encourage farmers to use treated sludge as manure. Through legal provisions, the government should demonstrate its capacity to convince and force industries to show their willingness to get involved in pollution prevention and control mechanisms. This would lead to far-reaching implications for conserving biodiversity, environmentally sustainable development and aiding the disadvantaged who make a living from traditional fishing, such as the Bote and Kumale communities.

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CHAPTER 5

Initiating the Improvement of River-Basin Management: Ombilin River Subbasin, West Sumatra, Indonesia

Helmi¹

Introduction

The Inderagiri river originates in the highlands of West Sumatra and flows to the east coast of Sumatra Island. The upper part of the Inderagiri river basin in the West Sumatra Province consists of three major rivers, one of which is the Ombilin river. This river originates from the Singkarak lake, which is fed by two other major rivers, Lembang/Sumani and Sumpur. The water supply in the Ombilin river depends largely upon the outflow from the Singkarak lake. The construction and operation of a hydroelectric power plant at the Singkarak lake since late 1997 have diverted (transferred) part of the water from the Singkarak lake to the Anai river basin, which flows to the west coast of Sumatra Island. This has reduced water supply and increased pressure on water users along the Ombilin river. Since then the improvement of Ombilin river water management has become a concern for various stakeholders.

River basin management and water allocation have increasingly become issues in West Sumatra as competition for water use between irrigated agriculture and other sectors of the economy increases. Integrated Water Resource Management (IWRM) is an important development agenda to address institutional problems and capacity building for the use, control, preservation and sustainability of water systems. The Government of Indonesia is in the processes of reforming its water resources management policy, putting IWRM principles into action. One of the elements of the new policy is related to the improvement of river-basin management. Although experience with river basin management has been developed in one basin, the Brantas river basin in East Java, this was not the case for other regions of the country until recent times. This paper presents the case of water management on the Ombilin river in Sumatra and attempts to identify relevant issues and their implications related to IWRM.

The next section of the paper outlines the policy and institutional context of river basin management in Indonesia. This provides an overview of the water management policy reforms and identifies aspects of the policy relevant to the improvement of river basin management in West Sumatra. The third section describes the setting of the Upper Inderagiri river basin and the Ombilin river subbasin. The fourth section discusses the impact of transbasin diversions and the institutional challenges facing water management in the subbasin. The last section presents tentative action plans for initiating improvement of river basin management.

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Policy and Institutional Context of River-Basin Management

Water Resources Management Policy Reform

The Government of Indonesia is currently reforming its water resources and irrigation management policy. This section presents the reform principles, which are closely related to the improvement of river basin management, especially in the West Sumatra context. There are four objectives of the reforms (BAPPENAS 2000):

- Improving the national institutional framework for water resources development and management.
- Improving organizational and financial framework for river basin management.
- Improving regional water quality management regulatory institutions and implementation.
- Improving irrigation management policy, institutions and regulations.

The first and the second objectives are closely related to the improvement of water allocation and river basin management. One of the five sub-objectives of the first objective clearly mentions the involvement of stakeholders (including the private sector) in river basin management and decision making. The proposed reforms in this subobjective cover three areas:

- Issuing government regulations, which put emphasis on the participation of stakeholders (public agency institutions, community, and the private sector) in water resources development and management.
- Amending the ministerial regulation to a) include stakeholder representatives in provincial- and basin-level water management coordination committees (Indonesian acronyms PTPA and PPTPA), and b) merging provincial water management committees (PTPA) with provincial irrigation committees.
- Establishing functional PTPA and PPTPA with stakeholder representation in key river basins in about eight provinces.

The second objective contains three subobjectives one of which is the improvement of the provincial regulatory framework for the management of the river basin and aquifers. This will be the basis for the development of effective water management institutions at the provincial and basin level.

With the enactment of the new water policy and subsequent related activities, there is a clear commitment by the government to improve river basin management in Indonesia. As mentioned earlier, even though there is experience with regard to the river basin management in the Brantas river basin (and lately in the Citarum river basin), this approach is not yet widely implemented. The new policy provides a basis for initiating the improvement of river basin management in other priority river basins in Indonesia.

River-Basin Management in Indonesia

The Government of Indonesia started to recognize river basins as the units of water management in 1982 through the enactment of Government Regulation No. 22/1982 on Water Regulation, in which Article 4, Chapter III stressed the use of the river basin as the basis for water resources management. In 1989, the Public Works Ministerial Regulation No. 39/PRT/1989 was issued to specify 90 river territories in Indonesia. Each river territory is composed of one or several adjoining basins. The objective of this regulation was to ensure that conservation and use of water in the basins were conducted in a holistic and integrated manner.

In 1990, Public Works Ministerial Regulation No. 48/PRT/1990 specified the authority for the management of water and river basins. Out of the 90 river basins, 73 basins are managed by provincial governments, 15 basins fall under the management of the Ministry of Public Works, and 2 basins, Brantas river in East Java and Citarum river in West Java under the management of public corporations. Therefore, incorporation of the idea of river basin management into policy and action is relatively new to Indonesia and the management framework, other than in the two basins under public corporations, is not yet developed.

Based on the Public Works Ministerial Regulation No. 39/1989, West Sumatra Province falls into six river territories. One of these is the Inderagiri river basin that, according to the Public Works Ministerial Decision on the division of the river territories, is under the authority of the Ministry of Public Works because the basin is located in two provinces. The upper part of the Inderagiri river basin is located in West Sumatra while the lower part is located in the Riau Province.

Upper Inderagiri Basin and Ombilin Subbasin

Setting

The Upper Inderagiri basin contains three major rivers, Lembang/Sumani, Sumpur, and Ombilin, and two lakes, Dibawah and Singkarak. Water from the Lembang/Sumani and Sumpur rivers flows into Singkarak lake, while the Ombilin river originates from the Singkarak lake and flows east to the Inderagiri river. The altitude varies from 164 m asl at the lowest point (near the confluence of the Ombilin and Sinamar rivers) to 1,200 m asl at the highest point where the Lembang river originates from the Dibawah lake. The water supply in the Ombilin river depends largely upon the outflow of the Singkarak lake while this lake is influenced by inflow from the Lembang/Sumani and Sumpur rivers. The water supply in the Lembang/Sumani river is largely determined by the outflow from the Danau Dibawah lake.

The Upper Inderagiri river basin generally falls under the humid tropic climate covering almost all of Sumatra. Average rainfall in the subbasin area is 2,026 mm/yr. The Ombilin river subbasin is the driest part, with annual average rainfall of 1,789 mm/yr., compared to the Sumpur river basin, which is the wettest with an average rainfall of 2,484 mm/yr. This is slightly higher than in the Lembang/Sumani river basin with an annual average rainfall of 2,200 mm.

The total area of the Upper Inderagiri basin was estimated at 3,060 km². The area includes 400 villages within three districts and three municipalities. Most of these villages (around 87 percent) are rural. Within the Upper Inderagiri basin, about half the area lies in the catchment

(subbasin) of the Lembang/Sumani, around 13 percent in the Sumpur river basin and 30 percent in the Ombilin river subbasin.

Demography and Employment

The total population of the Upper Inderagiri basin in 1997 was 662,425, with an average population density of 408 persons/km². The ratio of the urban population to the rural population is 0.28. This implies that the water supply for urban needs will be an important issue in the near future. In terms of households, the population data show that, in 1997, there were 150,466 households in the basin area with an average household size of 4.59. Only about 13 percent (or some 18,898) households are served by piped water supplies. Aside from households, some industries, offices and other social facilities are also served by piped water.

According to a 1993 agricultural census, about 68 percent of households (or 94,508 out of 139,831 households) were categorized as farm households. Since most of the households in the area are engaged in agriculture, water demand for agriculture will be one of the major issues in the basin.

In terms of income levels, more than one-fourth of the villages in the Ombilin river subbasin is categorized as poor villages. In the West Sumatra Province the incidence of poverty has increased sharply during the last few years because of severe economic crises (BPS 1998). The number of persons living below the poverty line increased from 9 percent (or 384,582 persons) in 1996 to an estimated 31 percent of the population (or 1,403,559 persons in 1998).

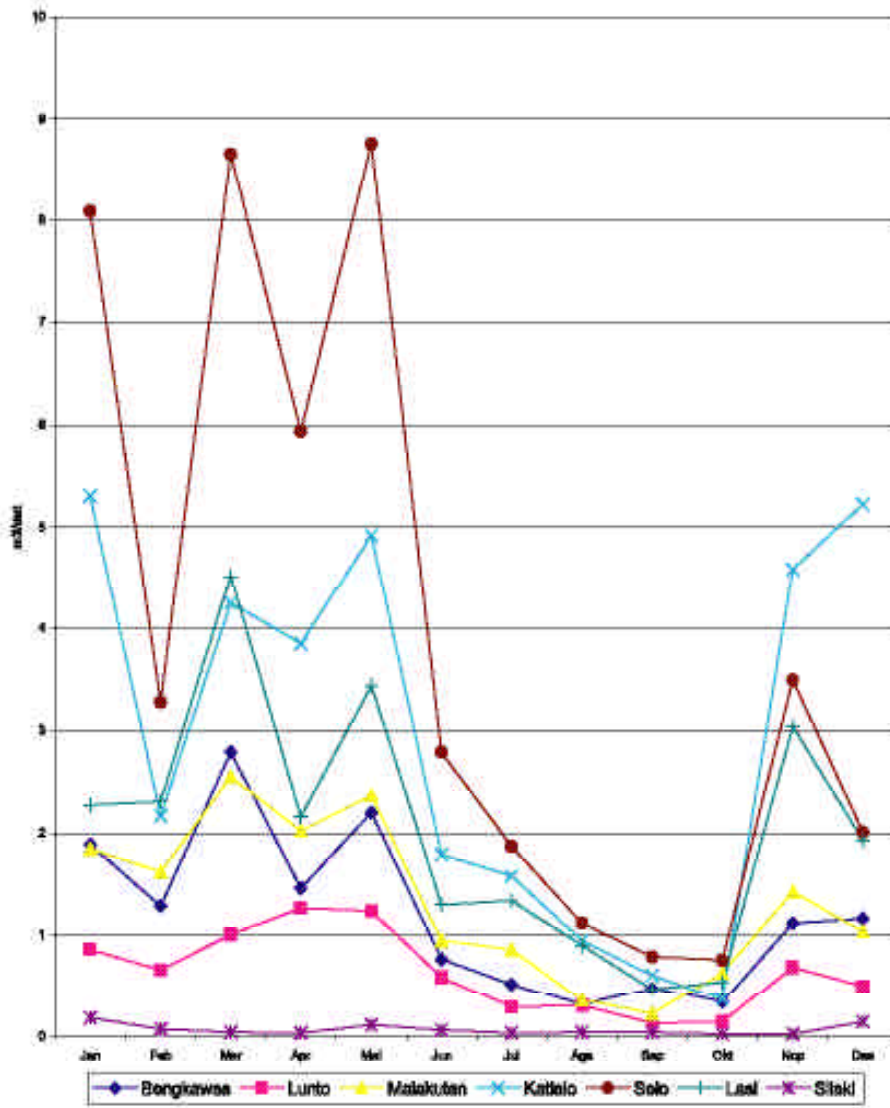
Zones of the Ombilin River Subbasin

Seven major rivers discharge into the Ombilin river, as shown in figure 1 and the dependable flow of these rivers is shown in figure 2. The Selo river has the biggest inflow into the Ombilin river, while the lowest is from the Silaki river. Based on the type of water use, the Ombilin river can be divided into three zones.

Zone A (upstream) is from the Singkarak outlet to the confluence with the Selo river. In this zone, water is mainly used for irrigation where water is lifted by waterwheels. Three rivers flow in to Ombilin river in this zone: Bengkawas, Katialo and Silaki rivers. In this zone, there were 58 waterwheels of which only 30 are currently functioning.

Zone B (midstream) runs from the confluence with the Selo river to the confluence with the Malakutan river. There are three types of water use in this zone: irrigation, domestic and industrial. The inventory found 77 irrigation waterwheels in this zone, with 38 of them being functional. In addition to the waterwheels, there are 5 pumping stations for irrigation. For domestic and industrial use, there are two pumping stations for drinking water and one pumping station for coal washing.

Figure 2. Dependable flow of seven rivers into the Ombilin river.



Zone C (downstream) starts from the confluence with the Lunto river and extends to the confluence with the Sinamar river. In this zone, water is mainly for irrigation, lifted by waterwheels. Two rivers flow into the Ombilin river, Lunto and Lasi rivers. In this zone, there are 231 waterwheels for irrigation of which only 116 are functioning. In addition, the zone has 9 pumping stations for irrigation.

Water uses vary among the three major rivers and lakes. At the Ombilin river, water is used for irrigation, industry, electric power generation and domestic water supply. In two other rivers, water is mainly used for irrigation and domestic water supplies.

Water Accounting for Ombilin-River Subbasin

Water balance computations were carried out for each zone. The average inflow to the Ombilin river from the Singkarak lake is estimated to be 3.333 m³/s. The results of water balance computations for each zone showed that the discharge flows in each zone are still much higher than the outflows or water uses for various purposes, as shown in table 1. In Zones A, B, and C only about 5.4 percent, 30.6 percent, and 12.7 percent, respectively, of the water is being used. The data tended to suggest that in Zone B pressure on water resources is highest followed by Zones C and A.

Table 1. Results of water balance computation for the Ombilin river.

Items	Zone A		Zone B		Zone C	
	Inflow m ³ /s	Outflow m ³ /s	Inflow m ³ /s	Outflow m ³ /s	Inflow m ³ /s	Outflow m ³ /s
Singkarak lake	3.33	-				
Bengkawas river	1.19	-				
Katialo river	2.97	-				
Silaki river	0.07	-				
Irrigation (agriculture)	-	0.41				
Water balance	7.56	0.41	7.15			
Selo river			3.96			
Irrigation (agriculture)			-	0.92		
Talawi Domestic WS Company			-	0.04		
PLN thermal power plant			-	0.01		
TBO thermal power plant			-	1.9		
Coal washing			-	0.14		
Rantih pump station (Domestic WS)			-	0.4		
Water balance			11.11	3.41	7.71	
Malakutan river					1.32	-
Lunto river					0.64	-
Lasi river					2.02	-
Irrigation (agriculture)					-	1.49
Water balance					11.69	1.49
						10.2

Further classification of the water balance components into water use categories (water accounting) indicated that the depleted fraction of gross and net inflow for the part of the Ombilin river under study is 0.34 (in this case, gross inflow is equal to net inflow). The process fraction of depleted water is 1 (because total depletion is assumed to be equal to process depletion), and the process fraction of available water is 0.43.

Stakeholder Identification

Four major groups of water users from various sectors have direct interests concerning water from the Ombilin river:

- Farmers irrigate, mainly using waterwheels to lift the water from the river.
- The coal mining company uses water for washing coal (used water goes back to the river).
- Domestic water suppliers provide water for the Sawah Lunto town and other consumers.
- The electricity company uses water from the Singkarak lake for hydropower generation and two thermal power plants are located along the Ombilin river.

There are other groups who do not cause consumptive depletion of water but use the river for various activities. They include fisherfolk; users of the river for bathing, washing and other personal needs; and those who collect building materials such as sand, gravel and stone from the river.

The Ombilin River Subbasin under Stress

This section analyzes four issues related to water management in the subbasin. These issues are a) interbasin water transfer, b) impact of the construction of the Singkarak HEPP on irrigated agriculture and other users, c) lack of a framework for licensing water rights and water charges, and d) lack of an organization for river basin management.

Interbasin Water Transfer

To gain sufficient head, the water used by the Singkarak HEPP is channeled by a tunnel through the mountain range to the Anai river, which flows to the west coast of Sumatra. To fulfill water requirements for power generation by the Singkarak HEPP, the outflow from the Singkarak lake to the Ombilin river was regulated to be between 2–6 m³/sec. This was a major reduction from the earlier average outflow of around 49 m³/sec. At the Ombilin river, especially along the 70-km length of the river that was the focus of this study, water is used for irrigation, industry, electric power generation and domestic water supply. The operation of the Singkarak HEPP has affected the availability of water for various uses along the Ombilin river, showing the competition for water use between the Singkarak HEPP and water users along the Ombilin river.

Water management responsibilities are fragmented among a number of government agencies. The tendency is that when any particular government agency has developed a particular water source, the control of water use is assumed to be in its hands. Other users are expected to adjust themselves to the changes in water availability.

The Impact of the Singkarak HEPP

The impact on irrigated agriculture mainly affects waterwheels, which were the main method of lifting water from the Ombilin river for irrigation until recently when some diesel pumps began to be used. No gravity irrigation scheme is found along the main stem of the Ombilin river. Pumping began because of the difficulties farmers faced in operating the waterwheels with the reduced flow in the Ombilin river. There are surface irrigation schemes on the tributaries of the Ombilin river, which are not affected by the operation of the Singkarak HEPP.

Farmers felt that waterwheels were the most suitable scheme under the previous physical conditions of the Ombilin river. The limited rice fields available; locations scattered over the narrow flat area along the river and the average width of the river around 50 m would make the construction of weirs for gravity irrigation very costly. In addition, the porous soil requires continuous flows of irrigation water.

The field inventory found some 184 waterwheels serving a total of 333 hectares of command area and 463 farmers. On average, one waterwheel serves 1.8 hectares and 2.5 farmers. At the time when the field inventory was conducted there were 14 pump irrigation units found along the Ombilin river, with a total command area of 138.5 hectares involving some 200 farmers.

The number of waterwheels, command area and number of farmers served declined markedly after the Singkarak HEPP was developed (table 2). Now, the number of waterwheels is only about half that before the operation of the Singkarak HEPP started in 1996. The current irrigated area is approximately 61 percent of that in 1996.

Table 2. Waterwheels, service area, and farmers 1996–2000.

Year	Number of Waterwheels	Total Service Area	Total Number of Farmers
1996	366	549	729
1997	296	470	621
1998	237	405	556
1999	195	343	478
2000	184	333	463

Source: Field inventory.

Increased O&M costs of the waterwheel irrigation scheme. For owners and operators of waterwheels, the reduction in the water discharge of the Ombilin river has caused several problems in the system operation and maintenance (O&M). The current discharge flows of Ombilin river, especially in the dry season, oftentimes cannot rotate the waterwheels or if they can, it is only with a very low rotation per minute (rpm). Consequently, operators have to lengthen the traditional weirs as a way of increasing water depth and directing water toward

the wheel so as to make its rotation faster. Another way of making waterwheels keep on operating is by reducing the number of water tubes so the waterwheel becomes lighter and easier to move. Nevertheless, the consequence of both choices is increased workload, cost of O&M and reduction in the capacity of the wheel to supply water that, in turn, decreases both the land that can be irrigated and the reliability of irrigation water.

Increased intensity of damage to traditional weirs and waterwheels occurs due to drastic increases in river discharge after sudden opening of the gate at the Singkarak outlet. According to the farmers, the gatekeeper usually opens it during the rainy season to avoid flooding the settlements and irrigated areas located in the lowlands surrounding the Singkarak lake. Consequently, the Ombilin river discharge increases during the rainy season because of the additional inflow coming from the Singkarak lake.

Table 3. Damage and rehabilitation costs before and after HEPP.

Items	Average Intensity/Cost (per Season)		Percentage of Increase
	Before HEPP	After HEPP	
Waterwheel damage	1	2.5	150
Weir damage	1	4.5	350
Rehabilitation costs of waterwheel	Rp 150,000	Rp 1,100,000	633
Rehabilitation costs of weir	Rp 50,000	Rp 425,000	750

Source: Socioeconomic survey.

For the owners and operators of the waterwheel irrigation schemes, increased damage intensity means more labor capital and costs. Results of the socioeconomic survey show that, on average, damage increased from once per season before the operation of the Singkarak HEPP to 2.5 times per season afterward.

Most farmers reported that irrigation water supply has been unreliable after the development of the Singkarak HEPP. As a result, the yield of rice on land irrigated by waterwheels has declined markedly. Some farmers reported a lighter effect while some others noted a considerable decline. The results of the socioeconomic survey found that as a whole, rice yields have dropped from an average of 4.2 tons/ha before the development of Singkarak HEPP to 3.1 tons/ha in 1999.

The results of performance assessment suggest that the performance of irrigated agriculture has declined during the last 5 years. Seven indicators were used to measure the performance: a) output per unit of cultivated area, b) output per unit of command area, c) output per unit of irrigation water, d) output per unit of available water, e) relative water supply, f) relative irrigation supply, and g) financial self-sufficiency. The main factor that caused the decline was the reduction in total water supply and irrigation supply at the field level.

These problems can be attributed to the absence of water management institutions in the Ombilin river subbasin under growing inter-sectoral competition for water. With regard to irrigation water management, a major point raised is that the existing irrigation technology (particularly traditional waterwheels) is no longer suited to the current condition of water scarcity. Opportunities remain to increase the performance of irrigated agriculture in the area

of the Ombilin river subbasin by establishing institutions for managing water in the basin, and by improving irrigation technology to cope with the increased scarcity of water.

Impact on industry and domestic water supply. The reduced flow in the Ombilin river has also affected the pump stations in the matter of coal washing and water quality for domestic water supply. PLN, the company operating the Singkarak HEPP, built a weir to improve the water level and so solved the problem.

Declining water quality in the Ombilin river has also resulted in some problems for the domestic water suppliers and consumers. The Selo river transports sediment, especially during the rainy season and from coal washing. Water quality downstream of the Ombilin river has declined since the operation of the Singkarak HEPP. Increased electric conductivity; soluble solid material (from 104 mg/l to 176 mg/l); pH (from 7.2 to 8.4); nitrate content (from 0.26 mg/l to 0.35 mg/l), chloride (from 4.62 mg/l to 8.4 mg/l); and sulfate (from undetected to 10.3 mg/l) were detected when records for 1994 and 2000 were compared.

The declining water quality has increased O&M costs of the domestic water suppliers. The manager of a domestic water company estimated that water treatment cost increased by almost 100 percent. However, at the time when the quality of raw water was very low, the domestic water suppliers did not perform water treatment since it would not yield any improvement in the quality of water. In such a condition, the domestic water company would distribute the raw water directly to the customers without treating it.

Frameworks for Licensing Water Rights and Water Charges

In principle, water rights are supposed to be given in the form of use rights and allocated by the government through licensing. Since water and sources of water are considered as embodying social functions, there are uses of water that require licenses, and there are those that do not. Tapping water for noncommercial drinking water and other individual domestic uses is allowed without a license as long as it does not harm the source of water and other water users' interests. According to Ministerial Regulation No. 48/PRT/1990, a government license is required for uses like domestic water supply, municipality and real estate, irrigation, animal husbandry, plantation, fishery, industry, mining, energy, navigation and disposing of waste.

The Minister of Public Works and the Governor are authorized to issue licenses for water use rights within their respective basins. The Minister of Mining and Energy issues licenses for groundwater use. Licenses for water use may be given to individuals or groups of individuals or any legal entity. A group having a license to use water is authorized to arrange water distribution among its members based on government regulations. Those granted licenses must pay fees to the Ministry or to the Governor. According to MR No. 48/PRT/1990, the fee is to be used for financing O&M of water structures and maintaining the sustainability of the water source. Every license on water use has a time frame depending on the kind of use. The fee is supposed to be reset every 5 years.

The transfer of water licenses is restricted. Article 18 MR 48/PRT/1990 states that giving up a water license or selling it to other parties may be allowed if the agency issuing the license gives its permission. The regulation, however, is not explicit on this exception. Formal water use rights and allocation are hardly implemented, except perhaps to some extent, in the two basins managed by the publicly owned companies. The problems included, among others, the

existence of gaps and inconsistencies in the formal regulations, policies and organizations. The lack of consensus on some key concepts (Pusposutardjo 1996) and the lack of hydrological data in most of the basins (Hehanusa et al. 1994), make it difficult for the government to conduct basin-level planning or even to make the right decisions on whether or not new uses of river water are justifiable.

Regulations provide that licenses for water uses that potentially affect the water balance must be based on general basin-level plans on development, protection and utilization of the basin water. In cases where such plans have not been made, the issuance of the licenses must be based on consensus made in the coordinating body, the PTPA.

In most of the basins, however, water allocation is governed by whatever the local communities accept as rules. In predominantly agricultural basins, *adat* (traditional customary rights) may govern water allocation. In the Ombilin river there were no local rules for water allocation since the challenge was in lifting the water from the river. In the context of waterwheel irrigation, the results of water accounting showed that, in aggregate, the water supply is sufficient, but the problem is the water level required to operate the waterwheels.

Where nonagricultural sectors have exerted their interests, claims over water may be based on political or economic power leading to transferring water from the agriculture sector (Kurnia et al. 1996). Nevertheless, government wields, and is sometimes capable of exercising, the authority in water allocation, including interbasin water transfer. Transferring water from the Ombilin river to the Anai-Sialang basin is an example. The decision about this transfer seems to have been made on the basis of studies done by the government. The original water users must now adjust to the new situation. The problems that have occurred with waterwheels and domestic water supplies downstream in the Ombilin river underline the importance of formalization of irrigation water rights in order to protect the interest of the poor and small farmers.

Lack of an Organization for River-Basin Management

As has been mentioned earlier, the incorporation of river basin management into policy and action is relatively new to Indonesia. Furthermore, the management framework is not yet developed, except in two basins in the island of Java managed by publicly owned corporations. In other provinces of Indonesia, the idea of river basin management is newly introduced. As the responsibility for water management is fragmented between a number of government agencies, a provincial water management committee (in Indonesian language abbreviated as PTPA) is supposed to be set up in all provinces. In West Sumatra the PTPA was set up in 1994. The characteristics of this committee are as follows:

- Its main function is to assist the Governor in coordinating water management at the provincial level.
- The specific tasks are a) data collection, processing and preparing materials to be used to formulate provincial policy on water management coordination; and b) providing considerations and advising the Governor on matters related to water supply, wastewater drainage and flood control.
- The members of the committee are from agencies related to water management (other stakeholders are not yet included as members of the committee).

There was no specific budget allocated for this committee, so its activities were carried out mainly on an ad hoc basis. When there were problems related to water supply, drainage, or flooding, a meeting of provincial staff would be held but it was not very clear whether the meeting was a PTPA meeting or just a meeting related to the performance of general government tasks.

The government regulation on the provincial PTPA has also an article stating that the Governor could establish basin-level water management committees (PPTPA) to assist the PTPA in performing its tasks. However, up until now this committee has not been formed in any of the six river basins located in the West Sumatra Province. As the conflicts over water allocation and use are tending to increase in West Sumatra, as illustrated with the case of the Ombilin river, clearly, there is a need to develop a framework for improving river basin management in the province. The case of the Ombilin river can be used as the pilot activity to develop the framework and capacity for integrated water resources management at the basin level in West Sumatra.

Initiating the Improvement of River-Basin Management

Core Elements of the Tentative Action Plan

The discussions in the preceding sections indicate that there is a need to develop effective water management institutions. Action plans for improving water management in the Upper Inderagiri river basin (especially in the Ombilin river) would consist of the following elements.

For a short-term action plan, the options that can be considered are as follows.

- In the short term, especially during the dry season, the problems faced by the users need to be solved by reviewing the existing water allocation rules and releasing more water from the Singkarak lake to the Ombilin river. For this purpose the handling of water allocation needs to be done systematically. The affected users along the Ombilin river are proposing that a kind of water board, which consists of all of the stakeholders be set up and given authority to regulate water allocation from the Singkarak lake.
- The technology for lifting water for irrigation with waterwheels and diesel pumps needs to be adjusted, given the changes in water level in the Ombilin river and the cost of operating the pumps. The soil porosity is high and there is a need for a 24-hour water supply. The waterwheels are very well suited for this environment but the reduced water level in the river is not sufficient to continue operating them efficiently with the current technology. With regard to the pumps, the farmers indicated that they have difficulties with the cost of pump O&M and are thinking about the possibility of using electric pumps for lifting water from the river. In this regard, the farmers proposed that the company dealing with electricity should provide a special discount for the electricity charge for the domestic water supply

and for the farmers who will use electric pumps for irrigation, as a “good-neighbor policy.”

For the longer term, the government needs to take initiative to set up a coordinating body (PPTPA or a kind of water management board/committee) at the subbasin level. The main task of this body would be to regulate and enforce the water allocation rules effectively, for which the national water resources policy has provided a legal basis.

The long-term action plan to improve water management would consist of the following:

- Reviewing all the water-related laws and regulations at the provincial level and adjusting them in accordance with the direction of the new national water policy. This will include laws and regulations related to strengthening the water resources management coordinating committee at provincial level (PTPA); establishment of the water resources management coordinating committee at (sub-) basin level; and reviewing the possibility of charging a tax for the use of surface water, and using the income generated from this to finance the operation of the coordinating bodies as well as river and watershed maintenance.
- The preparation for setting up of a coordinating and/or operating body for river (subbasin) management by using the Ombilin river subbasin as the pilot site.

Tentative Action Plan

Based on the core elements of the action plan presented above, the detailed actions for initiating the improvement of river basin management in West Sumatra are presented in table 4.

Conclusions

The conclusion of this paper is that the water use competition has raised the need to improve water management in the Ombilin river. However, frameworks for this are not yet developed. Current water policy reforms in Indonesia clearly provide a basis for improvement of the management. Measures should be taken to review existing provincial regulations related to water management, and a framework should be developed for river basin management. Capacity building for river basin management can be initiated through efforts to solve the problems of the Ombilin river, from which lessons could be used for other river basins in West Sumatra. An action plan could consist of four points:

- Review and revise provincial laws related to water resources management.
- Strengthen the provincial water resources management committee (PTPA) and establish a water resources management coordinating committee at river basin level (PPTPA) with the involvement of stakeholders.
- Improve provincial water resources information and decision support systems.
- Implement short-term action plans.

Table 4. Tentative action plan.

Action	Priority	Responsible	Timeline
<p>Review the current environmental policy and procedures to ensure they are up to date and effective.</p>	<p>High</p>	<p>Environmental Services</p>	<p>Q1 2024</p>
<p>Conduct an environmental audit to assess current performance and identify areas for improvement.</p>	<p>Medium</p>	<p>Environmental Services</p>	<p>Q2 2024</p>
<p>Implement energy-saving measures such as LED lighting, power management, and energy-efficient equipment.</p>	<p>Medium</p>	<p>Facilities Management</p>	<p>Q3 2024</p>
<p>Reduce paper usage by implementing digital workflows and encouraging double-sided printing.</p>	<p>Low</p>	<p>Human Resources</p>	<p>Ongoing</p>
<p>Establish a recycling program for paper, plastic, and glass waste.</p>	<p>Medium</p>	<p>Environmental Services</p>	<p>Q4 2024</p>
<p>Conduct regular environmental training for all staff members.</p>	<p>Low</p>	<p>Human Resources</p>	<p>Q1 2025</p>
<p>Monitor and report on environmental performance metrics.</p>	<p>Medium</p>	<p>Environmental Services</p>	<p>Q1 2025</p>
<p>Review and update the environmental policy and procedures annually.</p>	<p>High</p>	<p>Environmental Services</p>	<p>Q1 2025</p>

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CHAPTER 6

Development of Effective Water Management Institutions: The Upper Pampanga River Basin, Philippines

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Introduction

The Upper Pampanga river basin (UPRB) is one of the biggest river basins in the Philippines. This basin provides abundant water resources for a big population, growing industries, and agricultural production in a vast fertile riceland in the Central Luzon region. While current water resources are still abundant, there is an urgent need to protect and manage it for future generations. Moreover, the absence of a coordinating body to effect overall water management necessitates studying the UPRB.

This report presents the highlights of the diagnostic study conducted in the river basin to assess the physical facilities, water accounting, socioeconomic conditions and system performance within the UPRB. Based on the diagnostic study, issues were identified and the suggested reforms for effective water management are presented. Finally, an action plan is presented aimed at developing an effective water management institution to ensure sustainable water resources in the river basin.

Project Site

The UPRB is in the upper reaches of the Pampanga river basin, in Central Luzon, the Philippines, between longitudes 120° 40' E and 121° 28' E and between latitudes 15° 00' N and 16° 08' N (figure 1). The estimated total area of the basin is 420,000 hectares covering 2 cities, 1 Science city and 25 municipalities in the provinces of Nueva Ecija, Pampanga and Bulacan.

The average landholdings in the Basin are small, ranging from 1.4 to 3.0 hectares (BAS 1999) owned by 152,292 farming households that primarily cultivate rice. Onion, garlic, tomato and other vegetables are produced, especially during the dry season.

Agriculture is the major source of employment and income in the basin, particularly in Nueva Ecija, which is considered the Philippine's major rice producing province. Added to agriculture are agro-industries, such as livestock, including poultry and pig farms, and light industries, such as feed mills, rice mills, ice plants and cold storage of onion, that all contribute to the basin's economy. Commercial establishments abound in population centers within the basin, especially in first class municipalities like Santa Rosa, Gapan, and San Miguel and in

The UPRB has two distinct seasons. The wet season runs from May to November and the dry season from December to April. The average rainfall is 1,900 mm for a normal year and 1,100 mm for dry year. Rainfall during the rainy season is brought about by the southwest monsoon, accompanied by an average of 22 tropical depressions during this part of the year. Table 1 shows the basic profile of the basin.

Table 1. Basic profile of the Upper Pampanga river basin, Philippines.

<i>Basin Characteristics</i>				
General Information				
Geographical area		4,200 km ²		
Location		N 14° 45' to N 16° 10'; E 120° 20' to E 121° 15'		
Physiographic features		Plains 90% Mountainous 10%		
Average rainfall				
Normal year		1,900 mm		
Dry year		1,100 mm		
Agro-climatic Information (average from 1980 to 1999)				
Location	Total Rainfall (mm)	Total Evaporation (mm)	Average Temperature (°C)	Average Humidity (%)
CLSU	1,994	1,904	28	75
Cabana-tuan city	1,754	1,847	28	81
<i>Facilities/Assets</i>				
No. of irrigation schemes (surface irrigation)		4 major systems		
No. of hydro power plants		1		
No. of rainfall stations		2		
No. of pan evaporation stations		2		
Large reservoir	1 (2,996 million m ³)		Irrigation, hydro power, industry	
Shallow wells	1,571	Deep wells	11	
<i>Urban Centers</i>				
No. of urban centers	4	Area of urban centers	807 km ²	
<i>Socioeconomic Data</i>				
<i>Land Use and Agriculture</i>				
Total population	1.374 million (1990)	Cultivated area	254,490 ha	
	1.583 million (1995)	Urban land area	67,365 ha	
No. of households	308,347 (1995)	Irrigated area	123,357 ha	
Average household size	5			
Population density	341 persons/km ² (1995)	Average landholdings	1.4 ha to 3.0 ha	
Maximum population in Urban sector	490,425 persons/km (1990)	Major farm crops	rice, onion, garlic, vegetables	
Maximum population in Rural sector	884,470 (1990)	Cropping intensity	120% (1998)	
Ratio of urban: rural population	1:1.8		154% (1999)	
Per capita land area	0.006 km ² (1995)			
Households with piped water 28% of total				
Number of IAs (under NIS)	365			
Number of IA members (IAs under NIS)	62,104			

Sources: NCSO 1990 & 1995, PAG-ASA 1990–1999, and BAS 1999.

The surface water supply in the UPRB is provided by the Pantabangan reservoir, and the major river tributaries in the upper reaches of the Pampanga river, such as the Awilan, Digmala and Coronel rivers. Other sources of irrigation water in the basin are the Talavera and Peñaranda rivers. Within the basin is the Upper Pampanga River Integrated Irrigation System (UPRIIS), one of the biggest national irrigation systems in the Philippines. In 1975, the UPRIIS became fully operational and it is used mainly for irrigation. Small irrigation systems and rainfall provide the irrigation requirements of other rice producing areas outside the UPRIIS. Water in the basin is also utilized for hydropower. One plant produces 150 megawatts of electricity and water is reused for irrigation.

The Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) operates a hydro-meteorological station and a synoptic station within the UPRB. The first is the CLSU Agromet Station located at the Central Luzon State University, Muñoz, Nueva Ecija, and the other is the Cabanatuan Synoptic Station located 30 km south-southwest of the CLSU Agromet Station.

Several government agencies are tasked with the administration of water in the basin. Their interests and functions are administrative and regulatory in nature. These agencies are the following:

- National Irrigation Administration (NIA)
- National Power Corporation (NPC)
- Department of Environment and Natural Resources (DENR)
- Bureau of Soil and Water Management (BSWM)
- Philippine Atmospheric, Geophysical Astronomical Service Administration (PAGASA)
- Local Water Utilities Administration (LWUA)
- National Electrification Administration (NEA)
- Bureau of Fisheries and Aquatic Resources (BFAR)
- Department of Public Works and Highways (DPWH)

Despite the presence of these agencies within the basin, it is still beset with problems and issues such as siltation of waterways, land conversion, water pollution and the lack of a coordinating body to promote effective water resources management in the basin.

Results of the Diagnostic Study

Physical System

The physical system of the UPRB consists of the Pantabangan reservoir, the river system, the diversion dams and the irrigation channel network, which are used to supply water for irrigation, fisheries, municipal, industrial, and other requirements. Within the UPRB is the UPRIIS, which services 102,500 hectares, which area is about 24 percent of the whole basin.

Rice is the major crop in the UPRIIS, with an average annual production of 63 million metric tons. Communal irrigation systems (CIS) provide irrigation to about 2,500 hectares of ricelands and diversified croplands. Individually operated 4-inch shallow well pumps also contribute to the overall irrigated areas in the UPRB. As many as 1,571 units of shallow well pumps and engine sets with an average discharge of 9 liters per second (lps) were installed from 1997 to 1998.

The survey and evaluation of irrigation facilities indicated a deteriorating trend in their functionality over the years since the UPRIIS became operational in 1975. The most common problems observed were a) silted irrigation channels, b) absence of farm ditches and farm-level water control structures, c) inadequate drainage systems, particularly in low-lying areas, and d) poor maintenance of farm-to-market roads. The irrigation performance efficiency, estimated at 50–64 percent during the wet season and 53–65 percent during dry season, and the cropping intensity are contingent partly on the functional status of irrigation infrastructure in the UPRIIS.

Potential irrigable areas outside the UPRIIS can be converted into productive agricultural lands by the construction of more communal schemes. For this reason, small water impoundments, capable of supplying irrigation water to 10–20 hectares of riceland in the UPRB, are being programmed by the Department of Agriculture. Also, small farm reservoirs capable of irrigating 1–2 hectares of riceland are continually constructed. To this end, the NIA is mandated by the Republic Act No. 6978 to undertake a 10-year program for the construction of irrigation projects in the remaining 1.5 million hectares of irrigable lands throughout the country. Specifically, 50 percent of the funds allotted for the purpose is to be used for communal irrigation projects.

Additional physical infrastructures are being constructed by the Casecan Multipurpose Irrigation and Power Project (CMIPP). This project is expected to irrigate 35,000 hectares of agricultural land in June 2004 and provide hydroelectric power of 150 megawatts in March 2001. The irrigation component of the project consists of 64 km of the main diversion canal and 611 km of laterals and sublaterals, together with water control structures and irrigation facilities.

The need to rehabilitate and maintain the nonfunctional irrigation facilities in the UPRIIS has become imperative. Their deteriorating conditions have rendered most of them ineffective in controlling water for irrigation and drainage. A concerted effort involving the national government, concerned line agencies and local governments should therefore be geared towards the development of infrastructural facilities not only for irrigation and drainage but also for transport facilities such as farm-to-market roads.

Water Quality

Water in the Upper Pampanga river was categorized as Class A, while that in the Lower Pampanga River was categorized as Class C. Class A is good for municipal water supply requiring complete treatment (coagulation, sedimentation, filtration and disinfection) while Class C is meant for irrigation. Unfortunately, no data are available on the quality of water in the Pampanga river where its chemical, physical and biological characteristics are concerned.

However, visual inspection of the flowing water indicated a relatively high turbidity level due to sediment load, which may have affected the river biota population, particularly fish and crustaceans. This turbidity level has shown that the quality of water has indeed deteriorated steadily from Class A in 1975 to a much lower class at present. This deteriorating quality of water in the Pampanga river and its tributaries is attributed to increased agricultural activities, human settlements and deforestation.

On the other hand, groundwater in the UPRB has remained unaffected in terms of volume and quality. Groundwater drawn from deeper aquifers has remained the sole source of municipal water supplies in population centers such as the Cabanatuan city, San Jose city and the Science city of Muñoz, all located within UPRB.

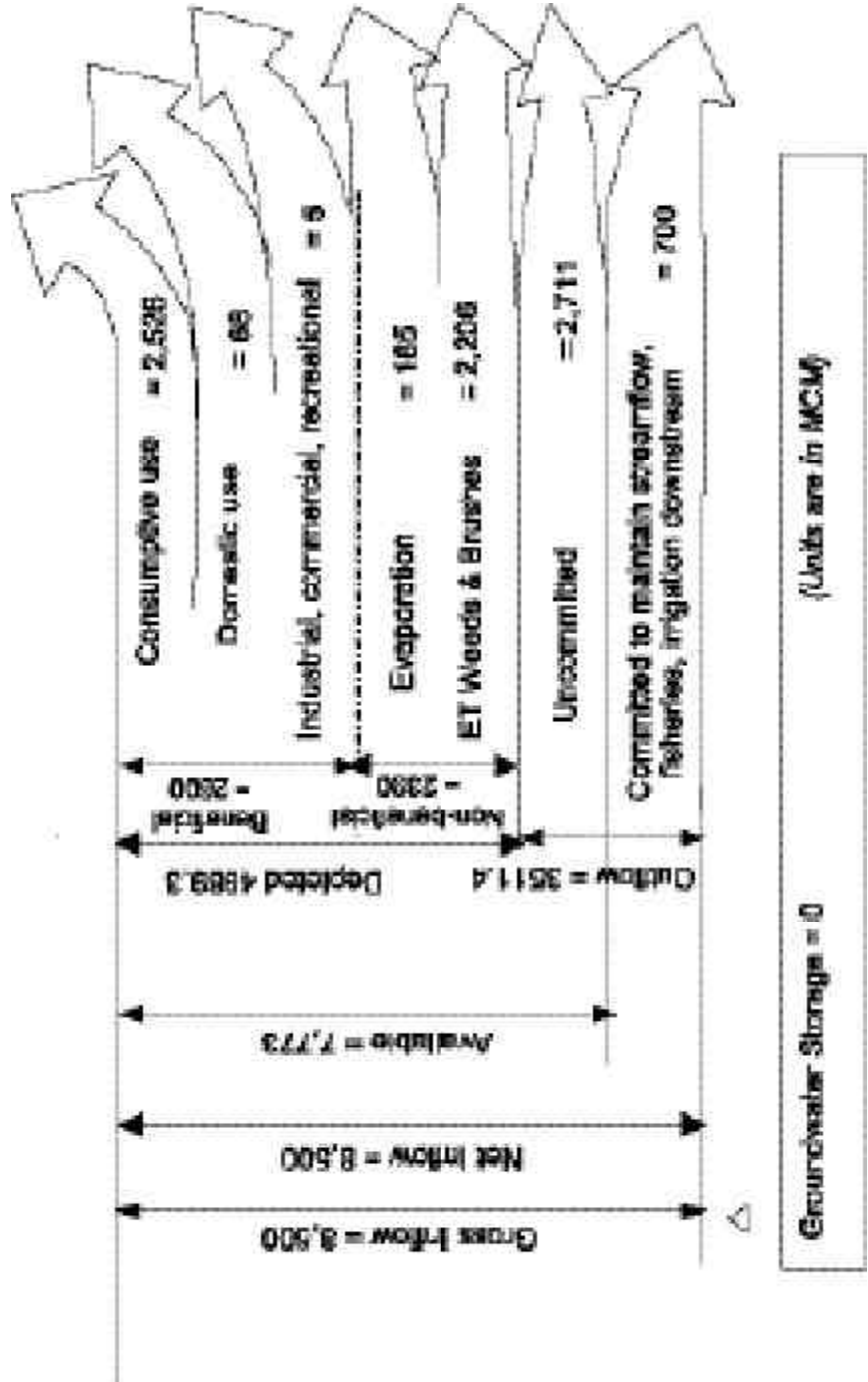
Availability of Water

Aside from natural rainfall from May to November, the basin's water supply is regulated by the Pantabangan reservoir, which is capable of irrigating 102,500 hectares of riceland. Flows from the Coronel, Digmala, Talavera and Peñaranda rivers also contribute to the overall irrigation requirement of the basin. The supply of surface water is more or less fixed by the average annual rainfall of 1,900–2,000 mm. However, surface water flows into the Pantabangan reservoir while the base flows of the Upper Pampanga river and its tributaries tend to decrease during the dry season when demand for irrigation is highest. This low base flow may be attributed to loss of land cover in the watershed. Coupled with the deteriorating water quality downstream, the available surface water supply for beneficial use may become critical in the next 10 to 20 years. Thus, the supply of groundwater might be relied upon to support the increasing water demand of all water use sectors in the basin.

Water Budget

The roughly estimated water budget of the UPRB gives an overall picture of the gross water inflow and its present level of depletion (figure 2). Over the long term no change was observed in the storage of the Pantabangan reservoir; groundwater withdrawals are replenished during the rainy season. The committed outflow for downstream users in the Pampanga delta for irrigation, fishery and maintenance of streamflow of the Pampanga river is 700 million m³ (MCM) leaving 7,800 MCM available water out of the annual inflow of 8,500 MCM. About 2,600 MCM are beneficially utilized for industrial and recreational use (5 MCM), domestic water supply (68 MCM) and consumptive use (2,526 MCM). For non-beneficial use, it is estimated that about 2,206 MCM of water are lost through evapotranspiration of weeds, brush and other vegetation.

Figure 2. Water accounting for the Upper Pampanga river basin, Philippines (1998–1999)



The uncommitted portion of the available water amounts to 2,711 MCM. Presently, most, if not all, of this amount of water drains out to the Pampanga delta, the Candaba swamp and finally to the Manila bay. This occurs because of the absence of storage facilities that can trap the water for later use.

In dealing with the water balance equation, some difficulties were encountered due to the unavailability or incompleteness of data regarding outflows and water depletion. The water accounting figures on uncommitted and committed outflows were arbitrary in nature and are subject to further refinement. Nevertheless, the resulting finger diagram provides a bird's eye view of water availability and its disposition in the context of future developments in the basin. More water storage facilities and water conservation measures are needed to optimize the use of the uncommitted portion of the available water in the basin.

Socioeconomic Conditions

The socioeconomic condition of the river basin provides a basis for a future agenda to improve water management. The UPRB is relatively large in terms of population, land area and coverage. In 1995, within the basin's administrative boundary there was a population of 1.58 million. The increased population pressure on land and other resources including water is likely to affect the river basin. The population growth rate is 2.86 percent per year, which is very high by international standards and higher than the country's (2.3%/yr.) and the region's (2.12%/yr.) growth rates. Unless efforts are made to minimize the growth rate, the population in the basin will be 2.1 million in 2005. The population density was 341/ha in 1995, an increase of 45 persons/km² within 5 years. The proportion of the population, which is highly dependent on the household for survival (0 to 19, and over 65-years olds), is relatively large, at 50 percent. The urban population was 36 percent in 1990, 13 percent higher than the 1980 level, and it is expected to increase because of the growing importance of the nonagriculture sector and migration in the domestic economy.

Farming households constitute about 50 percent of the total households in the basin. In Nueva Ecija, the average farm size has continued to decrease from 3.47 hectares in 1971 to 1.78 hectares in 1991. A similar trend was reported in Pampanga and Bulacan due to fragmentation and land conversion. If this trend continues, food supply in the basin will be a problem unless efforts are made to increase productivity per unit area.

Annually, on average, 218,710 hectares are planted to rice, 92 percent of which is irrigated paddy. However, the 3-year data (1996 to 1998) did not show any significant increase in area irrigated. In 1997, the major sources of irrigation were the national irrigation system (NIS-79%), the communal irrigation system (CIS-12%) and the pump irrigation system (9%). The average rice yield in the basin is still below the yield potential of modern rice varieties. From 1996 to 1999, the yield per hectare ranged from 3.0 to 3.62 tons/ha during the wet season and from 3.73 to 4.33 tons/ha during the dry season.

Data from 1992 to 1997 showed a decrease in area irrigated by NIS in 1993 and CIS in 1994 due to both insufficient water released and deteriorating irrigation facilities. In contrast, a significant increase occurred in area irrigated by pumps, from 400 hectares in 1992 to 10,000 hectares in 1996. The increase in service area by pumps could be attributed to an increase in the ownership of pumps, as a result of individual purchases and the distribution program of the Department of Agriculture.

The river basin is primarily agricultural. In Nueva Ecija, the labor force in agriculture is 57 percent although the corresponding ratio in Bulacan and Pampanga is only 30 percent. For the whole basin, the employment rate is 45 percent, while the unemployment rate is 4.7 percent. Most of the household heads are gainfully employed. There is more employment in the nonfarm sector in Bulacan and Pampanga than in Nueva Ecija. This has contributed to the big difference in household incomes in the river basin. In Nueva Ecija, 63 percent of the households had an income of less than 100,000 Philippine pesos (P) per year (US\$1.00=P54.4), as compared to less than 40 percent in Bulacan and Pampanga. In 1997, Nueva Ecija had the lowest per capita income of P20,959 while Bulacan had the highest at P31,343. The low household income and per capita income in Nueva Ecija could have been caused by the low productivity and low prices in agricultural produce. Efficient use of labor, fertilizer and water must be made to promote increases in agricultural productivity.

Considering that agriculture is the primary source of employment and income within the UPRB, the National Irrigation Administration Upper Pampanga River Integrated Irrigation System (NIA-UPRIIS) and its thousands of farmer beneficiaries, who are mostly members of the Irrigators' Associations (IAs), are considered as the major stakeholders of water from the UPRB. As of 31 December 1999, altogether 365 IAs in the whole of NIA-UPRIIS have been recorded, with a total membership of 61,880.

Most of these IAs are registered with the Securities and Exchange Commission (SEC) and currently have contracts with NIA.¹ They share in the management of operation and maintenance (O&M) of the irrigation system. The objective of the "shared management or participatory irrigation management" is to encourage the active involvement of the IAs in the O&M of the NIS. However, results of a recently concluded study, which reviewed the cost-recovery mechanism for the national irrigation systems, including the NIA-UPRIIS, revealed that "the NIA-IA partnership, in practice, is asymmetrical and that NIA controls the technical expertise and subsidizes maintenance and improvements in the canals that are being operated and maintained by the farmers (Shepley et al. 2000). In other words, the "paid" maintenance and contracts for collection of the irrigation service fee (ISF) do not provide enough accountability and incentives to the IA, and inhibit the farmers' capability for sustained O&M of the irrigation system.

The performance and capacity of the IA in the O&M of the irrigation systems are assessed annually using a NIA-devised functionality survey.² These assessments showed a

¹O&M contracts entered into by IAs with the NIA are of three types. Type I involves a canal maintenance contract. For this, an IA receives an incentive of P400 for every km or a total of P1,400/mo for a 3.5 km earth canal or a 7-km lined canal. In a Type II contract, the IA participates in system operation, ISF campaign and collection within its area of jurisdiction. An IA receives an incentive based on collection efficiency. Type III involves the transfer of the O&M of a system or part thereof to the IA, which amortizes the direct chargeable investment cost to NIA without interest for a period not to exceed 50 years.

²The functionality survey involves evaluating the IAs, based on a set of criteria considering the irrigation and organization-based management-related indicators and additional indicators.

downward trend in the number of functional IAs in the last 4 years. Inversely, the number of nonfunctional IAs has increased.

The diagnostic study involving the IAs and NIA-UPRIIS revealed certain realities, which can help explain the declining functionality status of the IA. One reality is that NIA field personnel and the IA officials were engrossed with ISF collection, probably because of NIA's policy of assessing its field offices in terms of financial viability. Since ISF is the lifeblood of the NIA, the field personnel are expected to exert their best efforts to collect ISF from the farmer beneficiaries. Another reality is that the O&M budget of NIA limits its capability to improve and rehabilitate the deteriorating facilities. Moreover, because of its limited budget, NIA often fails to give the O&M contract incentives to IAs on time.

It was found that the training, designed to enhance the IA's capability for O&M of the irrigation systems, was attended mostly by IA officials, and seldom by the members. This could be the reason why some farmers alleged that the IAs are "organizations of leaders," which means training in O&M hardly trickled down to the mass-based membership of the IAs. Moreover, another reality observed was the lack of personnel to assist and guide IAs so that they can effectively participate in all aspects of irrigation management. The NIA-UPRIIS, like the other field offices, has streamlined their field personnel. Those who remain with the agency are preoccupied with the ISF collection or the water distribution in the field.

These realities pose a big challenge to the NIA. With the implementation of Republic Act No. 8435, otherwise known as the Agriculture and Fisheries Modernization Act of 1997, which mandates NIA to accelerate the turnover of the management of the O&M of the NIS to the IAs, improvement of the IAs overall performance has become very important. Improving the performance of IAs is imperative as they constitute the biggest group of water users in the basin and as they can adversely affect the effective water management of the UPRB.

System Performance of UPRIIS/NIS Districts

The O&M expenses increased from P296/ha in 1989 to P645/ha in 1998. However, the actual area irrigated in all the UPRIIS districts has continued to be lower than what was programmed for both dry and wet seasons. A declining trend in irrigated area was observed: the highest area irrigated was 79,292 hectares in 1992 and the lowest was 48,484 hectares in 1998 when the basin was affected by the El Niño phenomenon. This decline in irrigated area means that irrigation needs of the districts cannot be sustained by effective rainfall, local flows from the different diversion dams within the service area, and releases from the Pantabangan Dam during the planting seasons. The available water from the system was not sufficient to increase the basin's cropping intensity as planned from 1989 to 1999. The yield was highly variable and did not show any significant improvement during the 11-year period studied.

The target collection efficiency of the system was set at 70 percent of the total collectibles. From 1993 to 1996, however, it was adjusted to less than 70 percent due to the wide exemption of areas affected by typhoons and other calamities. The collection efficiency ranging from 30 percent to 55 percent was much lower than the target collection efficiency. Water-gauging devices used to determine the inflow of water into laterals were not available. Hence, irrigation fees could not be charged in proportion to the quantity of water used. Due the low area irrigated and low paddy price during both dry and wet seasons it was hardly possible for the field

personnel of NIA to collect the ISF. The collection efficiency was strongly correlated with paddy price, but had a low correlation with area irrigated. Moreover, the implementation of Administrative Order No.17 (AO 17) issued on September 7, 1998 affected the total ISF collection. AO 17 has reduced the target collectibles by 26 percent; from P179 million (without AO 17) to P137 million (with AO 17).

Two other performance indicators were used to assess the operation of UPRIIS from 1989 to 1999. The first was output per unit irrigated area, computed as the value of production divided by irrigated area, and second was financial self sufficiency which is total income divided by O&M expenses. The first indicator showed an increasing trend during the dry season from 1989 to 1996. The best year was in 1996 with more than P 45,000/ha as a result of high farm gate price of P 10.00 per kg, and an increase in yield over its 1995 level. Conversely, in 1997, output per unit area decreased by 7 percent over the 1996 level because the 13 percent increase in yield was offset by an 18 percent decrease in the price level.

Wet season yield fluctuated, although an increasing trend was observed from 1993 to 1995, and again in 1997, because of the increase in farm-gate prices. These results indicated the importance of better farm prices in improving the total value of rice production because of the inelastic nature of the demand for rice. A price increase subsequently increases the total revenue. However, improving revenue in rice production requires complementary production inputs and reasonable price levels.

From 1989 to 1999, financial self-sufficiency was highly variable. Within the 11-year period, the system was not self-sufficient for four years (1993, 1995, 1997 and 1998). During these periods the increase in O&M costs was more significant than the increase in the total income. The financial situation was worst in 1998, with a very low self-sufficiency value of 0.60 as a result of low yield and low income from production. The highest self-sufficiency ratio was recorded in 1994 at 1.30, when income increased with a decrease in O&M.

The above data showed that the overall performance of the system has been affected by lack of funds for O&M and low ISF collection. When O&M are not sustained, facilities and equipment would fail to deliver enough water supply to the farmers and, as a result, farmers are unable to produce high yields and pay their ISF.

Suggested Institutional Reforms

The identified problems and vital issues relating to the physical facilities, water accounting, socioeconomic conditions and system performance within the UPRB were the basis for an institutional analysis of the basin. This analysis (presented in appendix 1) sought to identify the needed reforms to ensure more effective water management within the basin. Results of the analysis and the corresponding suggested solutions to the problems identified are herein presented and discussed.

Institutional Collaboration for Effective Water Management

Water at the UPRB, particularly within the NIA-UPRIIS service areas, has been found to be closely tied to agriculture, high population growth rates and population density, and an increasing rate of urbanization. This close linkage has raised the need for cooperation among the various agencies and interest groups within the basin. The researchers are of the view

that a multi-sectoral committee or core group should be formed composed of representatives from the NIA, DENR, LGU, National Power Corporation (NPC), local water districts, local communities and other interest groups. This group would be responsible for reviewing and integrating plans and projects or in developing an institutional framework that would define how the various stakeholders of the UPRB can collaborate and operate in an integrated manner. This integration is imperative because, at present, there is an apparent lack of effective mechanisms for coordination among agencies within the basin that are concerned with water management.

Adoption of O&M for Water Accounting and Valuation

Water accounting is crucial for planning and managing water resources. However, it is extremely difficult to do water accounting within the UPRB because of the lack of trained personnel responsible for getting the needed information. This is aggravated because of the inadequate or nonfunctional staff gauges and other measuring devices in strategic locations within the basin.

To remedy these situations, each LGU should install and maintain rain gauges and evaporimeters. Fund allocation for rehabilitation and installation of new gauging stations including maintenance could be provided by the Department of Public Works and Highways (DPWH), NPC, and NIA. The NPC and NIA can jointly undertake collection and maintenance of needed information within the basin.

In terms of valuation of water as a resource, several approaches are available depending on water use and sector. For irrigation, NIA charges an ISF for the service rendered in the delivery of water. The ISF collected is primarily used to fund the O&M of irrigation systems. With the issuance of AO 17 dated 7, September 1998, payment of ISF was socialized with the following rates: 75 kg/ha in paddy for wet season and 100 kg/ha for dry season for less than 2 hectares; 125kg/ha and 175 kg/ha for wet season and dry season, respectively, for 2 hectares to 5 hectares; and 200 kg/ha and 250 kg/ha for wet season and dry season, respectively, for 5 hectares and more. Payment in cash is computed based on the prevailing government support price for paddy. A 10-percent discount is provided to all farmers who pay the ISF before the due date.

However, the recently concluded study, which reviewed the cost-recovery mechanisms for national irrigation systems, pointed out that NIA's efforts to increase the level of ISF collection had been discouraging as a result of AO 17. Its ISF collection efficiency was at its lowest (34%) in 1998 when AO 17 was implemented, a huge decrease from 47 percent in 1997. While collection efficiency slightly improved to 36 percent in 1999, it was not enough to equal the level of collection prior to the implementation of AO 17 (Shepley et al. 2000). In the UPRIIS area alone, the reduction in total collectibles was estimated at 26 percent. The researchers are of the view that the abolition of AO 17 needs to be advocated and an appropriate ISF rate should be implemented such that 6.5 cavans/ha be charged in the diversion systems and 7.5 cavans/ha/yr. in the reservoir systems (Shepley et al. 2000).

For the water service sector, the rates may vary in the different water districts (WDs) because of differences in O&M expenses of the WDs, number of connections and presence and absence of subsidies. Recently, the National Water Resources Board initiated a series of fora to discuss the proposed increases in its fees and charges in compliance with Executive Order No. 197 (EO 197). EO 197 is a directive to all departments, bureaus and instrumentalities

of the national government including government-owned or controlled corporations to increase their fees and charges by not less than 20 percent to cover the full cost of services rendered.

Enforcement of Policies and Regulations to Protect Water Quality

The protection of all water resources against pollution from point and nonpoint sources is a recognized concern of the state and the local government units. Uncontrolled application of pesticides and chemical fertilizers in the paddy field plus wanton disposal of solid wastes, untreated animal wastes, municipal sewage and industrial wastes all contribute to the degradation of the quality of water. To counteract these threats, the Department of Environment and Natural Resources has issued Administrative Orders Nos. 34 and 35 series of 1990, which define the criteria of the quality of surface water and freshwater, prohibitions in discharging industrial or domestic sewage effluents and other restrictions.

Likewise, Presidential Decree No. 1067 issued in 1976 embodies rules and regulations for the protection of areas of surface water or any groundwater that may be declared by the DENR as protected areas. Occupants within a protected area are prohibited from conducting activities that may lead to the deterioration of the quality of surface water and groundwater. Mine tailings as well as application of agricultural fertilizers and pesticides are regulated by the DENR and AO in these protected areas where their application may pollute a source of water supply.

Within the UPRB, the problem of deteriorating quality of water arises due to increases in population and urban activities. Household wastes as well as wastes from micro-industries, especially in more urbanized areas in the basin, have started to create problems. Solid wastes are being thrown into irrigation canals disregarding municipal ordinances that protect the quality of surface water. If these municipal ordinances and other rules and regulations for the protection of the quality of water are not strictly enforced, pollution of water within the UPRB will be critical in the future.

Advocating Proper Water Management Technologies

Micro-level analysis of the crop production in the UPRB shows that the predominant cropping pattern is rice-rice. This cropping pattern requires a large volume of irrigation water that is drawn heavily from the main canal of the NIA-UPRIIS. Rice fields are flooded with water starting from land preparation until 2 weeks before harvesting.

Efforts have been exerted to teach farmers on proper water management in rice culture for minimizing wastage. In the past, training on rice production and proper water management at the farm level has been conducted by NIA and other government and nongovernment agencies. However, farmers have continued their conventional practices, indicating that the training has not been successful in attaining the objective of increased water efficiency at the farm level. The concern to increase the efficiency in the use of irrigation water was made more explicit in the provisions of RA 8435, the Agriculture and Fisheries Modernization Act, issued on July 10, 1998.

Strengthening IAs' Capability for Irrigation O&M

Traditionally, the NIA has been tasked with irrigation development in the country. Over the years, however, amendments in NIA's original charter have been made, particularly by virtue

of Presidential Directive (PD) No. 552 issued in 1974. The PD later paved the way for NIA to implement the shared management or participatory approach with irrigation management of O&M in the irrigation system. In the NIA-UPRIIS service areas, the first IA was organized in 1975. It was only in the mid-1980s that the proliferation of IAs began. Through the years, the IAs proved to be potent partners of the NIA-UPRIIS as they performed their roles and responsibilities pursuant to their O&M contracts with the NIA. Of late, however, the functionality of the IAs within the NIA-UPRIIS has indicated a downward trend according to results of the functionality survey conducted during the last 4 years.

NIA has indicated a willingness to consider transferring to the IAs the full or partial authority and responsibility for operating and managing the NIS in the service areas each of whose extent is less than 3,000 hectares. This impending transfer necessitates that IA's management capability be enhanced to prepare them for the responsibility of operating and maintaining the irrigation systems.

Action Plan

The results of the diagnostic studies and the institutional analysis were bases for a workable action plan that is proposed to improve the water management in the UPRB. Details of this plan are presented in the subsequent pages.

For the formation of the UPRB Coordinating Council, initially, a core group that will orchestrate the planning, implementation and evaluation of water resources management programs for the UPRB must be organized. However, this can only be realized when a position paper detailing the justifications for the need to form the UPRB Coordinating Council is prepared and presented to the various stakeholders of the basin.

Heads of the different agencies/organizations including the LGU and representatives of interested groups within the basin will be invited to join as members of the Council. The research team can serve as an ad hoc secretariat for the Council and be responsible in the monitoring, documentation and evaluation of all activities during the first year of its operation. Once organized, the UPRB Coordinating Council can line up activities and programs that will:

- improve the irrigation system performance;
- improve the temporal and spatial availability of water;
- strengthen and rationalize measurement, gathering and recording of the hydrological and socioeconomic data for water resources planning and management;
- monitor and evaluate the quality of surface water and groundwater; and
- improve the utilization of water.

Table 2 presents the details of the proposed action plan, indicating the activities, target outputs, and agencies involved.

Table 2. Continued.

Study	Sample	Design	Intervention	Follow-up	Primary Outcome	Secondary Outcome
11. Zamboni and colleagues (2012)	1000 patients with chronic low back pain	Randomized controlled trial	Yoga vs. physical therapy	12 weeks	Reduction in pain intensity	Improvement in functional status
12. Cholewicki and colleagues (2013)	150 patients with chronic low back pain	Randomized controlled trial	Yoga vs. physical therapy	12 weeks	Reduction in pain intensity	Improvement in functional status
13. Cholewicki and colleagues (2014)	150 patients with chronic low back pain	Randomized controlled trial	Yoga vs. physical therapy	12 weeks	Reduction in pain intensity	Improvement in functional status
14. Cholewicki and colleagues (2015)	150 patients with chronic low back pain	Randomized controlled trial	Yoga vs. physical therapy	12 weeks	Reduction in pain intensity	Improvement in functional status
15. Cholewicki and colleagues (2016)	150 patients with chronic low back pain	Randomized controlled trial	Yoga vs. physical therapy	12 weeks	Reduction in pain intensity	Improvement in functional status
16. Cholewicki and colleagues (2017)	150 patients with chronic low back pain	Randomized controlled trial	Yoga vs. physical therapy	12 weeks	Reduction in pain intensity	Improvement in functional status
17. Cholewicki and colleagues (2018)	150 patients with chronic low back pain	Randomized controlled trial	Yoga vs. physical therapy	12 weeks	Reduction in pain intensity	Improvement in functional status
18. Cholewicki and colleagues (2019)	150 patients with chronic low back pain	Randomized controlled trial	Yoga vs. physical therapy	12 weeks	Reduction in pain intensity	Improvement in functional status
19. Cholewicki and colleagues (2020)	150 patients with chronic low back pain	Randomized controlled trial	Yoga vs. physical therapy	12 weeks	Reduction in pain intensity	Improvement in functional status
20. Cholewicki and colleagues (2021)	150 patients with chronic low back pain	Randomized controlled trial	Yoga vs. physical therapy	12 weeks	Reduction in pain intensity	Improvement in functional status

Appendix 1. Institutional analysis of the UPRB.

Institution	Description	Type	Formal		Informal	Power	Resources	Autonomy	Accountability	Transparency	Effectiveness	Impact
			Legal	Regulatory								
1. UPRB	The UPRB is a constitutional body established in 1997 to monitor and report on the human rights situation in the country. It is composed of 11 members, including representatives from civil society, academia, and the government.	Independent	Yes	Yes	No	High	High	High	High	High	High	High
2. National Human Rights Commission	The NHRC is a government body established in 1993 to investigate and address human rights violations. It has the authority to conduct inquiries and file cases in court.	Government	Yes	Yes	Yes	Medium	Medium	Medium	Medium	Medium	Medium	Medium
3. National Endowment for Democracy	The NED is a non-profit organization established in 1983 that provides financial support to promote democracy and human rights in the country.	Non-profit	Yes	No	No	Low	Low	Low	Low	Low	Low	Low
4. National Endowment for Democracy	The NED is a non-profit organization established in 1983 that provides financial support to promote democracy and human rights in the country.	Non-profit	Yes	No	No	Low	Low	Low	Low	Low	Low	Low
5. National Endowment for Democracy	The NED is a non-profit organization established in 1983 that provides financial support to promote democracy and human rights in the country.	Non-profit	Yes	No	No	Low	Low	Low	Low	Low	Low	Low
6. National Endowment for Democracy	The NED is a non-profit organization established in 1983 that provides financial support to promote democracy and human rights in the country.	Non-profit	Yes	No	No	Low	Low	Low	Low	Low	Low	Low
7. National Endowment for Democracy	The NED is a non-profit organization established in 1983 that provides financial support to promote democracy and human rights in the country.	Non-profit	Yes	No	No	Low	Low	Low	Low	Low	Low	Low
8. National Endowment for Democracy	The NED is a non-profit organization established in 1983 that provides financial support to promote democracy and human rights in the country.	Non-profit	Yes	No	No	Low	Low	Low	Low	Low	Low	Low

Appendix I. Continued.

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<p>10. 3. 2000</p>	<p>10. 3. 2000</p>	<p>10. 3. 2000</p>	<p>10. 3. 2000</p>	<p>10. 3. 2000</p>	<p>10. 3. 2000</p>

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CHAPTER 7

Contextual Challenges of Developing Effective Water Management Institutions: The Deduru Oya Basin, Sri Lanka

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Introduction

This paper analyzes the institutional problems related to water resources management in the Deduru Oya river basin, the fifth largest river basin in Sri Lanka, and proposes institutional reforms required for better management of water resources. Institutions in this context include policies, rules, regulations and rights, and organizations that are required to plan and implement activities to address the problems related to water resources management in a river basin context. To understand the problems related to sustainable management of water resources, for irrigated agriculture in particular and other uses in general in a river basin context, the research adopted a multidisciplinary and multi-analytic approach whose framework is presented in figure 1.

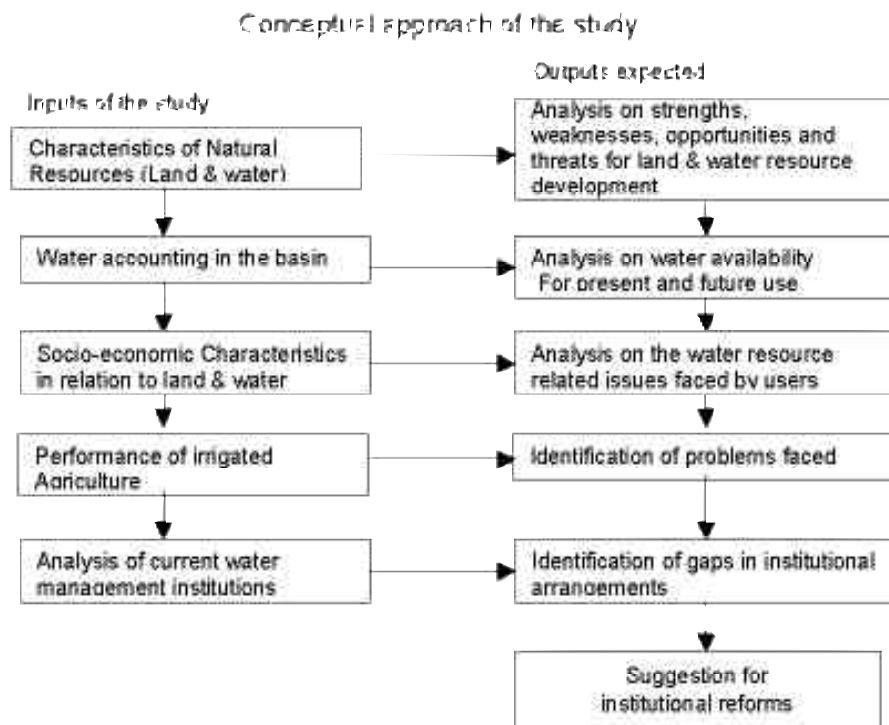
Methods Used for Data Collection

Primary and secondary data were collated for the analysis of various components of the study. The existing secondary data held by government agencies operating in the basin were used for the identification of the physical features of the basin. The data on physical characteristics were supplemented by field visits made to locations representing specific features, problems and important issues of water resources management. Data available at the agencies including the Irrigation Department, Meteorological Department and Land Use Planning Department were used for water accounting. Secondary data available in the offices of the Divisional Secretaries were used for identification of socioeconomic features in the basin. For analyzing the performance of irrigated agriculture the secondary data available at agencies, such as the Department of Agriculture, were used. Field trips to the basin helped develop better understanding of different water user sectors and their locations in the basin. Agriculture under small tank systems was analyzed by a sample household survey.

The most important component of the study, stakeholder consultation, was carried out through participatory rural appraisal sessions (PRAs) held with different water users in the basin. Existing government agencies were actively involved in helping organize meetings with different stakeholders for focus group discussions and workshops. This provided an

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Figure 1. Framework adopted in the study.



opportunity for stakeholders to discuss and share views on problems related to water resources management and to understand the concept of integrated water resources management in a river basin context. PRAs provided an opportunity for these groups to propose solutions for the emerging water-resources problems.

Physical Characteristics

This section describes the physical characteristics of the basin. In addition, water accounting describes existing water use and verifies the availability of water resources in the basin for future development.

Existing Natural Resources

Water resources. Rainfall is the only source of water for the Deduru Oya river basin. Water users in this basin benefit from direct rainfall, streamflow consisting of direct runoff and base flow or groundwater discharge, surface water storage in reservoirs and groundwater storage. The average monthly rainfall is presented in table 1. In an average year the basin area receives a monthly rainfall ranging from 108 mm to 280 mm from September to December. This period known as the *maha* (wet) season is the main cultivation season in the country. The period

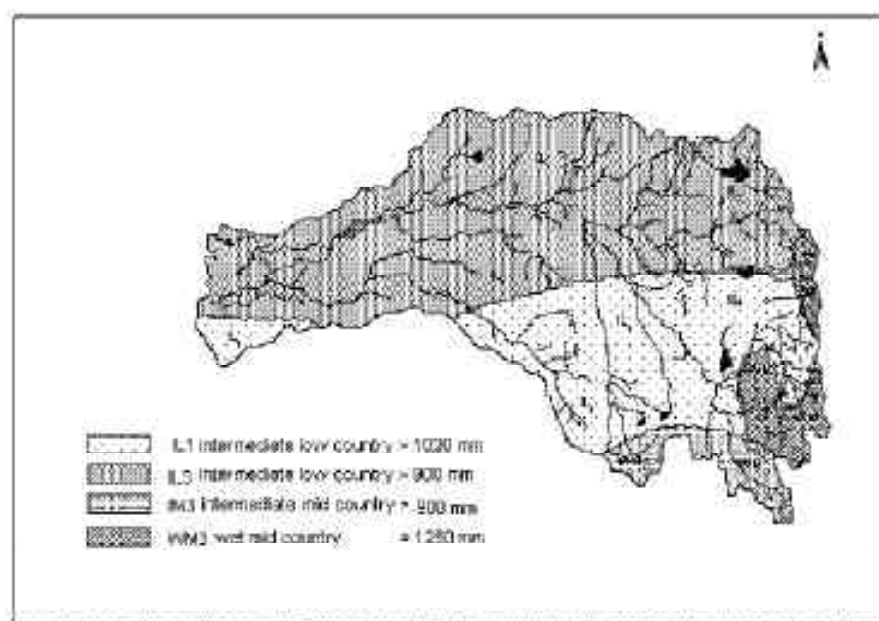
Table 1. Pump irrigation schemes in the basin

Divisional Secretariat (DS) Division	# of pumps	Maha Extent (ha)	Yala Extent (ha)
Mawathagama	41	35.2	20.7
Polpithigama	787	342.5	438.0
Ridigama	161	117.4	113.4
Ibbagamuwa	130	125.5	57.1
Ganewatta	194	219.8	126.0
Kobeigane	780	451.5	643.0
Wariyapola	1	60.7	20.2
Bingiriya	240	316.6	194.0
Total	2,334	1,669.2	1,612.4

Source: ECL report on Deduru Oya river basin profile, 1999.

from March to June is known as the *yala* (dry) season and is characterized by low rainfall. The basin area falls under two climatic zones, wet and intermediate and its subgroups as shown in figure 2. There is a significant variation in rainfall in these three zones. The upper watershed area of the basin in the wet zone generates runoff, which flows into the lower portion of the basin.

Figure 2. Agro-ecological regions in the Deduru Oya basin.

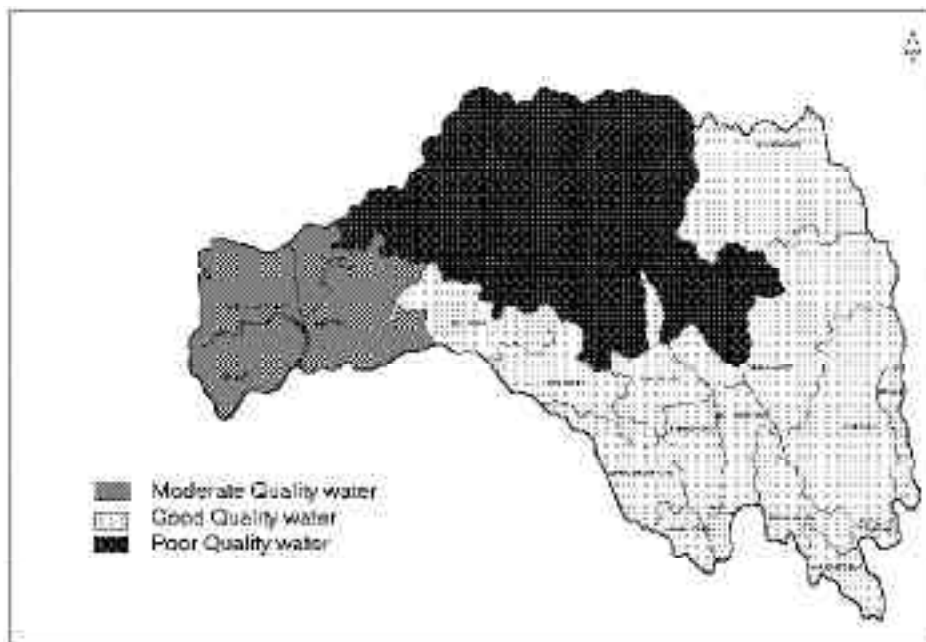


There are no significant variations in the temperature over the year. It varies between 25 °C and 30 °C within a year. Similarly, spatial variation of the temperature is also not significant in the basin.

Deduru Oya river (surface water resources). The Deduru Oya originates in the Matala hills (in the wet zone part of the centrally located hills in the country) and the basin extends to over 2,622 km². It has 15 sub-watersheds. Water-related development activities in the basin are heavily dependent on the hydrology of the river and streams. For example, the major irrigated agricultural schemes are located in sub-watersheds endowed with an abundant water supply. During the wet season, the river discharges a substantial quantity of water out of the basin. The figures for the period 1951–1978 indicate that annual discharge varies from 900 million m³ (MCM) to 2,000 MCM. It should be noted however that discharges are confined to the period from September to December.

Groundwater. The western downstream portion of the basin with a deep weathered soil profile and sandy soils is capable of retaining a substantial amount of groundwater in the regolith. The north-central part of the basin (i.e., Wariyapola, Nikaweratiya and Mahawa areas) has a comparatively thin regolith soil profile and, therefore, less groundwater potential. A common feature of this part of the basin is the poor quality of groundwater in terms of salinity, hardness and fluoride and iron content due to low circulation of groundwater. The degree of the quality of water is shown in figure 3.

Figure 3. DS divisions and degree of quality of water in Deduru Oya.



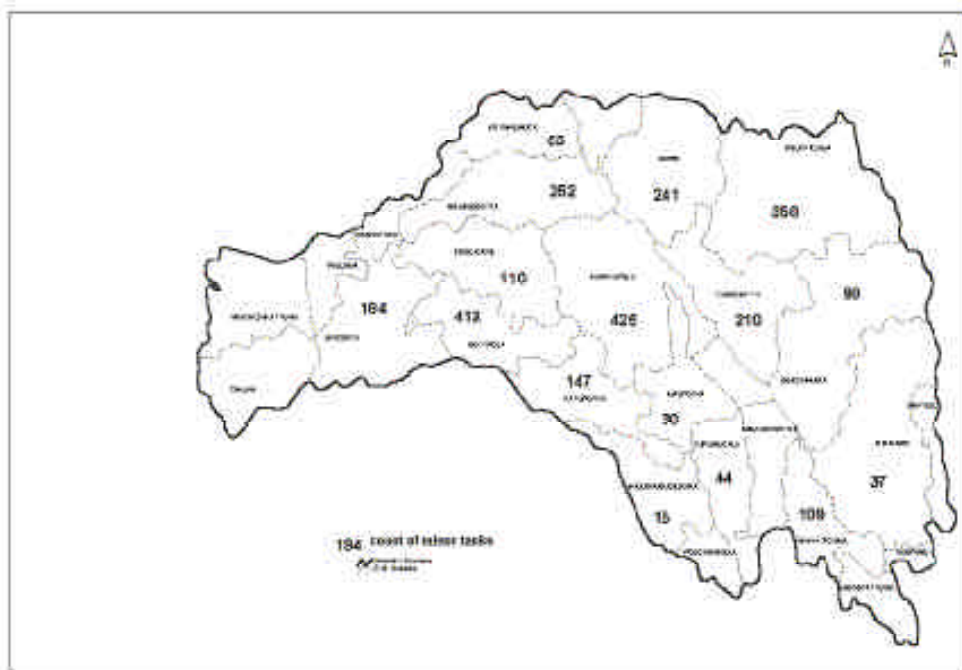
Soil types in the basin. About 38 percent of the basin area consists of red yellow podzolic soil. Water availability in such soil, 15cm/m is better than that of the other soil types in the basin. The second dominant soil type, which accounts for 36 percent of the basin area, is noncalci brown soil that has a water-holding capacity of 11 cm/m.

Other natural resources in the basin area. About 91 percent of the land area in the basin is utilized for various types of development activities. The remaining land area comprises forests, classified as dense forest (1.6%), open forest (0.4%), scrub (1.5%), grass (0.02%), both natural and manmade water bodies (4.4%), barren land (0.5%), mangroves (0.03%) and marshy land (0.02%). The total undeveloped land area, which is about 22,440 hectares, is equal to 9 percent of the total land area developed in the basin.

Physical Characteristics of Water Resources Development in the Basin

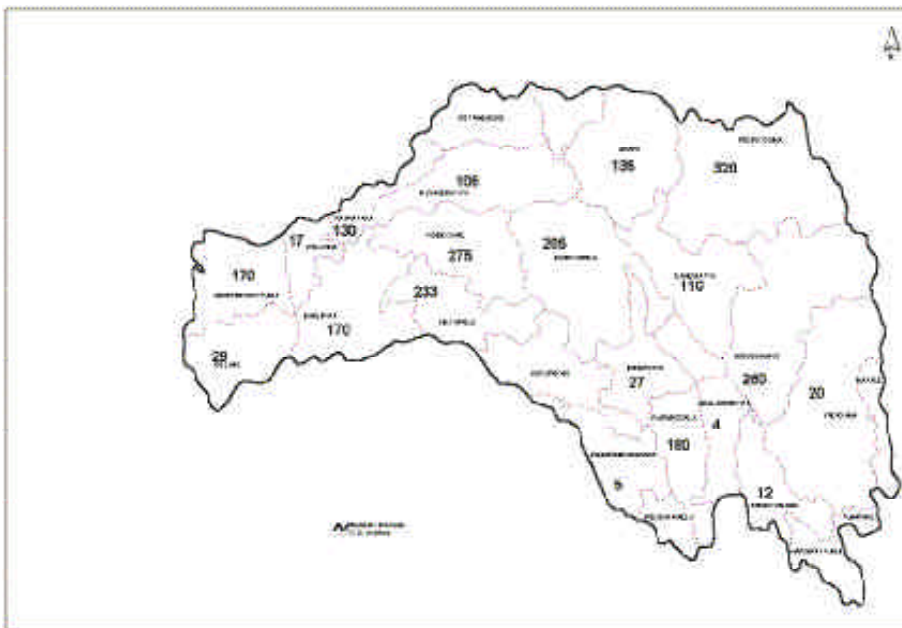
Irrigation systems. There are seven major and medium reservoirs constructed in the basin area to supply water for irrigated agriculture. About 6,320 hectares are cultivated under these tank systems. In addition, there are about 1,560 small village tanks serving nearly 12,000 hectares. These tanks have been registered in the Department of Agrarian Services. An equal number of small village tanks that are not registered in the government records exist in the basin. These tanks constructed by the farmers are farmer-managed and receive assistance from NGOs for major repair and rehabilitation activities. Figure 4 shows the Deduru Oya DS divisions and the distribution of minor tank systems.

Figure 4. Deduru Oya DS divisions and distribution of minor tank systems.



Groundwater extraction (agricultural wells). Extraction of groundwater through agricultural wells is an expanding water resource use in the basin. Most of the people tapping groundwater are the second- and third-generation members of farmer families without access to land and water in major, medium or minor tank systems. Some farmers cultivating under minor tank systems have wells in their paddy lands used for supplementary irrigation. In the yala seasons some farmers use them to raise other field crops (OFCs). Most of these wells have been constructed by farmers with assistance from the government or foreign-funded rural development projects. They are owned by farmers individually. The spatial variation of agricultural wells in the basin is shown in table 4. Farmers in the dry-zone areas of the basin tend to use them as a supplementary source of irrigation. At present, there are about 2,450 agro-wells in the basin and the number is increasing annually. The Deduru Oya DS divisions and agro-wells are presented in figure 5.

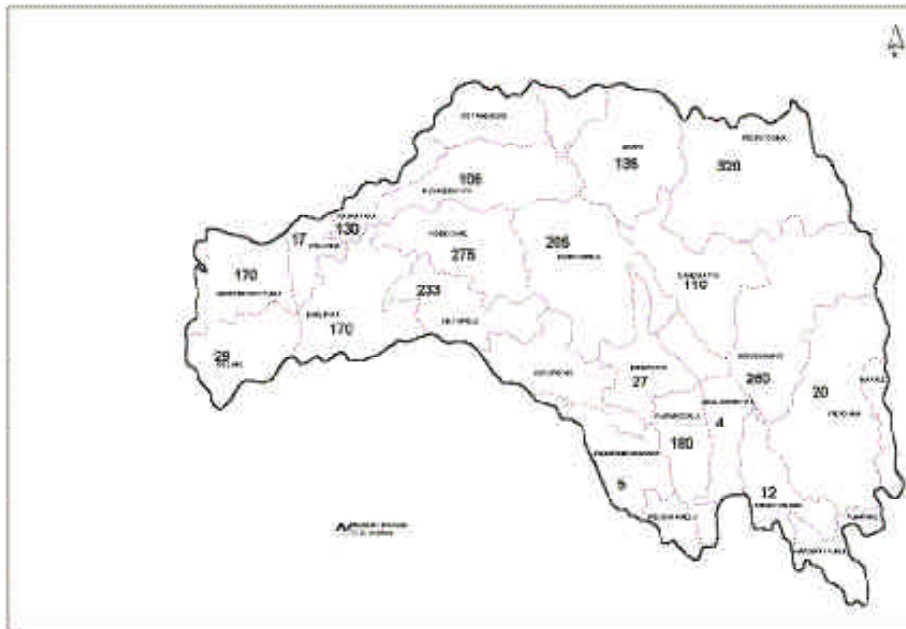
Figure 5. Agricultural wells in the basin.



Lift irrigation schemes. Lift irrigation is another means of extracting surface water for agriculture. There are lift irrigation schemes in the basin serving farmer groups formally recognized by the government. Also there are individual farmers tapping water in the river and its tributaries using water pumps. All these farmers are concentrated in areas below diversion points of the major irrigation schemes of the river. Farmers resort to lift irrigation for cultivation, as they have no access to water in the tank system. However, their operations are limited to periods when there is a base flow in the river. Farmers tapping water through lift irrigation have serious

problems at present due to the deepening of the riverbed as a result of excessive sand mining. The farmers using lift irrigation in downstream areas have problems of water quality due to intrusion of seawater. Details of these pumps and their spatial distribution in the basin are shown in both table 1 and figure 6.

Figure 6. Map of Deduru Oya indicating lift irrigation systems.



Domestic water (drinking)-supply schemes in the basin. Those with access to pipe-borne water supply amount only to 5 percent of the population in the basin. Drinking water is a serious problem for a third of the basin population, in the middle part of the basin area falling within the dry zone. This is mainly due to the shortage of groundwater and its poor quality in this part of the basin. Although there is a tributary of the Deduru Oya in this area, it cannot be used for augmenting drinking water supply schemes due to pollution. This tributary running through the Kurunegala town, the main city of the northwestern province, gets polluted due to wastewater and sewage discharge. The tail-end portion of the basin also has problems of drinking water due to salinity in the resources of groundwater and surface water. Only about 37 pipe-borne water supply schemes and 1,199 tube wells are available for the whole basin to provide drinking water to the communities in the basin area. There are no separate schemes or infrastructure to supply water for industries, livestock and other uses. The agricultural wells and other drinking water sources are used for these purposes.

Land development (existing land-use pattern). A large part of the basin consists of coconut plantations, representing about 36 percent of the total land area in the basin. The second largest land-use category is paddy lands, covering 17 percent of the land area in the basin. Nearly 14 percent of lands are home gardens, concentrated mainly in rural areas.

Water Accounting (Water Use for a Variety of Development Activities)

Major cultivation seasons in the basin are maha and yala seasons as indicated above. Paddy, which is the main crop grown under irrigation in the basin, requires irrigation. Other tree crops such as coconut and rubber do not require irrigation water although they consume a substantial quantity of water from the basin. Water accounting for yala and maha seasons shown in table 2 is based on observed cropping intensities and water consumption by forests and natural vegetation. The information in table 2 indicates that during maha seasons, a substantial quantity of water flows out of the basin ranging from 400–1,300 MCM.

Performance indicators. According to the indicator values given above, when net Depletion Fraction (DF)_(net) < 1 the basin is open and some utilizable water flows out of the basin. Available water was fully utilized only in two seasons, yala 1994 and yala 1996. Depleted Process Fraction indicates the efficiency of water use in the basin. Process Fraction in the range of 0.49–0.75 means that there is a possibility for the development of water utilization in the basin. But these values give only a general idea of the hydraulic behavior of the basin. Qualitative information gathered during the collection of field data and the actual field data shows that more runoff occurs in upstream areas located in the wet zone. The middle and tail-end parts of the basin, located in the intermediate zone, face water shortage problems in dry periods. These spatial variations in the basin need to be considered in the plans for increasing water use efficiency in the basin.

Socioeconomic Characteristics

Population

Table 4 presents the total population and population density in the basin area falling under each DS division. The special characteristic of the basin is the concentration of the population in its head- and tail-end parts. These head-end areas include the Kurunegala town, which is the main city of the Kurunegala district and its adjoining suburban areas such as Mallawapitiya, Mawathagama and Maspotha DS divisions. In the tail end, the Chilaw town located in the coastal belt has a high population density. Except for the people in the areas under these two major towns, the majority of the rest of the people are rural communities living in villages or small peasant townships. The lowest population values are reported from the dry-zone areas, Maho, Kotawehera and Nikaweraitya DS divisions in the basin. Analysis of data on population growth shows that the growth rate in the basin area is more or less equal to the national growth rate, that is 1.5. Of the population 40 percent are in the age group of 19–45 years while the population below 5 years and between 6–18 years is 11 percent and 26 percent, respectively. Those above 45 years of age constitute 24 percent of the total population of the basin area.

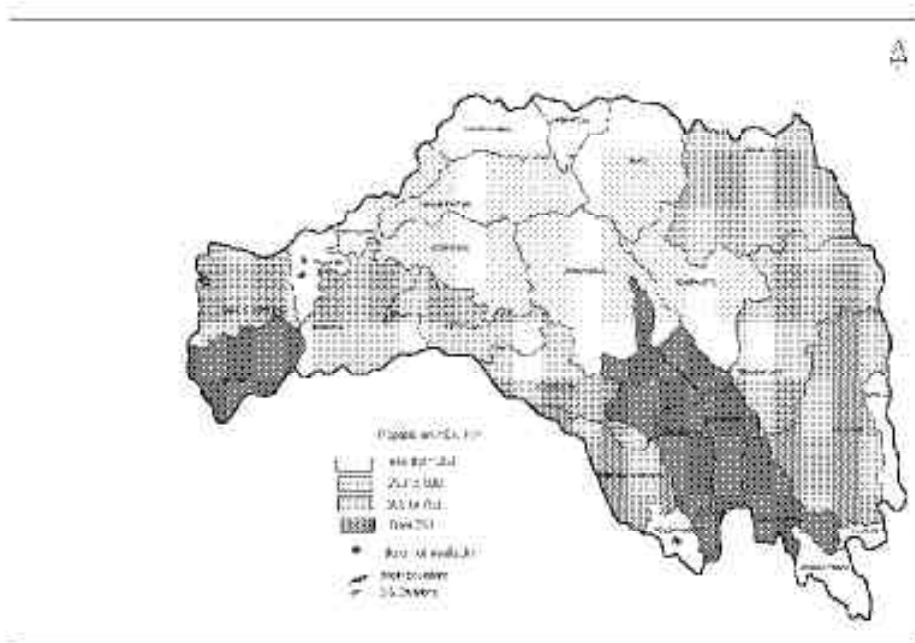
Table 4. Population and population density.

DS Division	Basin Population	Area under the DS Division (km ²)	Population Density (Persons/ km ²)
Ridigama	89,848	132.4	681
Mawathagama	57,464	68	845
Polgahawela	10,394	na	Na
Polpitigama	61,465	234.4	336
Ibbagamuwa	84,486	194	435
Mallawapitiya	43,835	47.5	923
Kurunegala	87,465	107	819
Weerabugedara	30,922	59.6	519
Ganewatta	38,010	191.2	199
Maspotha	40,551	45.5	891
Maho	52,934	247.5	214
Wariyapola	57,298	99.4	293
Katupotha	20,554	119.4	286
Kotawehera	20,310	266.2	176
Nikaweratiya	36,617	181	214
Kobeigane	33,549	125.6	267
Hettipola	71,120	202.3	352
Rasnayakapura	21,646	132	164
Bingiriya	56,000	185.9	377
Pallama	4,001	na	Na
Aracchikattuwa	19,430	115.2	337
Chilaw	24,768	80	751
Total	962,667	2,754 ^a	310 ^a

These values indicate that the members of the younger generation below 18 years of age dependent on adults constitutes 37 percent of the total population of the basin area. Figure 7 presents the population and population density of the DS divisions of the Deduru Oya.

About 95 percent of the population have a formal education. According to a survey carried out in 1994 a majority of people who had a formal education have completed secondary education (Grade 5–10). Fifteen percent have an education above G.C.E. (OL&AL), which is the senior secondary education level of the country.

Figure 7. Population and population density in DS divisions in Deduru Oya.



Employment

Agriculture is the major form of employment of 40–50 percent of the population in most of the DS divisions in the basin. Private-sector employment accounts for 10–22 percent of employment in most of the DS divisions while the public-sector employment ranges from 7 to 25 percent. The other main income-generating activities in the basin are trade, self-employment, fishing and animal husbandry. Many people depend on fishing in the DS divisions, as in Arachchikattuwa and Chilaw in the coastal area, in the tail end of the basin.

Economic Activities

The economy of the Deduru Oya basin is predominantly agricultural. Coconut and paddy are the main crops cultivated in the basin. Most of the river basin falls within the area known as the “Coconut Triangle,” the area in which coconut cultivation flourishes. Analysis of data on land use in 14 DS divisions shows that more than 50 percent of land in 6 (43%) DS divisions, 40–50 percent of land in 4 (28%) DS divisions, 30–40 percent in 2 (13%) DS divisions and 20 percent in another 2 (13%) DS divisions are under coconut cultivation. Most of the coconut lands are smallholdings below 2 acres. For example, in most of the DS divisions more than 80 percent of coconut lands are below 2 acres in extent. It is a main income source providing a regular cash flow to the smallholding peasants in the basin. However, due to land fragmentation and unregulated felling of coconut trees, coconut cultivation is likely to diminish in significance in the near future.

Paddy cultivation is another means of livelihood of the people in the basin. It is cultivated under major and medium tank and anicut systems, small village tank and anicut systems and also under rain-fed conditions.

Livestock

Livestock farming is also an important means of livelihood for some households in the basin. There are livestock farms of different scales raising cattle, goats and poultry. The availability of grazing facilities in coconut lands has helped promote cattle farming. The data collected from seven DS divisions representing head-, middle- and tail-end areas of the basin show that cattle and poultry farming are successfully implemented all over the basin, especially in areas like Ibbagamuwa, Kobeigane, Bingiriya and Chilaw.

Industries

As one can expect, the main industries in the basin are paddy and coconut-based. Intensive data collection on industries in ten DS divisions shows 364 coconut-based industries and 566 rice-based industries. The rice-based industries are greater in number in major irrigation scheme areas, while more coconut-related industries are found in areas like Bingiriya where there are large coconut estates.

Shrimp farming is the main activity in the tail-end part of the river basin. There are a large number of shrimp farms in Chilaw and Arachchikattuwa DS divisions in the basin. For example, in 1977, there were 126 and 73 shrimp farms in Arachchikattuwa and Chilaw, respectively. They differ in scale; some shrimp farms are more than 50 acres in extent. Shrimp farms are located in the coastal zone of the basin. They have created some environmental problems for the coastal ecosystem. The water management projects, especially agricultural schemes, are located in the middle and head of the basin and therefore, these water management projects have not created any negative impacts on the performance of shrimp farms. Many of them operate without the approval of the relevant authorities. Since this is an industry bringing in foreign exchange, some operate with the approval of the Bureau of Investment (BOI).

Sand mining, brick making and tile making are also major industries in the area. Sand-mining activities can be observed from Ridigama DS division up to Chilaw. Members of the poor village communities work in these sand-mining industries operated by some big businessmen. Due to the informal nature of the operation there are no data on the number of people employed and the scale of operation. Brick- and tile-making activities are observed in Chilaw, Arachchikattuwa, and Ganewatte areas. In the 10 DS divisions intensively studied, there are 15 tile-making industries and 104 brick-making industries.

Income and Poverty

Families earning below Rs.1,500 per month (US\$1=Rs83.5) are regarded as members of absolute poverty groups by the government, which pays an allowance called *samurdhi* to such people. (The beneficiary families for the *samurdhi* program are chosen, based on their monthly income. No other criteria are used to select them. The international criteria such as calorie intake are not adopted to select beneficiaries. On the other hand, such data are not available in government offices in the basin area.) According to data on *samurdhi* beneficiaries available

at government offices, more than 60 percent of the families in the basin belong to the absolute poverty group. There are some suburban areas and dry-zone areas where more than 80 percent of families are in the absolute poverty group. High population density, widespread unemployment, and very small landholdings characterize these pockets of poverty in the suburban areas. The pocket of poverty in the dry zone areas is characterized by the dependency on paddy cultivation under minor irrigation systems, low productivity and low cropping intensity. It can be observed that shortage of land and water resources is the main reasons for poverty in this river basin.

Performance of Irrigation Systems

Performance of irrigated agriculture in a given geographical area in the basin is dependent upon the seasonal rainfall and access to water in the river or its tributaries. Performance varies from system to system within the basin. The performance of the irrigation system is assessed here using indicators such as cropping intensity, yield and water duty. Comparisons are made between irrigation systems based on the size of the systems and management systems adopted in them. In Sri Lanka, irrigation systems are categorized by the size of the command area into major and minor systems, above 80 hectares as major and below 80 hectares as minor. The government manages the major and medium schemes in Sri Lanka jointly with the farmers, while minor tank systems are farmer-managed.

Major systems in the basin include the Batalagoda tank, Magalla Wewa (Ride Bedi Ella), and Hakwatuna Oya and Kibulwana Oya schemes. There are about 6,000 hectares of paddy lands under these systems. Medium schemes include Karawita, Meddakatiya, Wennoruwa and Hulugalla tank systems, and several anicut (diversion weir) systems like Kospothu Oya. Command areas of these systems are around 1,000 hectares each. Another most important sector in paddy agriculture is the small village-tank systems. There are about 3,228 small tank systems providing subsistence to village communities in the basin.

Seasonal Cropping Intensity of the Basin

As can be observed from table 5, the cropping intensity is higher in major irrigation systems, which have a more reliable water supply than that in water-short minor systems. For example Ridi Bedi Ela (Magalla) and Batalagoda have 175 percent cropping intensity. Table 5 shows the average seasonal cropping intensity in major, medium and minor irrigation schemes located in the basin. In major irrigation schemes, the average annual cropping intensity is about 1.75 or a little more. Interviews with farmer leaders indicate that it can be increased up to 2.00 if the water management is further improved. But the cropping intensity in small schemes cannot be increased substantially due to water scarcity during dry seasons. These systems cannot achieve 200 percent cropping intensity due to water shortage in the yala seasons. Although water is not a serious problem for these schemes, the tail-end farmers face water shortage due to poor water management and problems in the physical system. Kibulwana Oya is a water-abundant scheme with 200 percent cropping intensity. As Kibulwana is better-managed with farmer participation, water-related problems are not serious in this system.

A major problem in minor tank systems is water shortage for the yala (dry) season cultivation. Some tank systems face water shortages towards the end of the season. Cropping

Table 5. Cropping intensity.

Year	1994	94/95	1995	95 /96	1996	96/97	1997	97/98	1998
Season	Yala	Maha	Yala	Maha	Yala	Maha	Yala	Maha	Yala
Climatic Condition	Dry	Average	Wet	Dry	Average	Dry	Wet	Wet	Wet
Major irrigation	0.77	0.98	0.78	0.96	0.53	0.91	0.52	0.98	0.66
Minor irrigation	0.41	0.78	0.61	0.39	0.17	0.64	0.35	0.97	0.27
Rain-fed	0.19	0.86	0.63	0.25	0.16	0.78	0.53	0.95	0.28
Overall	0.39	0.84	0.65	0.43	0.23	0.74	0.45	0.97	0.34

intensity in these systems varies from 100–150 percent depending on their geographical locations. For example, in tank systems in areas like Ridigama and Bingiriya in the intermediate zone, the cropping intensity is about 150 percent while it is 100–120 percent in areas like Kobeigane, Wariyapola and Kotawehera, which are areas in the dry parts of the intermediate zone. Also due to the weakness of farmer organizations, farmer participation in O&M is weak in these systems and, as a result, water is not efficiently managed. Silting and sedimentation of tanks and development activities in the catchment areas have threatened the sustainability of tanks.

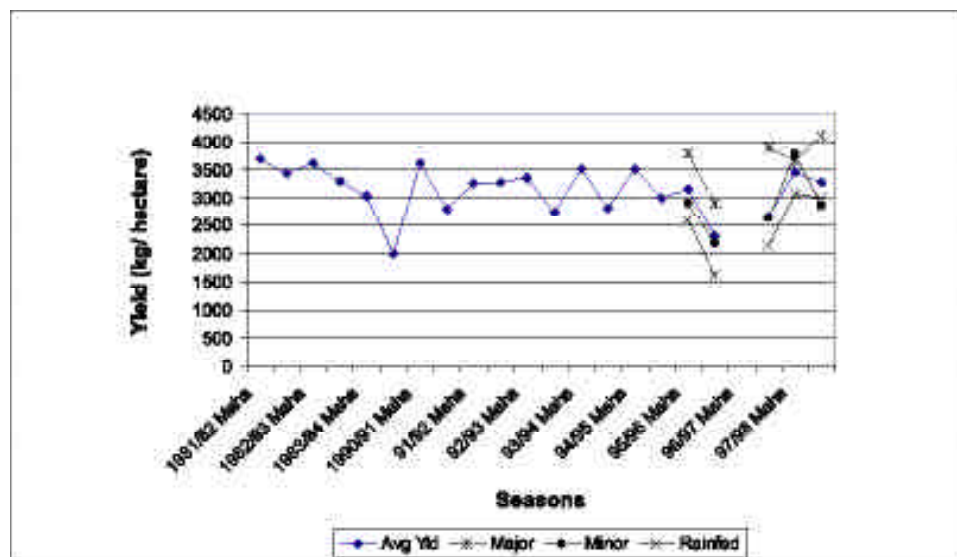
Yield Performance

The average paddy yield (kg/ha) in the Kurunegala district is given in the Statistical Abstract published by the Department of Census and Statistics and in figure 8. The average yield in the Kurunegala district, a large part of which falls within the basin, ranges from 3,000 to 3,400 kg/ha. The yield values for major and minor irrigation systems show that the yield ranges from 3,000 to 4,000 kg/ha and from 2,100 to 2,900 kg/ha in major and minor systems, respectively. Clearly, this indicates that yield is comparatively high in major irrigation systems with a reliable water supply.

The data obtained from the household survey carried out in small tank systems show that cultivation under small tank systems has become less profitable and less attractive with the increased cost of inputs, particularly farm power and labor. The survey further highlights that there is a significant change in income sources of people in these tank systems compared to the situation that prevailed 10 years ago. The number involved in agriculture has been reduced by 21 percent while there is a 16-percent increase in private- and public-sector employment in rural villages in the basin. The data are indicative of a trend among the youth to seek employment outside agriculture due to its less-rewarding nature and lack of social recognition.

In addition to water shortage and the high cost of production, paddy farmers face such problems as shortage of good-quality fertilizer and agro-chemicals that affect the performance of paddy cultivation. In addition, they face marketing problems and lack access to new farming technologies developed at research stations.

Figure 8. Average paddy yield in the Kurunegala district.



Water Use Efficiency in Major Irrigation Schemes

Data on water duty, obtained from the Department of Irrigation, for major irrigation schemes in the Deduru Oya basin are given in table 6. The data indicate that water duty is higher in the yala seasons than in the maha seasons when the basin experiences high rainfall.

Table 6. Water duty.

Season	Kimbulwana Oya Scheme	Batalagoda Scheme	Hakwatuna Oya Scheme	Magalla Scheme
1996/97 maha	na	na	0.8 m / ha	na
1997 yala	na	1.7 m / ha	1.5 m / ha	na
1997/98 maha	na	na	0.4 m / ha	na
1998 yala	na	na	na	na
1998/99 maha	na	na	na	na
1999 yala	1.7 m / ha	na	0.9 m / ha	na

Source: O&M Branch, Dept. of Irrigation; na = data not available.

When the performance of the jointly managed major and medium systems is compared with that managed by farmers shows that jointly managed systems perform better. However, this is not due to the difference in the management systems. The key factor for low productivity and low cropping intensity in minor systems is water shortage due to lack of a reliable water source. Also the subsistence-oriented farming communities in small village tank systems always try to avoid risks. Unreliability of rainfall in the yala season drives them to avoid cultivating their lands in this season. This results in low cropping intensity in those tank systems. The farmers face water shortage even in maha towards the end of the season, as they do not attend to paddy cultivation activities with the onset of rain. They first attend to highland cultivation, which is more reliable and productive. They get low yields in the maha seasons too due to this reason. No data are available on water duty in minor tank systems to compare them with those in major systems for water use efficiency. However, it is generally believed that water use efficiency in minor systems is higher than that in major systems.

Cultivation under Wells and Lift Irrigation

According to the Agriculture Development Authority, the institution dealing mainly with agricultural wells, there are 2,453 agricultural wells in 20 DS divisions. Data and information collected show that these wells are not fully utilized or the cropping systems proposed for them are not adopted due to various socioeconomic reasons and water-related problems. Some water from wells intended for agriculture is used for brick-making because it is more profitable than cultivation of OFCs.

Lift irrigation systems using water pumps to tap water from the Deduru Oya and its tributaries can be observed from the head to the tail-end part of the basin. There are three lift irrigation schemes cultivating paddy in the Kobeigane and Bingiriya areas. In addition, there are a large number of water pumps used for both paddy and OFC cultivation. The problems that farmers face using agro-wells and lift irrigation for agriculture include water scarcity and salinity, and problems related to the marketing of their crops.

Institutional Characteristics

The nature of the institutions involved in the development and management of water resources, their roles and functions and problems encountered by them in the execution of prescribed roles and functions are described in this section. The organizations involved in water resource management, policies, rules and regulations in force in the country for managing water and other natural resources and the involvement of community-based organizations (CBOs) are also discussed.

Government Institutions Involved in Development and Management of Water Resources

Though positive policy reforms are occurring in the water sector at present, no institution with responsibility for overall management of water resources has been set up as yet in Sri Lanka. More than 20 sectoral departments and agencies exist at the level of the central government for water resources administration and management. The most important national administrative bodies and institutions involved in the management of water and other natural

resources include ministries such as the Ministry of Irrigation and Power, the Ministry of Agriculture and Lands, the Ministry of Forestry and Environment, the Ministry of Mahaweli Development, and the Ministry of Fisheries and Aquatic Resources at central-government level. The most important departments and government bodies functioning under these ministries at central-government level are the Irrigation Department (ID),² the Department of Agrarian Services (ASD), the Irrigation Management Division (IMD), the National Water Supply and Drainage Board (NWS&DB), the Water Resources Board (WRB), the Agricultural Development Authority, the Forest Department, the Inland Fisheries Development Authority, the Coastal Conservation Department and the Geographical Survey and Mines Bureau of (GS&MB).

In 1987, an amendment (Thirteenth Amendment) was introduced to the constitution of the country devolving power and authority enjoyed by the central government to the newly established provincial councils and the administrative bodies, organizations and institutions formed under the provincial administration. After these changes, the provincial-level departments under provincial ministries carry out the water and other resource-management tasks within the powers and authority vested in them. At the local level, local government bodies like the urban councils, municipal councils, and pradesheeya sabhas also perform water-management functions related to domestic water.

The ID is responsible for the planning, design and construction of major and medium irrigation schemes. It is also responsible for the O&M of the system above the distributary channel level. The IMD is responsible for the coordination of the agricultural-plan implementation, initiation of Farmer Organizations (FOs) for tertiary system management and also for strengthening of FOs for joint management activities through project committees formed in major irrigation systems. Similar arrangements also exist in medium irrigation schemes through the joint management committees under the Management of National Irrigation Systems (MANIS). The communities themselves manage small village tank systems. The ASD handles institutional development activities in village tank systems.

The NW&SDB is a national-level agency responsible for domestic and industrial water supply, sewage and surface drainage. It is involved mainly in developing drinking water supply schemes. Activities of the WRB are limited to carrying out hydrological investigation of groundwater resources and groundwater resource development. The roles of these two institutions are limited to those of users and have no role in control of groundwater extraction and use.

The National Environmental Authority is the institution responsible for the enforcement of laws, rules and regulations in the Environmental Act to control the pollution of water and other natural resources. The power vested in the Environmental Authority has been delegated to Provincial Councils at present, enabling the provincial authority to play an important role in environmental protection. The Coastal Conservation Department is the agency responsible for the protection of natural resources and environment in coastal areas.

Apart from these organizations, there are a large number of organizations involved in agriculture and natural resources management activities. The Electricity Board can use water resources in the country for hydropower generation. The Mahaweli Authority is involved in water resources development activities in the Mahaweli system areas. Other institutions

²In November 2000, a reorganization of Ministries occurred, and accordingly the ID comes under the new Ministry of Irrigation and Water Resource Management.

involved include District Secretaries at District level and Divisional Secretaries at divisional level with authority over land and irrigation management activities and coordinating responsibilities. Others include the Department of Agriculture (DOA), the Department of Animal Production and Health (DAPH), the Samurdhi Authority (attached to the Divisional Secretary's office), the Coconut Development Board, the Agriculture Development Authority, the Forest Department, the Department of Inland Fisheries, and the Cashew Cooperation and Minor Export Crop Development Department. The local government bodies like pradesheeya sabhas, municipal and urban councils also have roles in water resources development in areas under their jurisdiction.

The CBOs functioning in the basin are mainly the FOs in small tank systems, medium and major schemes, *kapruka* societies formed recently by the Coconut Development Board, multipurpose cooperative societies, milk producers' cooperatives, cooperative societies formed by farmers engaged in poultry farming, samurdhi associations formed by the Samurdhi Authority and the Environmental Associations formed recently by the Environmental Development Assistants working in the DS offices. However, these CBOs were found to be extremely weak, lacking capacity to attend to the resource- management tasks effectively.

Since the institutions involved in water resources management and agriculture are numerous they require coordination mechanisms at different levels to successfully plan and implement water- and agriculture-related activities. The coordinating committees functioning at present includes the Agrarian Service Committees, and AMA Committees (committees established to coordinate agricultural development at field level) at the Agrarian Centre level. They are held with the participation of field-level officers of line agencies and farmer representatives. In each DS division there is a DS level Agricultural Committee (DSAC) attended by a limited number of farmer representatives and line agency officials working in the DS division. Above the DS division level there are District Agricultural Committees (DACs) in each district. This committee is chaired by the District Secretary and is attended by line agency officials working at district level and farmer representatives from major, medium and minor irrigation systems. Forest Protection and Law Enforcement Committees (Environmental Committee) are at DS and district levels. These committees are held after the monthly meeting of the DSAC and DAC with the participation of officials attending these two committees. The major function of this committee is the protection of forest resources.

Other coordinating committees include electorate-level committees chaired by Members of Parliament of the respective electorates to plan and monitor infrastructural and agricultural development activities in the electorates. Officials of agencies working in the electorate attend these meetings. At the district level there is a District Level Development Committee chaired by the Chief Minister of the province to plan and monitor the development activities of the district.

National Policies, Rules and Regulations on Natural Resources Management with Special Emphasis on Land and Water Resources

Policies. Up to very recent times, the government policy for water resources development was the construction of large-scale new irrigation settlement projects and rehabilitation and renovation of the existing schemes to achieve self-sufficiency in rice, income generation and employment for the growing population. Surface-water resources were owned by the state. The O&M of major and medium irrigation were also a state responsibility. Water users remained

passive recipients of the benefits. Handing over larger responsibilities of O&M of the irrigation system to farmers and improving efficiency in irrigation water management in existing irrigation systems through farmer participation have become the government policy since 1988.

In the past, the government policy was directed at the development of the irrigation sector and there was no attempt to address all the matters related to water in a holistic manner through appropriate policy measures. The newly established Water Resources Secretariat (WRS) has already developed policies in this direction for which the approval of the Parliament has also been obtained.

Rules and regulations. A large number of rules and regulations exist for the development and management of water resources. They empower different government agencies to develop and manage water and land resources or to control pollution of natural resources. The authority and power vested in the organizations through these acts overlap. They include the Irrigation Ordinance No.32 of 1946, Crown Land Ordinance (State Land Ordinance) of 1947, and the Electricity Act No.19 (as amended in 1950). There are also land laws and environmental regulations aiming at the proper use and control of land, water and other natural resources.

Institutional problems. Institutional problems in the basin can be observed at different levels. The main problems related to the organizations include:

- The power and authority over water-related matters are vested in different agencies through various acts and regulations. There is no institution with overall responsibility over water resources management.
- The responsibilities of the existing water institutions often overlap, as they have been created to address specific needs at certain periods of time.
- The power and authority over natural resources management and environmental protection have not been decentralized. This is a serious problem for the DS level government agencies and local government bodies in effectively attending to the natural resources management tasks.
- Lack of resources for the Agrarian Centre level and DS level committees and local government bodies to attend to resources management tasks effectively.
- Lack of interest on the enforcement of laws relating to natural resources management.
- Intervention by politicians in natural resources management activities.
- Lack of commitment of some government officials and their inefficiency.
- Weaknesses of existing CBOs like FOs, Environmental Committees, etc., to effectively attend to resources management activities.

A major institutional problem related to coordinating mechanisms at different levels, such as ASC, DS, and district levels, is that even though they play an important role in implementing

the agricultural plan, their effectiveness in managing natural resources like riverine resources, forests, lagoons and the environment at large is minimal. Also they have the following problems regarding integration:

- The DS level Agricultural Committee (DSAC) has no resources, power or authority to deal with problems related to natural resources management problems or to implementation of the agricultural plan. It is just a committee and not a legal body.
- The ASC-level committees like the AMA (the coordinating committee at the ASC level) do not function, as they have no benefit to offer to the farmers. Divisional Officers of the ASD have no authority over agency officials to get their participation at these coordinating meetings.
- Departments and ministries do not adopt integrated approaches at the level of their headquarters. It cannot be adopted at the DS or ASC level due to this reason.

The following problems are observed in existing legislation:

- Duplication and overlapping of functions of the institutions due to empowering of different institutions with the same function through different enactments.
- Loopholes in government acts on land and water resources and environmental protection.
- Lack of clear policies, rules or regulations for water allocation among different sectors or over water rights.

Conclusions and Recommendations

As highlighted above, the main resource constraint in the basin is the temporal and spatial nature of its water scarcity. The spatial water scarcity in the basin is mainly due to its spread in different agro-climatic regions, such as intermediate and dry zones. The temporal water scarcity is due to the shortage of rainfall in the yala season. Low cropping intensity and low productivity, reported in medium and minor tank systems as well as in major schemes like the Hakwatuna Oya result from water scarcity. The major resource management problems observed in the basin are the pollution of surface water and groundwater, depletion of groundwater, erosion of river banks and stream reservations (a reservation is the portion of land adjacent to the river and its tributaries that is reserved to protect the riverbanks and river-related ecosystem), soil erosion in tank catchments and sedimentation. Surface water is polluted as a result of discharge of wastewater and pollutants to irrigation canals, streams and watercourses. This is mainly an urban phenomenon. The authority over enforcing regulations relating to this is vested with the Central and Provincial Environmental Authorities, Urban Councils or Municipal Councils depending on the scale of industries or enterprises causing such pollution. Groundwater pollution is reported mainly in coastal areas due to seawater intrusion along the river, due to sand mining and excessive extraction of ground water using tube wells. Lack of clear policies, rules and guidelines for extraction of groundwater is a major institutional constraint leading to groundwater pollution.

The major cause of groundwater depletion is unregulated sand mining in the river and its tributaries. The riverbeds have deepened due to unplanned and excessive sand mining in rivers and their tributaries. As a result, the level of the river water is lowered, especially during the dry season. This, in turn, has resulted in decreasing the water levels in the shallow wells constructed close to the riverbanks. It is understood that the Mines and Mineral Act provides sufficient authority to arrest this problem but the problems in implementing regulations are with the bureaucracy at the central government level and not with agencies operating at field level. This highlights the necessity of devolving power and authority to institutions at provincial and DS levels for them to effectively attend to natural resources management activities.

Common properties like stream reservations and tank catchments are formally considered to be state property, though there may be some privately owned lands among them. Divisional Secretaries have power and authority to take action against encroachments on such property. But various political and social pressures and resource constraints hinder them from attending to these activities. Also, there are no special programs to stimulate community members to take over and manage these common properties through tree planting and other soil conservation measures.

Other than these resource management problems, inefficient water management is reported from major and medium irrigation systems. If the proposal for the construction of a new reservoir in upstream areas is implemented, Batalagoda and Redi Bedi Ela schemes cannot expect an abundant supply of water. This will require better water management on the part of the irrigation managers and farmers in these schemes. In minor tank systems, there are no special efforts to assist farmers to use water efficiently through management innovations, to avoid crop failures and low yield due to water scarcity towards the end of the season. During most months of the year, certain portions of the river are dry, creating water-scarcity problems. This situation will be aggravated in the future with the increasing competition for water from other uses such as industries and the domestic water supply.

If we examine the present government policies, they indicate a shift of focus from the government's earlier approaches for water resource development and management. Many changes are taking place in the policy arena and institutional reforms are underway to address some of these issues. Following the steps taken by many countries that faced water-related problems, such as water pollution, withdrawal of freshwater and water scarcity, Sri Lanka too has shifted its focus from the development of irrigation schemes to the management of the basin to achieve water conservation and protection of quality of water for the use of agriculture and other sectors. The government is concerned with handing over the resource management responsibilities completely to the beneficiaries of irrigation systems even though the emphasis in previous decades was on joint management with them. We recommend the government address the institutional problems at the national level by adopting the following policy measures:

- Setting up of a Water Resource Council to address all matters related to water in a holistic manner. This is in progress at the moment.
- Development of a master plan for water usage. Steps need to be taken to develop a water allocation policy to make optimum use of available water resources, to cater

to competing demands of different sectors like irrigation and power generation in a sustainable way.

- Development of comprehensive river basin plans for major river basins.
- Handing over of larger responsibilities over O&M of irrigation systems to farmers, and improving efficiency in the management of irrigation water in existing irrigation systems through farmer participation.
- Increasing productivity in existing irrigated land through crop diversification and higher cropping intensities.
- Rehabilitation of irrigation systems.
- Development of criteria for assessing groundwater resources and development of ground water resources for agricultural and domestic uses.
- Expansion of programs for water supply and sanitation to provide adequate drinking water and sanitation facilities.

In addition to these, the following institutional reforms are required at the field level to address the problems at the field, DS and district levels:

- Strengthening of District- and DS-level agricultural committees as coordinating bodies for water and other natural resources management by introducing necessary amendments to existing rules and regulations.
- Introducing provisions to make the concerned line agencies to be accountable to the committees.
- Establishment of monitoring cells at District and DS levels to monitor the progress of resources management activities.
- Introducing clear procedures for evaluating and rewarding the performance of line agency officials.
- Introducing necessary amendments to the Acts and Ordinances for the smooth functioning of the proposed committees.
- Institutional development at ASC level for better O&M of minor irrigation systems.
- Demarcation of river reservations through surveys to arrest widespread encroachments on riverine resources and other common properties.
- Handing over of common properties like tank catchments and reservations for conservation to the farmer communities.
- Creating awareness among national-level and local-level politicians about problems related to the management of natural resources.

CHAPTER 8

Water Policy, Management and Institutional Arrangements: The Fuyang River Basin, China

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and Shuiling Lei¹*

Introduction

Faced with a rapidly expanding gap between water supply and demand, and increasing competition among sectors in China, especially in the northern regions, water issues have received increasing attention. In the past, water problems were treated mainly as engineering problems, and most water research focused on improving the efficiency of water use through innovating water-delivery technology (Wu et al. 1986; Chinese Academy of Sciences 1991; Xian Institute of Water Resources 1995). The absence of incentives in the adoption of water-saving technologies at the level of the farm household reveals the importance of water management and institutional arrangements. The growing evidence also shows that water management and institutional arrangements are important measures for dealing with water shortage problems (World Bank 1993; IWMI and FAO 1995). The conflicts among various stakeholders and the inability to implement the water law and policies result in increasing water shortage and inefficient water use in China (Wang 2000). Although China has issued numerous water policies and regulations since the 1980s, many policies are either too general to implement or lack the institutional support system to implement the policies (Wang and Huang 2000a). Recent reforms in the water-management agency reflect that China's government has gradually realized the importance of institutional setting and policy in managing the water sector.

While the importance of institutions and management has received attention from both decision makers and scholars recently, few studies can be found in the literature that systematically examines these issues at the national or subnational level, and at the river-basin level. Based on the case study of "Development of Effective Water Management Institutions" in the Fuyang river basin of China, and general review of national laws,

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institutions and policies in the water sector, this paper explores the possibilities for institutional reforms that can better foster integrated and sustainable use of water at national, regional and river basin levels.

This paper is organized as follows. The first section is the introduction. The second section discusses basic characteristics and water accounting analysis of the basin and irrigation system in the Fuyang river basin (FRB). The next three sections mainly discuss water policy, management and institutional arrangements at national, river basin, and irrigation system levels. The sixth section discusses the empirical research on determinants and impacts of property rights innovation for groundwater irrigation systems. The last section provides concluding remarks on emerging challenges of water management.

Basic Characteristics and Water Accounting Analysis

Location, Climate and Socioeconomic Characteristics of the FRB

Traversing five prefectures (Handan, Shijiazhuang, Xingtai, Hengshui and Cangzhou) of southwest Hebei province, the Fuyang river is one of two branches of the Ziya river, a main branch of the southern part of the Hai river (see figures 1 to 3). The basin covers 22,814 km² with a population of 15.64 million in 1998. The FRB has a temperate monsoonal climate and is in a dry subhumid region. The annual average temperature is about 13 °C and the annual mean precipitation for the basin was 543 mm in the period 1956–98. More than 70 percent of the rainfall occurs between June and September. Table 1 summarizes the basic characteristics of the FRB.

Figure 1. China and the location of the FRB.

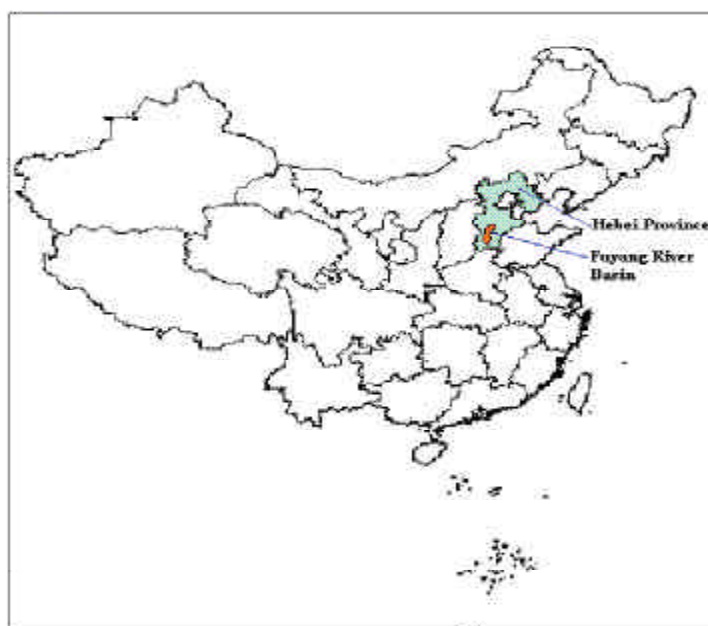


Figure 2. The hydrological Network of the FRB.

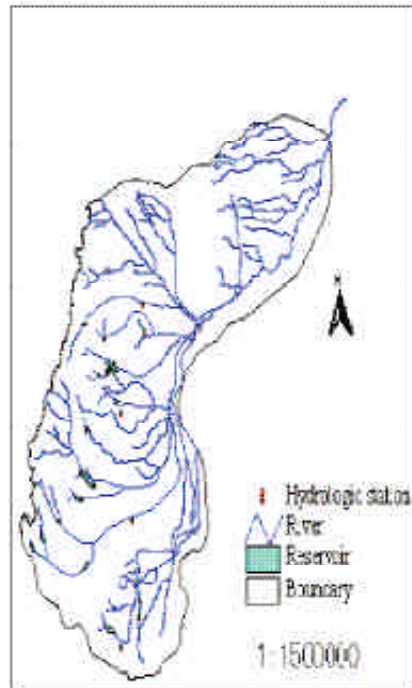


Figure 3. The divisions of the FRB.



Table 1. Basic characteristics of the FRB.

Variables	Values
Total area (km ²)	22,814
Total population (million persons)	15.64
Population density (persons/km ²)	686
Number of major urban centers	4
Number of prefectures	5
Number of villages	9,092
Urban population (million persons)	4.37
Rural population (million persons)	11.27
Per capita water availability (m ³) ^a	868
Share of agricultural employment (%)	67
Proportion of population living below official poverty line (%)	6
Cultivated area (1,000 ha)	1239
Proportion of irrigated area (%)	83
Multiple cropping intensity (sown area / cultivated area)	1.55
Average annual rainfall (mm) (1956-1998)	543
Annual average evapotranspiration over many years (mm) (1956-1998)	1,562
Maximum temperature (°C)(1956-1998)	42.6
Minimum temperature (°C) (1956-1998)	-20
Average temperature (°C) (1956-1998)	13
Average dry months per year (<5 mm rainfall) (1956-1998)	4

Note: If the years are not indicated, the values are for the year of 1998.

^aEstimated by the authors based on water accounting analysis in the FRB.

Source: Hebei Provincial Water Resources Bureau and Hebei Provincial Statistic Bureau.

The basin is a slightly more agricultural and rural-oriented region with 72 percent of the population in the rural sector in 1998 (compared to 70% for the nation as a whole). The growth of industrialization and urbanization was slower than in the rest of the country, partly due to scarcity of water in this region. Irrigation plays a critical role in the agriculture of the basin and has developed faster in there than in the rest of Hebei Province and China. The share of irrigated land in the FRB reached 83 percent in 1998 (rising from 69% in 1985), which is much higher than in the Hebei Province (67%) and the average national level (54%) in the same year (State Statistics Bureau 1999). Wheat and maize are dominant crops; followed by vegetables, oil crops, soybeans, cotton, tubers and rice.

Hydrological Characteristics of the FRB

Based on our water accounting analysis, per capita water resource availability in FRB is not very high, only 868 m³ (table 2). Shares of groundwater and surface water were 82 percent and 18 percent, respectively in 1998. Agriculture is the largest water consumer but the share of agricultural water use has been declining over time, from 81 percent in 1993 to 75 percent

in 1998, mainly due to increasing domestic consumption (from 5% to 10%). Limited by many reasons, the share of industrial water use increased only one percent (from 14% to 15% between 1993 and 1998).²

Table 2. Water accounting for a normal year of 1993 in the FRB.

	Total 10 ⁶ m ³	Components 10 ⁶ m ³
Inflow		
Gross inflow	12,290	
Precipitation		12,100
Surface sources from outside basin		190
Storage change	1,053	
Surface water		-34
Groundwater		1,087
Net inflow	13,343	
Outflow	54	
Available water	13,298	
Depletive use		
Process depletion	10,110	
Irrigated crop evapotranspiration		6,431
Nonirrigated crop evapotranspiration		2,567
Orchard evapotranspiration		689
Industrial uses		330
Domestic uses		93
Non-process depletion	1,500	
Forest evapotranspiration		1,500
Non-beneficial depletion	1,690	
Evapotranspiration from uncultivated lands		1,315
Evapotranspiration from lying fallow lands		259
Free water surface evaporation		116
Total depletion	13,300	
Accounting indicators	Value	
Depleted fraction (ratio)		
of gross flow	1.08	
of available water	0.98	
Process fraction (ratio)		
of gross flow	0.82	
of depleted water	0.76	
of available water	0.74	
Productivity of water		
Gross value of production in million US dollars	689	
Gross value of production per unit of		
gross inflow (\$/m ³)	0.056	
available water (\$/m ³)	0.051	
crop evapotranspiration (\$/m ³)	0.077	

²In 1998, for the national as a whole, the shares of agricultural, industrial and domestic uses of water were 69%, 21% and 10%, respectively.

With a total length of 403 km in the main river, the Fuyang river has 14 major branches. All branches of the Fuyang river flow into the main river at Aixinzhuang, Ningjin County in Xingtai Prefecture. The outflow of the surface water from the basin is measured at the Aixinzhuang hydrologic station. Figure 4 shows that the outflows from the basin dramatically decreased from an average of more than 500 million m³ in the 1970s to a discharge of less than 100 million m³ in the 1980s. It became a nearly closed basin in the 1990s except for 1996.

Groundwater is the most important water source in the FRB. With the increasing demands of agricultural, domestic and industrial uses of water, groundwater exploitation increased rapidly and the groundwater table (both shallow and deep) fell substantially, at more than 1 m annually in the past two decades (figure 5). Due to the overexploitation of groundwater, cones of depression have developed in all five prefectures, centered in the cities. Urbanization, industry and population growth have also led to increasing pollution of surface water and groundwater, which further sharpened the water-scarcity situation in the FRB.

Figure 4. Trend of discharges at Aixinzhuang Hydrometric Station, 1957-98.

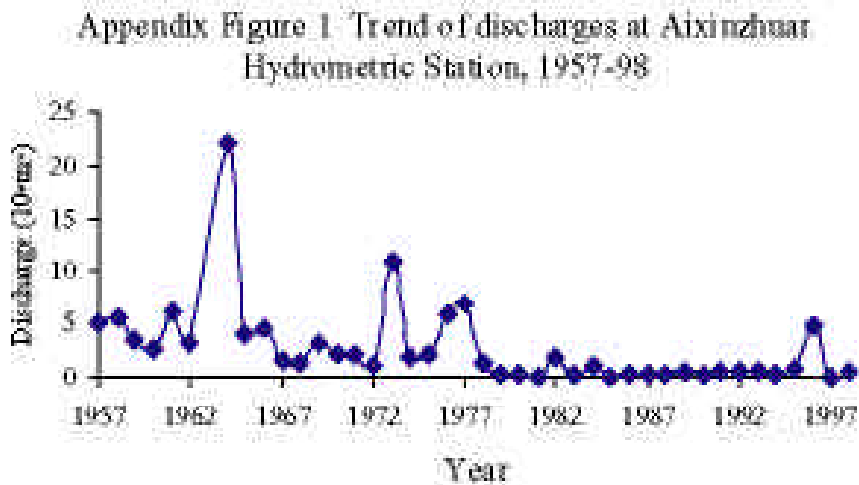
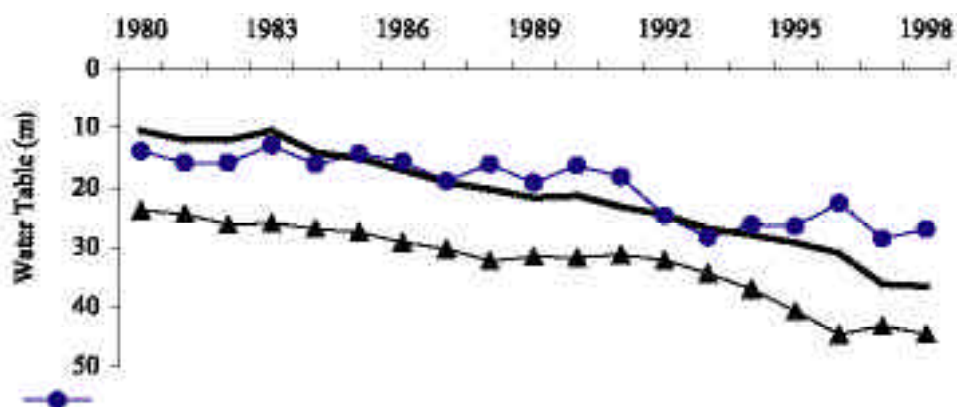


Figure 5. Trends of groundwater table in Bailuobao, Jiuzhou, and Longhua, 1980–98.

[Appendix Figure 2. Trends of groundwater table in Bailuobao, Jiuzhou, and Longhua, 1980-98.]



Overview of the Fuyang Irrigation District

As one of three large surface water irrigation systems in the FRB, Fuyang Irrigation District (FID) is located in the upstream part of the basin. The district includes 30 townships and 731 villages from 6 counties and the Handan city. The maximum irrigation capacity from surface water can reach 43,000 hectares. The average annual irrigated area with surface water in the district was 24,000 hectares in 1962–98, about 56 percent of total surface water irrigated areas in FID or 2 percent of the total irrigated area in the FRB. Total population in the FID is 1.26 million, about 8 percent of the total population in the FRB. The district is relatively rural with a 77-percent rural population, compared to 72 percent for the whole basin, in 1998.

Water-Accounting Analysis

Three representative years in the FRB (1993 for a normal year, 1996 for a wet year and 1998 for a dry year) were selected to conduct the water accounting analysis.³ The results for a normal year in the FRB are presented in table 2. They show that both the depleted fraction of the available water and the process fraction of the available water are very high, even under the conditions of groundwater overdraft during both the normal and dry years. This suggests that the additional water for further exploitation is very limited.

³Based on water accounting approach presented by Molden and Sakthivadivel.

To achieve sustainable development, the water storage change in the basin over a long-term period should be zero. In the past, groundwater was overdrafted, resulting in a declining groundwater table and other environmental problems. The current outflow from the basin is insufficient to maintain sustainable development in the downstream regions. Agriculture is the primary water user in the basin. Water available for agriculture is expected to decrease in the future as demand for domestic and industrial water uses increases. Generally, industry and domestic sectors have priority over water allocation when there is a water shortage. Increased productivity of water in the agriculture sector will be an important tool for alleviating water shortages in the basin in the future.

Increasing evidence in the FRB shows that existing water problems (such as increasing water shortage, decline groundwater tables, serious water pollution and decline of financial ability of irrigation systems) can be mainly attributed to poor water allocation and management, ineffective water policies and legal system and various water management conflicts among stakeholders and agencies. Any regional and river-basin water problems will be influenced by the national water management and institutional environment. In the next section, we discuss the national water law, management, and institutional arrangement problems, followed by a discussion of the relevant water management problems, based on our field studies in the FRB and irrigation systems in the basin.

National Water Law System, Management Institutions and Policies

The Legal System

The emerging water shortage and environmental problems associated with social and economic development in China have accelerated the development of the water law system since the 1980s. In recent decades, four water laws and nearly 50 water management regulations have been issued. According to the contents of these regulations, we grouped the latter into 9 kinds (figure 6). However, the water law and regulations were always too general to be implemented, and amending existing legislation and issuing necessary new legislation were both very slow, which reflect sharp conflicts among various stakeholders.

Structure and Conflicts of Water Management

In China, water resources are administered by a nested hierarchical administrative system. Figure 7 presents the structure of water management institutions in China. The Ministry of Water Resources (MWR) is at the highest central level directly under the State Council, with Water Resource Bureaus at the province, prefecture and county levels. Water management stations at the township are the lowest levels of state administration. The MWR not only provides technical guidance, issues water policy and regulates subnational water resource bureaus but also influences the local bureaus through allocating investment on water infrastructure from the central government.

Figure 6. Legal system for water in China.

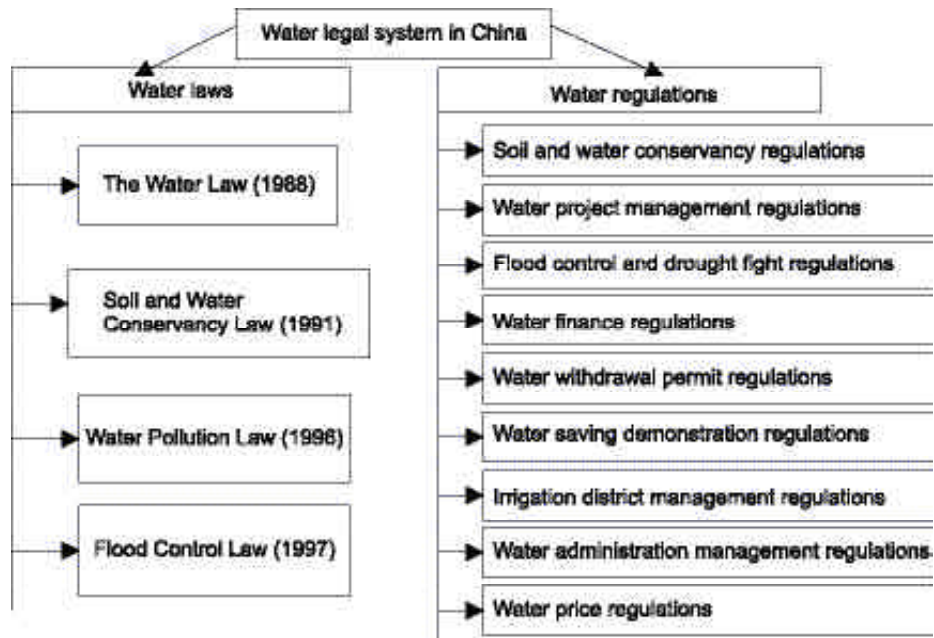
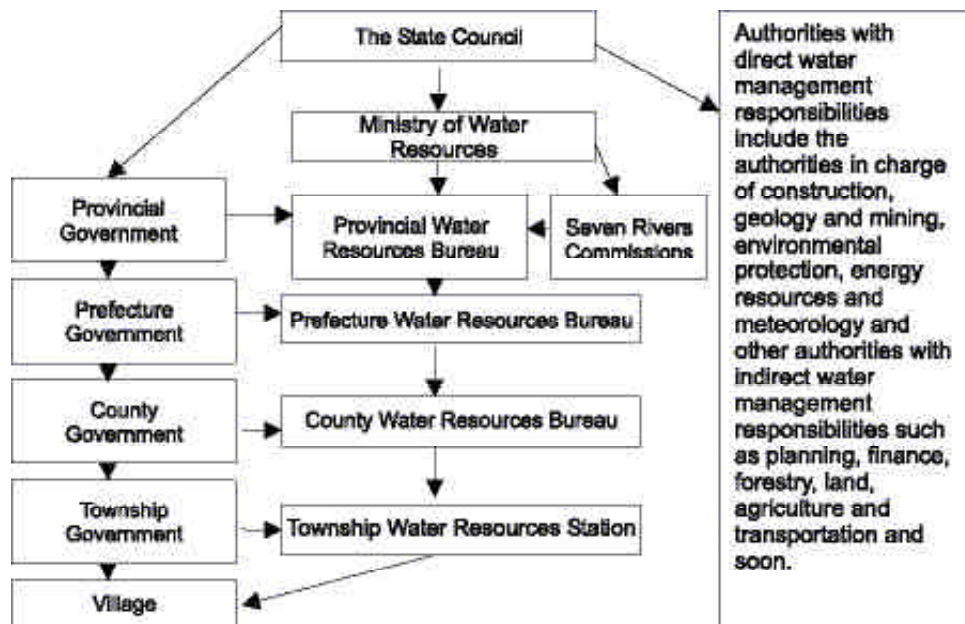


Figure 7. Structure of water management institutions in China



This system of water administration is supplemented by seven river commissions under the MWR that are responsible for coordinating water allocation among provinces through implementing the MWR policies. However, these cross-provincial river commissions have little decision-making power (Lohmar et al. 2001). Besides the two main water management systems of the MWR, there are several other government authorities, such as the ministries, bureaus or agencies of construction, geography and mining, environment protection, energy resource, meteorology, finance, and so on, which have some direct or indirect responsibilities in managing water resources (figure 7). The diverse functions of water use and diverse objectives and interests of many water management authorities result in various water-management conflicts present in rural and urban water use, surface water and groundwater balance, water quantity, and water-quality controls. Water management conflicts between management agencies, horizontal and vertical systems and between the upstream and downstream have not only accelerated water shortages, but also contributed to poor management, allocation and utilization efficiency of water resources (Wang and Huang 2000a).

Reforms of the Water Management Agency

To strengthen water management and resolve the water conflicts discussed above, China has been trying to reform its water management system since the late 1980s, particularly through a recent reform initiated after the mid-1990s. The reform took a bold move in division of the water-management functions among various stakeholders, though the ability to implement the reform is questionable (Wang 2000). By the reform policy, the MWR is provided with an exclusive right to manage water resources. If the reform is successfully implemented, some relevant water-management responsibilities currently controlled by other authorities are expected to be transferred to the MWR. By mid-1999, about 7 percent of the counties in Shanghai, Shanxi, Shanxi, Hebei, Henan, Anhui, Heilongjiang, and Shenzhen had established Water Affairs Bureaus (WABs) to consolidate the water management system. For the rest of China, the implementation of the reform has not been initiated, but is expected to shift to the WAB management system.

Water Withdrawal Permit System, Water Resources Fee and Water Markets

According to the 1993 regulation on the Implementation Method of Water Withdrawal Permit System, any individual or organization that draws water from a river, lake or groundwater over a certain levels must apply for a water withdrawal permit from the WRBs at various government levels. However, implementation of the above policies has proved to be problematic. The monitoring costs are high and the conflicts among various stakeholders and sectors make it almost impossible to follow the national water permitting system. In China's agricultural sector, there are millions of small farmers and many individually owned groundwater irrigation wells, so effective implementation of water management arrangements at the individual level (such as water withdrawal permitting, policy and fee collection) is a serious problem. Unlike some countries such as America, Mexico and Chile that allow the

trading of legal water rights, transferring a water withdrawal permit or water use rights is currently prohibited in China. But with rising water shortage problems over time, informal groundwater markets have emerged spontaneously in some water shortage areas (Wang 2000).

Reform of Water Finance and Pricing

After the rural institutional reform was initiated in the late 1970s, the planned financing system in the water sector has been gradually decentralized. The major reform has been focused on the responsibility of water management and finance between the central and local governments and between the government and farmers. The central government has focused its responsibility on the operating costs of the institutions directly under the MWR and the finance for special and nationwide projects, such as large flood and drought-control projects. The finance and management of small-scale rural water- conservancy projects have been transferred from higher to lower-level governments. Since the early 1980s, with progress in the financial reform, the share of investment in water projects in the total investment in the national infrastructure has declined from 5–7 percent to less than 3 percent (table 3).

Table 3. The share of government investment in water projects.

Year	Water Infrastructure Investment
	Total National Infrastructure Investment (%)
1951–1957	5.3
1957–1965	7.6
1965–1975	7
1975–1982	5.9
1982–1986	2.7
1986–1990	2.2
1990–1997	2.8

Source: Wang 2000.

Declining public agricultural and irrigation expenditures attracted attention to the sustainability of agricultural development and future domestic food supply. Investment policy reviews led to increased investment after the early 1990s (table 3). However, due to the weaknesses of the fiscal system, the new policy to increase public investment in agriculture and irrigation has hardly been implemented. There are many policies and regulations that have been promulgated regarding the provision of a minimum level of agricultural and public goods, but there is no budget to back them up. Without sufficient budgets, policies cannot be effectively carried out.

Although the central government has encouraged local governments to increase water prices and improve methods of collecting water fees, such as extending volumetric water pricing, the actual collected water fees can only cover project operation, management and normal maintenance, while there is no capacity for irrigation management to complete large-scale repairs, rehabilitation and reconstruction. Further, the rate of actual collection of water fees is always lower than 70 percent in most regions (Wang and Huang 2000b).

Water Regulations, Management Institutions and Financing in the FRB

The local governments in the FRB issued water management regulations mainly focusing on water pricing, water finance, collection of water resource fees, water withdrawal permit systems, and water-saving measures. Several water regulations aimed at increasing the efficient use of water were issued earlier than the corresponding national regulations, which reflect the water-scarcity situation and local government's attention to economic measures in solving water-shortage problems. On the other hand, management regulations of the river basin have not been formulated.

Unlike the seven large river basins, the FRB has no special river-basin management organization. In principle, water in the FRB should be allocated by the Hebei Province Water Resources Bureau (HWRB) through coordinating five prefectures within the basin. In practice, the HWRB has very limited power in allocating water among prefectures and counties in the basin. Water management in the basin is administered mainly by the local governments at prefecture or county levels. Lack of integrated management in the FRB results in inconsistent local economic structure and water endowment.

In addition to the management conflicts between horizontal and vertical agencies, local water resources bureaus, urban construction bureaus, environmental protection bureaus and other relevant bureaus also have many conflicts in managing rural and urban water, surface water and groundwater, water quantity and quality. To implement the State Council's 1998 organizational and management reform, local governments in the FRB declared that they would complete the water management reform especially in realizing urban and rural integrated water management by the end of 2000. By 1999, about 49 percent of counties in the FRB had established Water Affairs Bureaus compared with the national level of 7 percent in the same period (Ministry of Water Resources 1999).

Reforms in Water Allocation, Finance and Pricing in the FID

Water Allocation in the FID

Five seasonal Fuyang river branches flow into the Dongwushi reservoir that plays an important role in surface water supply for the FID. Table 4 shows that the annual inflow of surface water in the FID has a general declining trend and the share of agricultural water use has

Table 4. Total annual surface water inflow and allocation in the FID.

Year	Total Inflow (million m ³)	Total Water Use (million m ³)	Water Losses in River Canal (million m ³)	Water Supply for Downstream Irrigation Districts (million m ³)	Share of Agricultural Water Use (%)
1960s	475	190	71	214	52
1970s	398	225	56	117	44
1980s	276	165	45	65	51
1990s	294	183	46	65	36

Source: Management Authority of the FID.

also decreased over time. Industrial and domestic water uses have priority in water allocation; downstream water users received declining water inflow from upstream.

Water Finance in the FID

In 1962, the Management Authority of the FID (MAFID) under the Handan prefecture water resources bureau was set up with 9 irrigation subdistricts (branches). Government investment was a dominant financial resource for the surface water system of FID before 1981 but it has been almost fully replaced by the revenue generated by MAFID (table 5). Before 1983, all income came from the collection of water fees, though the amount was very small. With the reform of the financial system in the water sector initiated after the 1980s and to improve the financial capacity for maintaining surface water system, the MAFID started to run its own enterprises and businesses such as fishing, plastic firms, and metal-processing firms.

Table 5. Investment in surface water systems of the FID.

Year	Total Investment (Million Yuan in 1990 prices)	Investment sources (%)			Expense shares (%)		
		Government Fiscal	MAFID's Revenue	Farmer	Labor Input (000 days)	Maintenance	Construction
1955–58	2.37	96	4	0	70	0	100
1962–69	2.22	96	4	0	593	43	57
1970–79	1.48	68	29	4	3,588	40	60
1980–89	1.23	69	32	0	190	29	71
1990–98	0.62	0	100	0	2	100	0
1955–98	1.46	74	25	1	1,044	47	53

Source: MAFID.

Table 6. Income and expenditure in the surface water systems of FID management division.

Year	Income (Million Yuan)	Income sources (%)			Expense shares (%)		
		Water Fee	Others*	Expenditure (Million Yuan)	Engineering Input (000 days)	Management	Others ^a
1962–1969	0.25	100	0	0.18	56	44	0
1970–1979	0.45	100	0	0.37	44	56	0
1980–1989	4.42	96	4	2.87	7	10	83
1990–1998	6.19	93	7	5.63	12	15	72
1962–1998	2.88	94	6	2.28	13	16	72

Note: Income and expenditure are real values in 1990 prices.

^a Means incomes through operating enterprises in the FID.

Source: MAFID.

However, the income generated from these commercial activities was not sufficient to offset the decline in government investment (tables 5 and 6). Our field interviews also reveal that the income from the commercial sources is mainly used to compensate for the lack of core funding for the local staff salaries in the surface water system of MAFID (Wang and Huang 2000b).

Before the early 1980s, farmers' contribution to the surface water system was mainly through their contribution of *yiwugong* (obligatory labor) in the maintenance and construction of water projects at the local community level (table 5). *Yiwugong* has declined significantly since the 1980s. On the other hand, the water fees paid by farmers have increased rapidly over the same period. In terms of investment priority, investment in the surface water system has shifted from new construction projects to maintenance over time.

Water Price Reform and Water Fee Collection Approaches in the FID

Although the local government tried to implement volumetric water pricing measures for surface water, it has hardly been implemented due to measurement difficulties. At the local level, the water fees based on crop areas were collected by village leaders or people appointed by the MAFID. Recently, the water fees have been merged with the other payments that farmers have to pay for the services provided by the local village and township such as education, rural infrastructure development, and other public services as well as agricultural taxes. In most areas, these merged or aggregated payments are often linked with the government grain-procurement system that allows the farmers to pay all these merged fees in grain equivalent (in kind). In 2000, learning from some other irrigation districts, one subdistrict in the FRB established water user associations to overcome the difficulties in collecting water fees and to improve the management of field canals.

Table 7 shows the trends of water fees (prices) in both nominal and real prices (in 1990) for use in industry, domestic water supply, and irrigation from 1971 to 1998. Water prices for various uses had been kept constant until the late 1970s, then raised significantly in nominal terms thereafter. Despite the significant rise in water prices in the past three decades, *Table 7. Delivery prices of surface water from water suppliers in the FID.*

Year	In nominal prices (yuan/m ³)			In 1990 real prices (yuan/m ³)		
	Industry	Domestic	Irrigation	Industry	Domestic	Irrigation
1971	0.006	0.001	0.002	0.013	0.003	0.004
1975	0.006	0.001	0.002	0.013	0.003	0.004
1980	0.010	0.002	0.003	0.019	0.004	0.006
1985	0.050	0.010	0.007	0.081	0.016	0.011
1990	0.232	0.051	0.019	0.232	0.051	0.019
1995	0.278	0.064	0.054	0.161	0.037	0.032
1998	0.365	0.128	0.069	0.204	0.072	0.039

Source: MAFID.

the water prices for various uses are still much lower than the true productive value of water. Indeed, water prices in real terms for industrial and domestic uses had declined in the first half of the 1990s. While the agricultural water prices kept rising, though at a slower rate after the late 1980s, they were much lower than the prices of other uses.

Property Rights Innovation in Groundwater Irrigation

There are different management systems for surface water irrigation and groundwater irrigation. The surface irrigation system has been mostly controlled by government agencies, such as the FID, though a contract management system was implemented in some periods. Compared with groundwater irrigation, surface irrigation has basically not changed in property rights since the 1980s. Therefore, we will focus on the evolution of property rights in groundwater irrigation systems. In this section, we present the results of our recent surveys from a randomly selected sample of 30 villages and 87 sample groundwater irrigation systems ⁴ in three counties (2 counties in FRB and the other in the nearby basin) of the Hebei Province.

Investment in Groundwater Irrigation Systems

Groundwater irrigation investment was mainly financed by the local villages and townships with varying extents of government financial subsidies, prior to the implementation of the household production responsibility system (HRS) initiated in the late 1970s. Farmers always contribute family labor for constructing a groundwater irrigation system. Collective ownership dominated all groundwater irrigation systems. With the implementation of HRS, the declining collective role in the local economy and growing private (farmers) involvement in groundwater irrigation, investment from collectives and the government has dropped considerably, while farmers' investment has increased significantly since the early 1980s (table 8).

Table 8. Groundwater irrigation investment in the 30 sample villages in Feixiang, Yuanshi and Qinglong counties, Hebei Province.

Year	Sources of Groundwater Irrigation Investment (%)					Total Investment (Million Yuan) ^a
	Total	State	Collective	Farmers	Others	
1983	100	21	12	67	0	203
1990	100	10	11	69	11	85
1998	100	3	5	92	0	170

Note: Feixiang and Yuanshi counties locate in FRB, Qinglong county located in neighboring basin of FRB.

^a Real price in 1990.

Source: Authors' surveys in 30 randomly selected 30 villages from 3 selected counties of the Hebei Province.

⁴One tube well and its relevant facilities are defined as a unit of groundwater irrigation system.

Characteristics of Property Rights Innovation

In this study, we divide groundwater irrigation systems into two groups with different property rights: collective and noncollective. For collectively owned irrigation systems, we further classify them into purely collectively owned and quasi-collectively owned irrigation systems; the latter is for those irrigation systems in which both collectives and farmers or other organizations jointly owned the system. Noncollectively owned irrigation systems are also classified into two subgroups: individual privately owned and shareholding by several individuals.

The most significant change in the property rights of groundwater irrigation systems in our study area is shifting from collective to noncollective. The share of noncollectively owned irrigation systems increased from 17 percent in the early 1980s to 69 percent in 1998 (table 9).

Table 9. Changing structure of property rights in groundwater irrigation systems, 1983–98.

Year (%)	Collective v Noncollective		Within Collective		Within Noncollective	
	Collective	Noncollective	Pure	Quasi	Shareholding	Private
1983	83	17	52	48	100	0
1990	56	44	24	76	99	1
1997	32	68	16	84	87	13
1998	31	69	18	82	86	14

Source: Field survey in 30 villages in three counties, Hebei Province.

Within the collective property-rights system, pure collectively owned irrigation systems have been gradually replaced by quasi-collective systems (table 9). The noncollectively owned groundwater irrigation systems were dominated by the farmers' shareholding in the initial stage of property-rights changes due to credit constraints of individual farmers. However, the individual privately owned irrigation systems have been growing rapidly since the early 1990s, increasing from only 1 percent in 1990 to 14 percent in 1998.

Determinants and Impacts of Property Rights Innovation

Econometric analyses of the determinants of property rights innovation⁵ show that the noncollective property rights of the groundwater irrigation system are induced by many factors, including changing resources endowments, environmental stress, weakening local collective economy, market development, improving human capital, and financial policies (table 10, and Wang et al. 2000). Among these factors, increasing water scarcity, overexploitation of groundwater, and increasing population pressure are major factors that led to rapid expansion of noncollective groundwater irrigation activities.

⁵Data from 30 sample villages are used in this model.

Table 10. Determinants of property rights innovation in groundwater irrigation.^a

Variables	Share of Noncollective Property Rights of Groundwater Irrigation System (%)		
	OLS		Random effect model
	Case 1 ^b	Case 2 ^b	
Constant	-132.022 (-0.69) ^c	-404.156 (-4.55) ^{***}	-111.367 (-1.99) ^{**}
Water resources endowments			
Groundwater table level in the last year (log)	4.817 (1.39)	66.031 (3.33) ^{***}	13.246 (2.64) ^{***}
Share of surface water use in irrigation (%)	0.430 (2.72) ^{***}	0.435 (3.07) ^{***}	0.455 (3.21) ^{***}
Environmental stress			
Per capita cultivated area (log)	-3.262 (-0.27)	-83.075 (-2.54) ^{**}	-31.740 (-1.90) ^{**}
Local community economic power			
Per capita real net income of farmers (log)	-9.370 (-1.11)	-11.570 (-1.23)	-11.740
Per capita income of village collective (log)	-4.074 (-1.82) [*]	1.340 (0.72)	0.250 (-0.13)
Human capital in local community			
Share of agricultural labors who received middle school or higher education (%)	1.979 (5.54) ^{***}	0.038 (0.07)	1.595 (4.06) ^{***}
Policy dummy variables			
With fiscal subsidies for water project	9.359 (1.25)	13.479 (2.12) ^{**}	13.873
With subsidized loan for water project	-27.680 (-4.14) ^{***}	-62.107 (-2.10) ^{**}	-30.018 (-2.90) ^{***}
Road condition dummy	13.383 (1.84) ^{**}	21.947 (2.24) ^{**}	19.037 (2.29) ^{**}
29 village dummy variables ^d	- ^e	omit	-
R ²	0.458	0.833	0.619
Adjusted R ²	0.413	0.755	-
F	10.31	10.63	-
Chi ²	-	-	137.77
Degree of freedom	110	81	110

^a The sample size is 120.

^b "Case 1" does not include the village dummy variables while "case 2" includes village dummy variables.

^c Numbers in parentheses are t statistics (case 1 and case 2) or z statistics (random effects model); "^{*}", "^{**}" and "^{***}" represent statistically significant at 10%, 5% and 1%, respectively.

^d Coefficients for village dummy variables have not been listed.

^e "-" indicates the variable has not been included in model.

Table 11. Estimated results of stochastic water production frontier model.

Variables	Water Production(log) ^a			
	Case 1 ^b		Case 2 ^b	
	Coefficient	T statistic	Coefficient	T statistic
Constant	2.410	(16.24) ^{***c}	2.408	(16.79) ^{***8}
Fixed cost (log)	0.080	(2.85) ^{***}	0.081	(2.88) ^{***}
Variable cost (log)	0.255	(5.95) ^{***}	0.254	(6.00) ^{***}
Labor (log)	0.389	(7.16) ^{***}	0.389	(7.38) ^{***}
Average water table level (log)	0.049	(0.92)	0.056	(1.04)
Dummy for 1997	0.034	(1.52)	0.033	(1.46)
Dummy for 1998	0.026	(1.21)	0.027	(1.23)
County dummy: Feixiang	-0.196	(-2.51) ^{**}	-0.208	(-2.64) ^{***}
County dummy: Yuanshi	-0.106	(-2.02) ^{**}	-0.110	(-2.07) ^{**}
Variables influencing technical efficiency				
Constant	0.459	(7.77) ^{***}	0.460	(8.38) ^{***}
Dummies for property right				
Noncollective	-0.084	(-2.44) ^{**}	- ^d	-
Shareholding	-	-	-0.088	(-2.87) ^{***}
Private	-	-	-0.028	(-0.40)
Dummy for management with bonus	-0.085	(-1.99) ^{**}	-0.101	(-2.59) ^{***}
Irrigation system scale:				
Annual maximum irrigated area (ha)	-0.023	(-12.57) ^{***}	-0.022	(-13.89) ^{***}
Management ability of manager				
Schooling years (years)	0.001	(0.16)	0.001	(0.17)
Irrigation system age				
Founding years (years)	-0.014	(-2.19) ^{**}	-0.013	(-2.19) ^{**}
d ²	0.019	(4.64) ^{***}	0.018	(6.12) ^{***}
r	0.912	(24.98) ^{***}	0.907	(26.56) ^{***}
Max. likelihood value	155.09		155.72	
Average value of technical efficiency	0.818		0.819	

^aThe sample size is 189.

^bProperty right dummy variables in "case 1" are divided into two kinds: collective and noncollective; while those in "case 2" are divided into three kinds: collective, shareholding, and private.

^c"***", "**", and "*" represents statistically significant at 10%, 5%, and 1%, respectively.

^d "-" variable not included in model.

Econometric results (table 11) show that in case 1 (dummy variables for property rights are divided into collective and noncollective) the coefficient of noncollective property rights is statistically significant and positively related with technical efficiency. It implies that the changes of property rights in favor of noncollective and market-oriented mechanisms in irrigation have significant impacts on the technical efficiency⁶ of the water-supply sector after controlling for all other impacts⁷ (Wang and Huang 2000a). Further, innovation of noncollective property rights for groundwater irrigation was also found to have statistically significant impacts on cropping patterns and agricultural production (Xiang and Huang 2000).⁸ In particular, the expansion of private or noncollectively owned irrigation stimulates cropping pattern changes in favor of high- value cash crops and against grain crops. This change raises farmers' income as the former are more profitable and the additional water is available for later crop cultivation through the increase in water use efficiency, due to the changes in irrigation property rights.

Policy Implications

The above findings have strong policy implications for raising water productivity and farmers' income. The ongoing expansion of private and shareholding groundwater irrigation should be encouraged and integrated into the government irrigation investment programs. The current government fiscal and financial/credit policies that favor collectively owned irrigation as well as the large irrigation projects owned by the state should be revisited and reevaluated.

However, our study also warns that if water prices do not fully reflect the marginal value of water use (including externalities affecting other water users), then, property rights innovation toward privatization might lead to overexploitation of groundwater and water table declines. Therefore, to promote sustainable development of water resources, future water resources policy should emphasize on property rights innovation, rationalizing water prices, and better groundwater management institutions.

Concluding Remarks

Declining groundwater levels, reduced surface water discharges, and increasing water competition among stakeholders with growing water demands have been presented in China, one of the most water-short countries in the world. If these trends continue and the government does not respond to these trends with proper policies in the future, water shortage could threaten China's economically and environmentally sustainable development.

⁶Technical efficiency is defined as the ratio of observed water output to potential water output (water frontier output).

⁷Data of 87 samples of groundwater irrigation system are used in estimation.

⁸In this research, we assume institutional variables to be exogenous variables.

Although limited water endowment is one important reason for an expanding water demand and supply gap, the existing legal system, regulations, management and other water-related policies add to the unbalanced and unsustainable use of water in China, particularly in the northern regions. The water management and organizational conflicts between rural and urban water allocation, between surface water and groundwater, and between horizontal and vertical management authorities will hardly be solved if the system is not reformed. A better-enforced system of laws and regulations, and a more effective institutional setting that facilitates the implementation of integrated water management at national, regional and water-basin levels need to be established.

Although the seven large-river commissions were established to coordinate water allocation and flood control across provinces, the impacts of these commissions are more on flood control than on water allocation due to the limited power of the commissions. Generally, there is no interregional water management authority in the small water basins. The local governments based on administrative jurisdictions often separately manage the water in the small water basins. Within the administrative jurisdictions, water supply and demand are controlled and managed by too many authorities that have different interests and, therefore, resulting in various conflicts in balancing water use in the region. Increasing conflicts, unbalanced and inefficient water allocation among sectors and between upstream and downstream within the river basin have made integrated river basin management very essential.

Although central and local governments have successfully developed surface water and groundwater resources through mobilizing every possible financial and human capital by administrative measures that greatly supported national and local social and economic development, growing evidence shows that administrative measures alone cannot solve increasing water shortage problems. Market-oriented water management measures, such as rational water price, water market, water rights transfers and property rights innovation for water facilities, should be emphasized and introduced into central and local water management systems.⁹

Our study on property rights innovation also suggests that the private and shareholding groundwater irrigation system can improve the efficiency of water use. The existing government fiscal and financial policies in irrigation investment need to be revised to encourage the development of this market-oriented irrigation management system.

⁹Farmers' responses to water prices, water markets and water rights transfers need to be studied in the future.

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Part III
Study of Irrigation Investment, Fiscal Policy
and Water-Resource Allocation in
Indonesia and Vietnam

CHAPTER 9

Integrated Economic-Hydrologic Modeling of the Brantas Basin, East Java, Indonesia: Issues and Challenges

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Introduction: Motivation for the Modeling Study

This paper describes the integration of economics, hydrology and policy simulation in a unified, basin-scale model applied to the Brantas basin, East Java, Indonesia. The paper has four primary objectives. The first objective is to provide a context and a justification for integrated model development within the broader framework and objectives of the Indonesian component of the project titled “Irrigation Investment, Fiscal Policy, and Water Resource Allocation in Indonesia and Vietnam.” This study is funded by the Asian Development Bank (ADB) and conducted by the International Food Policy Research Institute (IFPRI) and its Indonesian partners: Perum Jasa Tirta, the Center for Agricultural and Socioeconomic Research (CASER), and the Directorate General of Water Resources Development (DGWRD). The second objective of the paper is to describe current conditions in the water sector within the Brantas basin, and to relate these conditions to project objectives. The third is to provide a summary description of the integrated approach to basin-scale modeling. The fourth, and most important, is to describe the development, structure and application of such an integrated economic-hydrologic-policy simulation model for the Brantas basin. As the project is still in its early stages, there can be no discussion of results except to give a description of the process.

In describing the development of this model, we will highlight several issues and challenges we have encountered to date that will be, hopefully, broadly relevant to practitioners of integrated watershed modeling in other locations as well. This paper is intended to complement the paper by Sunaryo (2000), included in these proceedings. Sunaryo (2000) describes the history of water resources development in the Brantas basin, as well as the legal and institutional framework and guiding principles.

The IFPRI/ADB study is motivated by several critical and interrelated factors currently affecting many emerging economies of South and East Asia, and the Brantas basin specifically.

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These include: a) increasing demand for both agricultural commodities and freshwater resources; b) increasing competition between the agricultural and nonagricultural sectors for available freshwater; c) deterioration of irrigation infrastructure and escalating costs of developing new irrigation capacity; and d) deterioration of water quality as a consequence of both agricultural and nonagricultural activities. Effective physical limits to freshwater resources in many Asian basins, as in the Brantas, dictate that institutional reform and alternative economic incentives and policy strategies are required to cope with increasing scarcity and competing inter-sectoral demand. The project is designed to assist national and regional policy makers and river basin authorities to make appropriate policy decisions for the development and allocation of water resources, and to establish priorities for the reform of institutions and incentives that affect water resource allocation, particularly the irrigation sector.

The project consists of three components: a) An assessment of water allocation mechanisms and institutional structures for river basin management and effects on irrigation management, b) An assessment of the effects of taxation, pricing policy and irrigation investment on the incentives for irrigated farming; and c) The development and application of tools and integrated impact analysis to assess the effects of components a) and b). The focus of this paper is on the third component, although it must be emphasized that the integrated basin model is a tool to accomplish the broader objectives of the project, and not an end in itself.

The basin-level component a) consists of technical and institutional analyses of alternative water allocation mechanisms and their impacts on agricultural productivity, growth and sustainability, and on environmental quality within the basins. Basins selected for detailed study are the Brantas in East Java, Indonesia, described in this document, and the Dong Nai basin in southern Vietnam, described in a companion paper prepared for this workshop (Ringler et al. 2000). The specification, testing and application of formal (mathematical) models integrating basin hydrology, economics and policy scenarios are key components of the basin-level studies. The national-level component b) consists of a complementary analysis of national tax policies that influence irrigation development, operations and maintenance; of agricultural input and output pricing policies; and of trends in public expenditures for irrigation and water resources. The structure and approach of the project are predicated on the observation that national fiscal policies can act to either reinforce or mitigate effects of policies at the basin level. An integrated approach is believed to be particularly relevant in evaluating the feasibility of using direct water charges to recover irrigation costs. If irrigated farmers are heavily taxed through general fiscal and price policies, effective irrigation cost recovery through direct water charges will be much more difficult to achieve.

Two points deserve emphasis. First, that the modeling approach is explicitly predicated on principles adopted at the 1992 United Nations Conference on Environment and Development held in Dublin, specifically that *Water development and management should be based on a participatory approach, involving users, planners, and policymakers at all levels* for which the river basin provides the appropriate framework, and that *Water has an economic value in all its competing uses and should be recognized as an economic good* (Calder 1999, 52). The comparative evaluation of policy instruments is correspondingly based on the collective economic benefit generated under each policy scenario, appropriately

constrained to reflect social norms and the statutory environment. Second, that the viability of the irrigated agriculture sector is of paramount importance to the authors and sponsors of this study, as consistent with the mission of IFPRI and the CGIAR: to increase agricultural productivity, protect the environment and alleviate poverty.

Basin Profile and Description of Major Water-Sector Issues and Challenges

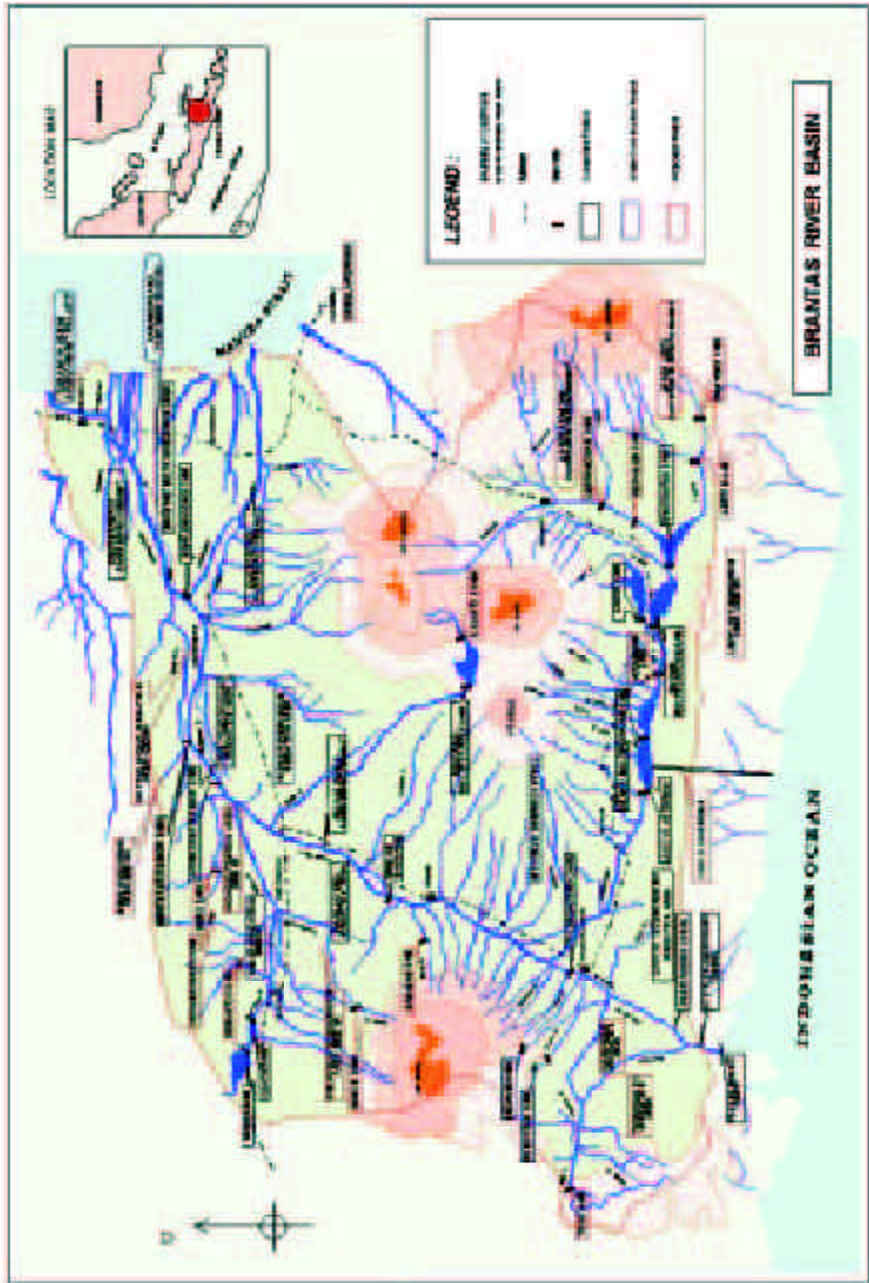
Physical Setting and Description of the Brantas Basin

The Brantas basin lies entirely within the Province of East Java, Indonesia between east longitudes 110° 30' and 112° 55' and between south latitudes 7° 01' and 8° 15'. The basin, approximately 12,000 km² in area, is bracketed by volcanic massifs, and contains two active volcanoes: Mt. Semeru to the east, and Mt. Kelud near the basin center. Mt. Semeru is continuously active, although eruptions are not cataclysmic and most ash falls outside of the Brantas basin. Mt. Kelud has been active in approximately 15-year cycles in recent decades, most recently in 1990, and eruptions have had catastrophic consequences on occasion. Risk of civil disaster from volcanic eruptions is a major concern in the basin. Volcanic ash is both a major source of soil fertility and a primary cause of reservoir sedimentation. Basin geology consists of tertiary formations including basalts and andesites in the volcanic uplands, marine limestone underlying the plains and deltaic areas and consolidated volcanic ash throughout. The plains and the delta consist of alluvial soils (silt, clay loams) well suited for paddy cultivation.

The basin lies within the Intertropical Convergence Zone, in which the semiannual reversal of prevailing winds results in distinct wet (November–April) and dry (May–October) seasons. During the wet season, there are around 25 rainy days per month, compared to 7 or fewer during the dry season. Annual precipitation is around 2,000 mm on average, with roughly 80 percent occurring in the wet season. The mean annual temperatures range from 24.2 °C at Malang (elevation 450 m asl) to 26.6 °C at Porong in the delta, and relative humidity varies seasonally from 55 percent to 95 percent.

Figure 1 shows the Brantas basin and its primary topographic and hydrologic features. The Brantas river is approximately 320 km long, and has its headwaters in the Arjuno volcanic massif, a major topographic feature dominating the southeast-central portion of the basin. It courses clockwise around the massif, first south through the Malang plateau (elevation 400 m asl), then west through the major dam and reservoir complex consisting of Sengguruh, Sutami/Lahor, Wlingi, and Lodoyo, respectively. At the confluence with the Ngrowo river in the Southwestern portion of the basin, the Brantas turns north through the agriculturally productive plains region and finally east through the delta, also an important paddy-growing area, where it discharges into the Madura Strait. Primary tributaries above the delta include the Lesti (southeast), Ngrowo (southwest), Konto (central), and Widas (northwest) rivers. The Upper Brantas channel slopes are relatively steep (>0.005); and much more gentle lower in the system (≤ 0.001).

Figure 1. Map of the Brantas basin showing key features.



The Brantas enters the delta downstream (east) of Mojokerto, where it is regulated by the New Lengcong barrage (NLB). The barrage, reconstructed in 1973 on the site of a structure of the colonial era, partitions the Brantas into four major channels: the Surabaya and Porong rivers and the Porong and Mangetan canals. The canals provide irrigation for the extensive agriculture in the deltaic region. The Porong river essentially serves as a floodway and the Surabaya river serves as the primary water supply to the major port city of Surabaya. Within the Surabaya city, the Surabaya river further bifurcates into the Mas and Wonokromo rivers. Discharge at NLB is entirely controlled by gated structures, and the barrage is the lowest point on the Brantas system at which the main stem discharge can be measured directly. Annual discharge at NLB averages around 250 m³/s, with a strong seasonal cycle reflecting the seasonality of precipitation. Measured, reconstructed and estimated discharges at NLB are summarized in table 1.

The agricultural economy of the basin is centered on the cultivation of paddy, nearly all of which is irrigated. Other important food and cash crops include maize, cassava, soybean, peanut, tobacco, coffee and sugarcane. Dry-footed crops grown primarily in the dry season, including maize, soybean and peanut, are collectively known as polowijo. Prevalent rotations include paddy-paddy-polowijo, paddy-paddy-fallow, and paddy-polowijo-other. Table 2 summarizes the harvested area, production and value of agricultural produce within the Brantas basin for 1995.

Table 1. Mean annual discharge, specific discharge and basin yield ratios, Brantas river at NLB (8,444 km²).

Study	Mean Annual Discharge (Q) m ³ /sec.	Specific Q m ³ /sec. per 100 km ²	Equivalent Depth mm	Yield Ratio Runoff/Precipitation	Period of Data Gathering
SRPCAPS					
Natural, 1999	257	3.04	960	0.52	1970–1996
JICA II Natural 1998	238	2.82	889	0.48	1977–1996
Van der Weert 1994	163	1.93	721	0.39	na
SRPCAPS					
Measured 1999	233	2.76	870	0.47	1971–1997

Major Water Management Issues and Challenges in the Brantas Basin

Irrigated agriculture is by far the largest consumptive use of water in the Brantas, currently consuming around 19 percent of the total annual discharges and 72 percent of annual discharges utilized consumptively or nonconsumptively. Other significant withdrawals are made by municipal and industrial users. Aquaculture in the delta utilizes residual and return flows. A significant quantity of hydropower is generated within the basin, and flushing flows are required to maintain standards of water quality, particularly in the region below the NLB. Brantas water is used recreationally as well. Summaries of water use by sector appear in table 3. Recent major studies of water management in the basin, particularly the Master Plan IV (JICA 1998) and the SRPCAPS (Binnie and Partners 1999) have identified several issues as the

Table 2. Harvested area, production, yield, and value at wholesale of important crops, Brantas basin.

Commodity	Harvested Area (ha)	Production (MT)	Yield (MT/ha)	Wholesale Price (Rp/MT)	Value at Wholesale (M Rp)	Percent of Total
Total paddy	433,703	2,260,670	5.21	455,229	1,029,123	55.35
Wetland paddy	422,471	2,223,495	5.26			
Dryland paddy	11,232	37,175	3.31			
Maize	239,039	945,198	3.95	377,735	357,034	19.20
Cassava	55,170	884,947	16.04	157,437	139,323	7.49
Sweet potato	5,310	71,251	13.42	227,954	16,242	0.87
Peanut	19,104	20,606	1.08	1,450,000	29,879	1.61
Soybean	67,659	82,408	1.22	1,136,130	93,626	5.04
Mung bean	8,423	8,030	0.95	280,000	2,248	0.12
Cashew	8,781	1,543	0.18	7,500,000	11,570	0.62
Coconut	85,030	87,948	1.03	314,694	27,677	1.49
Coffee	19,095	8,439	0.44	4,640,000	39,157	2.11
Clove	16,550	4,407	0.27	2,950,000	13,001	0.70
Kapok	19,648	6,897	0.35	400,000	2,759	0.15
Cotton	90	51	0.57	320,000	16	0.00
Tobacco	9,913	21,003	2.12	3,430,000	72,039	3.87
Tea	342	539	1.58	2,800,000	1,510	0.08
Sugarcane	94,630	592,627	6.26	40,000	23,705	1.27
Cacao	2,297	246	0.11	1,340,000	330	0.02
Total	1,084,784	4,996,810			1,859,240	

Notes: 1. Basin totals have been defined in terms of the 9 Kabupaten and 5 Kotamadya located totally or partially within the Brantas basin. Of these, Kabupaten Trenggalek lies partially outside the basin so that numbers appearing in the table are biased upward.

2. Source of production figures: Province of East Java (1999) Jawa Timur Dalam Angka 1998; for year 1998.

3. Source of wholesale prices: www.fao.org, market wholesale prices for year 1995 (latest available).

Table 3. Summary of water withdrawal estimates, million m³/year.

Category of Use	JICA	JICA ^a	SRPCAPS	WRMM	GSAS
Irrigation	2,138.0	1,943.2	1,929.57	2,067.0	3,192.7
Domestic	470.6	108.0	421.40	207.0 ^b	421.1
Industrial	215.0	104.0	255.00	118.0	142.8
Fisheries	16.7	40.8	NA	NA	NA
Flow augmentation	0.0	0.0	236.52	315.0	272.5
Total abstractions	2,840.4	2,196.0	2,842.5	2,707.0	4,029.1

^aDirect surface abstractions only; excludes groundwater use and transfers.

^bPDAM only; excludes non-PDAM rural withdrawals.

primary challenges currently facing water-resources managers in the Brantas, as discussed in the following sections.

Water quantity

The quantity of water available in the dry season is currently barely sufficient to meet existing demand, particularly when in-stream water quality objectives are considered. This is particularly (but not exclusively) a concern in the high-consumption region below the NLB, which includes the Brantas deltaic irrigation systems, the Greater Surabaya municipal area and a high percentage of the Brantas basin industries. In dry years such as 1997, fully 100 percent of Brantas flows reaching the NLB are utilized. This current level of dry-season utilization also fails to reflect the large percentage of the existing population that is currently not served, or served poorly by the PDAMs (municipal water supply companies). According to SRPCAPS 1999, in 1995 only around 2 million of the basin's 14 million residents were served directly by the PDAMs via either house connections or standpipes. Demand is increasing as a function of growth in both population and income, and the potential for recycling return flows below the NLB is limited. On an annual basis, however, the Brantas is not fully allocated, a substantial amount of the wet season flow entering the Madura Strait unused. This reflects both the strongly seasonal distribution of runoff and the limited extent of reservoir storage within the basin. Active storage within the basin's eight reservoirs is currently around 360 million m³, equivalent to only 3–4 percent of the annual discharge.²

Water quality

Water quality in the Brantas-Surabaya is often poor, leading to adverse impacts on both public health and economic development. Zones of particularly poor quality of water include the reach immediately downstream of Malang and the Lower Brantas-Surabaya area. Problems of water quality are currently primarily related to biochemical oxygen demand (BOD) from domestic waste and industry. Problems are not limited to dry-season flows. Significant elevations in BOD have been observed during wet-season runoff, suggesting that animal and other wastes accumulate during the dry season and are mobilized during the wet season. Mobilization of contaminated sediments by wet-season flushing flows is also suspected.

Sedimentation of reservoirs

Volcanic activity occurs both continuously (Mt. Semeru) and episodically (Mt. Kelud) in and around the Brantas basin, resulting in the deposition of large quantities of ash. Volcanic sediment is a primary source of reservoir sedimentation, with Mt. Kelud deposits adversely

²One m³/sec. per year is equal to 31.5 million m³ of storage. Thus, 360 million m³ is equivalent to roughly 11.4 m³/sec. continuous discharge on an annual basis, or 23 m³/sec. flow continuous augmentation over the dry season.

affecting Wlingi and Lodoyo reservoirs, and Mt. Semeru deposits affecting Sengguruh and Sutami, respectively. It has been estimated that the Sutami reservoir has lost nearly 50 percent of its gross storage and 40 percent of its active storage since its construction in 1972 due to sedimentation. The Sengguruh reservoir, which was completed in 1988 primarily to serve as a sediment trap for Sutami, has lost over 80 percent of its original gross storage (JICA 1998). New storage is considerably more difficult and expensive to develop than were existing reservoirs.³ Solutions to the ongoing problem of reservoir sedimentation involve expanded upland conservation efforts, such as the Sabo (check-dam) development and rehabilitation occurring on Mt. Kelud.

Low water-use efficiency

In 1999, SRPCAPS estimated that overall efficiency of irrigation water use is quite low in the Brantas delta, around 27 percent, and this inefficiency contributes to the frequently observed water shortages in this region. Overall efficiency is defined as the combined effect or product of intake efficiency, system operating efficiency and on-farm (tertiary unit) efficiency. Return flows in the delta cannot in general be reused, although they may provide flushing flows to the brackish fishponds. Inefficiencies for irrigation systems above the NLB have less-profound consequences, since most return flows from upstream systems can be recycled in the delta and Surabaya. Primary factors contributing to inefficiency include poor timing of deliveries and deteriorating infrastructure. Domestic water use efficiency is also low, with system losses in the Surabaya area estimated to be 30–45 percent of gross deliveries.

Poor cost recovery in irrigation

Indonesian farmers do not pay directly for irrigation water, as domestic (PDAM) and industrial users do. Ramu (1999) notes the fact that PJT's revenues are largely derived from the sale of water to nonagricultural users creates an allocation bias against agricultural users. Although an irrigation service fee (ISF) system exists, collections are sporadic and insufficient to cover irrigation-related operation and maintenance (O&M). Under current ISF, farmers are charged a fixed amount per hectare per season depending on the crop grown (US\$1=Rp 9,450), so that no incentive exists for increased efficiency. JICA (1998) has estimated that PJT would need to levy a volumetric water charge of Rp 25/m³ to recover both irrigation investment and recurring O&M costs, an amount only slightly below the corresponding municipal water charge (Rp 30/m³).⁴ The observation that many farmers within the Brantas surface irrigation systems invest in powered pump sets to augment surface water deliveries demonstrates that they are not unwilling to pay for irrigation water, however, provided that the timing and quantity correspond to their cropping requirements.

³JICA (1998) estimated the unit water costs for five proposed dams, which range from Rp. 890 to Rp. 2,200 per cubic meter at current June 1997 prices, assuming a 12% discount rate.

⁴Prices ca. June 1997.

Conflicting and overlapping institutional responsibilities

Numerous State, Provincial, *Kabupaten/Kotamadya* (district/municipal), and local agencies are involved in planning and managing water and related land resources in the Brantas basin. The theoretical guiding principle of *One River, One Plan and One Integrated Management* is thus violated to some extent in practice. For example, while PJT provides bulk water to irrigation systems located on the Brantas and main tributaries, it does not operate or manage these systems; this is done by the Provincial or District Water Resources Service (under Public Works, now KIMPRASWIL). JICA (1998) describes a number of additional cases where tasks are duplicated, or where a given agency's mandate is obscure. In addition, the Republic of Indonesia is in the process of implementing an ambitious program of decentralization (regional autonomy). The consequences of decentralization on basin water management are not yet clear, but some PJT staff members have voiced concern over the potential for conflict and inconsistency in water allocation and management practices.

Availability and consistency of data

The quantity and coverage of hydrologic and socioeconomic data for the Brantas basin is, at first inspection, reasonably complete and extensive. However, there are indications that certain important variables, including reservoir inflows and channel discharges, are subject to bias due to changes in stage-storage relationships or channel cross-sectional profiles, both due to sedimentation and/or scour. Low-flow discharge measurements are, in many cases, known to be poor or nonexistent due to the location and elevation of stilling wells. Irrigation return flows are not measured, and must be reconstructed using water balance accounting.

Integrated Economic-Hydrologic Modeling and Policy Analysis

Overview of the Integrated Economic-Hydrologic Model

The integration of economics and hydrology within a common, holistic modeling framework is justified by several factors. First, multi-objective optimization modeling, often integrated with simulation modeling, is a tool of established value to both water engineers and agricultural economists, and the language of mathematics is common to both. Second, advances in computing power, along with the development of increasingly powerful and efficient optimization algorithms, permit the solution of increasingly complex models. Third, the river basin provides a natural framework for the analysis of both hydro-systems and water-based economies. Fourth, the two disciplines are extensively interpenetrated, as water enters as a factor of production in many economic processes, and economic factors are primary drivers of design and decision making in water resources engineering. Finally, the need to anticipate the impacts of new economic policies in the water sector requires integrated modeling, given that policy experiments, if actually implemented on a broad scale, would require years to yield meaningful interpretation, and might involve considerable political risk. A state-of-the-art review of integrated economic-hydrologic modeling at the basin scale is

provided by McKinney et al. (1999) and will not be duplicated here. Interested readers can find this document on-line at IWMI's website as SWIM Paper No. 6. An application of the integrated model to the Maipo basin in Chile is described in Rosegrant et al. 2000, which is also available on-line at IFPRI's website as EPTD Discussion Paper No. 63. An additional application of the modeling approach in the Aral Sea region is described in McKinney and Cai 1997.

The integrated economic-hydrologic-policy analysis model (henceforth called "integrated model") being developed for the Brantas basin is based on the Maipo model (Rosegrant et al. 2000), but it is anticipated to differ in many respects, reflecting differences in the respective hydrosystems and agricultural economies. The model structure outwardly resembles a conventional network flow optimization model, such as WRMM (Binnie and Partners 1999). Model nodes, which represent sources of inflow to the system (reservoirs, river reaches, etc.), points of water storage, control, diversion and abstraction (dams, reservoirs, barrages, weirs, etc.) and demand sites (irrigation, municipal, industrial, hydropower, etc.) are linked via spatially permissible flow paths, which can represent natural or artificial channel reaches. Inflows to the system, including effective precipitation, are model boundary conditions, and storage, channel and spillway capacities are model constraints.

The integrated model differs from a standard network flow model in many key respects, however. Demand for water by sector and by location is endogenous to the integrated model, and it represents the interaction of technical/economic water production or utility relationships in agriculture, industry and households with the costs of delivering water to each potential consumer under assumptions concerning the structure of water pricing, entitlements, public institutions, social custom and law. Thus, for example, decisions concerning the type and area of crops planted in an irrigation system during a particular season are decision variables within the integrated model, and not simply assigned *ex ante*. In addition, surface-water-groundwater interactions are made explicit, and aquifers are included as points of inflow, storage, recharge and abstraction. In the Maipo version of the integrated model (Rosegrant et al. 2000), water quality (specifically salinity) and its impact on agricultural productivity were also included, although the role of water-quality simulation in the Brantas basin model has yet to be determined. The integrated model is structured and intended to go well beyond the customary approach of optimization models, which tend to focus on traditional engineering ("hard") solutions such as the reoperation of reservoir facilities. It is designed to evaluate nonstructural-, noncontrol-based ("soft") approaches to the optimization of benefits as well, including the pricing of water, establishment of water use rights and related policy and institutional changes.

The objective function of the integrated model is the combined, net water-generated revenue function for the basin. This unified objective function takes the generic form:

$$Max\{Z\} = \sum_{irr} Z_{irr} + \sum_{ind} Z_{ind} + \sum_{mun} Z_{mun} + \sum_{hydro} Z_{hydro} + \sum_{fish} Z_{fish} \quad (1)$$

where, *irr*, *ind*, *mun*, *hydro*, and *fish* refer to net benefits (profits) over irrigated agricultural, industrial, municipal, hydroelectric, and aquacultural demand sites, respectively. The negative

impacts of degraded water quality are assumed to enter into the net benefits functions as costs of treatment and/or production losses. Alternatively, water-quality objectives or standards can be incorporated directly as model constraints.

Each term in the objective function takes the general form of a profit function (Chambers 1988), emphasizing the contribution of water as a priced input: net revenue (benefit) equals gross revenue less variable costs associated with water:

$$Z_i = (y_i \cdot P_{y_i} - w_i \cdot P_{w_i}) \quad (2)$$

where,

y	output y quantity
P_{y_i}	price of output(s) y
w	quantity of water consumed
P_{w_i}	unit price of water
i	index of demand site

In equation (2), y may be a vector of outputs, and is assumed to be a function of multiple inputs of which water is always represented explicitly. The preliminary functional forms of several of the respective benefit (profit) functions are discussed subsequently.

Table 4 provides a summary classification of the integrated model in standard terminology (Singh 1995). The model is coded in the high-level language GAMS (General Algebraic Modeling System), which is coupled with the large-scale nonlinear optimization solvers MINOS and CONOPT (Brooke et al. 1998.) Model development is expected to follow a recursive process in which specification, testing, application and subsequent refinement take place concurrently. The process is depicted in figure 2, adopted from McKinney et al. 1999. The first stage of model development consists of the specification of a relatively simple network flow optimization model, which is intended primarily to verify hydrologic water balance. Validation at this stage consists of comparing integrated model output with the output of the existing WRMM (Binnie and Partners 1999) and RBAM (Optimal Solutions Ltd. 2000) network flow models of the Brantas basin, which are currently maintained by the PJT staff; and with historically observed reservoir levels and discharges. Subsequent versions will incorporate endogenous production decisions, surface-water-groundwater interactions, important tributary systems and water quality.

In the following sections, specific components of the integrated model will be described in some detail. Particular emphasis is given to the irrigated agriculture sector, which is of central importance in the study. In the first section, we discuss the representation of the physical system. The physical system is understood to consist of physical entities with explicit locations, including dams, reservoirs, power plants and demand sites; and physical relationships such as water balance, hydropower and water-production functions. The second section describes the economic aspects of the model, which consist primarily of benefit (profit) functions and attending parameters and assumptions describing economic behavior. The third section contains a brief discussion of economic incentives and policy strategies, and the means by which they are implemented within the model.

Table 4. Important attributes of the Brantas basin integrated model.

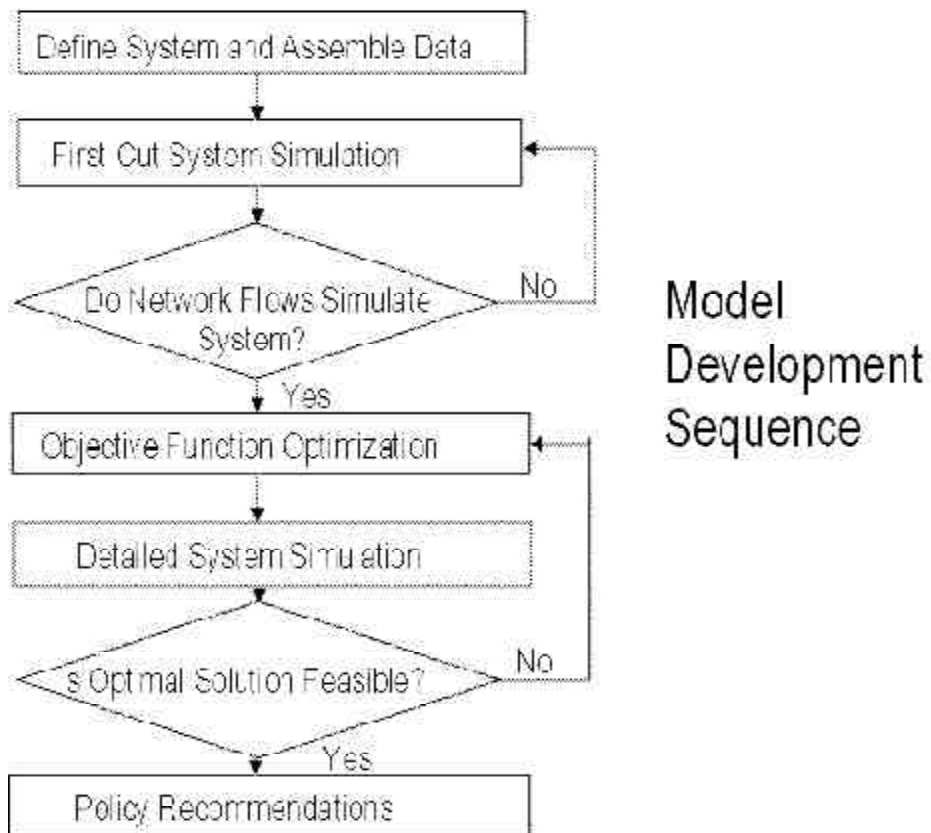
Model Attributes:	
Model type	Optimization + Simulation
Model structure	Modular, spatially distributed processes
Degree of integration	Holistic
Process description	Deterministic ^a
Spatial domain	Basin (12,000 km ²) + groundwater
Time domain	Multi-year planning horizon ^b
Time step	10-day
Governing equations	Algebraic
Objective function	Maximize net basin income derived from water ^c
Solution algorithm	Numerical, NLP
Language	GAMS/CONOPT/MINOS

^aPossible to structure as chance-constrained.

^bSingle-year operational version also under development.

^cAppropriate social and legal constraints apply.

Figure 2. Stages of integrated model development



Physical Components of the Model

The preliminary framework for the Brantas basin integrated model has been adapted from the existing WRMM and RBAM network flow models developed by Binnie and Partners as part of the SRPCAPS 1999 and by Optimal Solutions, Ltd. (2000). In this initial framework, only the Brantas main stem and the Ngrowo subbasin are included, surface- water-groundwater interactions are not included, water demand is exogenous, and economic relationships are not specified (the objective function is based on social priority weighting). Figure 3 depicts the schematic for this simplified model. The use of a simplified basin representation is predicated both on the need to establish a preliminary baseline calibration, and on the ready availability of hydrologic data consistent with the simplified system as assembled for the WRMM and RBAM projects. It must be emphasized that the final policy simulation model will be greatly expanded relative to the preliminary version.

Calculation of Natural Flows

The integrated modeling approach described here does not include an explicit rainfall-runoff component.⁵ Inflows entering the system at reservoirs, channel reaches or aquifers are, therefore, one set of boundary conditions for the model, reflecting historical patterns of precipitation and discharge.⁶ To provide these boundary conditions it is necessary to develop “natural” flows for each appropriate node or component comprising the model. Natural flows are those flows that would be observed in the absence of any artificial water regulation or manipulation, including storage, abstraction, discharge or redistribution outside of the natural flow network. Natural flows are required for several reasons, perhaps the most important of which is to ascertain the true incremental flow contribution from each increment of drainage area as defined by the location of model nodes. Three discrete sets of estimated natural flows were made for numerous locations within the Brantas basin by JICA (1998), SRPCAPS (1999) and Optimal Solutions, Ltd. (2000), and have been adapted selectively for the present study.

Natural flows evaluated at exterior nodes are simply measured discharges at these locations, since it is assumed that there is no significant regulation upstream of these points. For all interior nodes, natural flows must be reconstructed by water balance. For a generic node i (e.g., a weir location) connected upstream to a single node ($i-1$) the calculation for each time step takes the general form (time subscripts implicit):

$$Q^n_i = Q^n_{i-1} + \sum_{i-1}^i A - \sum_{i-1}^i R + \sum_{i-1}^i \frac{\Delta S}{\Delta t} + Q^{in}_i \quad (3)$$

⁵Rainfall-runoff modeling may eventually be required to augment existing inflow data, particularly for tributary subsystems.

⁶Alternative climatic regimes can be modeled as well.

Figure 3. Model schematic of the Brantas main stem.



where, Q_i^n	natural flows at node i	(m ³ /sec.)
A	abstractions between nodes (i-1) and i	(m ³ /sec.)
R	return flows between nodes (i-1) and i	(m ³ /sec.)
ΔS	changes in storage between nodes (i-1) and i	(m ³)
Δt	model time-step	(sec)
Q_i^{in}	inflow between nodes (i-1) and i, added to modeled flows at node I	

Natural flows are calculated recursively from upstream (exterior) nodes proceeding downstream. Where storage reservoirs are present, net evaporation must also be included in natural flow calculations.⁷ In addition, in 1999 SRPCAPS calculated the implicit fraction of precipitation constituting inflow (Q^{in}) for each sub-catchment. A certain degree of consistency across sites is anticipated, and deviations from this pattern (roughly 50% of precipitation enters the flow system, varying by altitude, soil type and ground cover) were used to identify and diagnose potential errors in the flow statistics.

Reservoirs

The Brantas basin contains eight reservoirs or barrages having significant storage capacity (table 5). Total current active storage is approximately 350 million m³, which is only around 3 percent of the total annual discharge of the Brantas, and 17–18 percent of dry-season flows. These are multipurpose facilities, providing flood control in the wet season, water supply and power generation. Operating rules differ by season and by forecast hydrologic regime (normal, low-, high-flow years) as determined by the Provincial Water Management Committee. Five of these reservoirs (Sengguruh, Sutami, Lahor, Wlingi and Lodoyo) are located in series on the Brantas Main Stem; Wonorejo is within the Ngrowo sub-catchment, Selorejo is in the Konto sub-catchment and Bening is within the Widas sub-catchment. The simplified model includes all reservoirs except Bening, so that less than 10 percent of the total basin storage is excluded from this first-cut model. In the context of the integrated model, reservoirs are described in terms of their respective water balances, stage-volume, and stage-area relationships, hydropower generating capacity and spillway constraints; and direct precipitation and evaporation are accounted for.

One hypothesis following from the relatively small volume of active storage in the basin relative to annual flows is that strategies to optimize the productivity of water will not depend to any great extent on reservoir reoperation, since the scope for reoperation is simply too limited. In the long run, effective storage within the basin will probably have to be increased, although very few suitable (low-cost) sites remain. JICA (1998) evaluated several proposed dam and reservoir construction projects, and concluded that three of these are financially justifiable given current and projected economic conditions. These projects (Beng, Genteng 1 and Kedungwarak dams), when completed, would add around 270 million m³ to available collective storage within the basin (JICA 1998). This is a significant increase over current storage but the resulting collective storage would still be less than 10 percent of annual flows.

⁷Brantas reservoir outflows are typically corrected for water surface evaporation already, so this step is redundant in the current model.

Table 5. Storage reservoirs in the Brantas basin in operation or under construction in 2000 (million m³).

Reservoir Name	Year Completed	Design	Design	Current	Current	Year of Survey
		Gross Storage	Effective Storage	Gross Storage	Effective Storage (SRPCA Estimate)	
Sengguruh	1988	21.50	2.50	3.37	1.17 (1.24)	1996
Sutami	1972	343.00	253.00	183.42	146.63 (153.1)	1997
Lahor	1977	36.10	29.40	32.88	26.54(26.85)	1995
Wlingi	1977	24.00	5.20	4.97	1.41(0.94)	1996
Lodoyo	1980	5.80	4.20	2.35	2.35(2.35)	1996
Selorejo	1970	62.30	50.10	48.76	44.51(44.5)	1993
Bening	1981	32.90	28.40	31.70	28.05(26.0)	1993
Wonorejo ^a	2001				106.00(83.0)	
Total ^b					356.66(337.98)	

^aEffective=Design storage for Wonorejo is variously given as 106 Mm³ and 89.4 Mm³ in JICA II. The reservoir is currently filling and is expected to contribute to dry-season flows commencing 2001.

^bTotal includes Wonorejo.

Hydropower generation

The Brantas basin presently contains nine hydropower facilities, eight of which are currently operating. The location and capacity of these facilities are summarized in figure 3 and table 6. They are categorized as reservoir facilities, for which effective head varies with the extent of reservoir storage, and run-of-river stations, for which head is essentially constant. Within the model, power generation is estimated using a standard approach based on effective hydraulic head, turbine discharge volume and efficiency. The general form of this equation is (Mays and Tung 1992):

$$P = C \cdot \gamma \cdot Q \cdot h \cdot \eta \quad (4)$$

where, P	power generated	(kWh)
C	numerical coefficient to conserve units	
γ	unit weight of fluid	(N/M ³)
Q	rate of discharge	(M ³ /sec.)
h	effective energy head	(M)
η	turbine efficiency	

Q is a decision variable, and h is a state variable functionally related to reservoir storage. In practice, the design maximum generator output and corresponding head and discharge are known for each hydropower facility, and power generation can be calculated using the ratios of actual head and discharge to design values.

Power generation is a nonconsumptive use of water, and does not degrade water quality, although the extent and timing of power demand can and does conflict with the demand for

water in various consumptive uses, at least during certain periods. Hydropower represents roughly 16 percent of the installed generation capacity in the Brantas basin (1993).

Table 6. Hydropower generation capacity and annual output, Brantas basin.

Hydropower Facility	Peak Generating Capacity (kW)	Annual Power Output (Million kWh)
Sutami ^a	70,000	213.2
Tulungagung	36,000	184.0
Wlingi	54,000	164.98
Sengguruh	29,000	98.56
Lahor ^b	35,000	75.8
Wonorejo	6,500	31.7
Lodoyo	4,500	31.7
Selorejo	4,500	20.0
Bening ^c	650	1.9
Total	240,150	821.84

Source: Annex 1 in JICA.

^aSutami contribution to combined Sutami-Lahor output.

^bLahor contribution to combined Sutami-Lahor output.

^cAnnual output for Bening based on assumption of 8 hours per day at maximum output. Members of the PJT staff report that Bening is not currently producing power.

Municipal demand sites

Municipal water demand included in the integrated model is associated with the regional water supply companies, or *Perusahaan Daerah Air Minum* (PDAM). There are 14 PDAMs in the Brantas basin, corresponding to districts (*kabupaten*) and municipalities (*kotamadya*). Some individual PDAMs such as Surabaya Kota operate multiple withdrawal and treatment plants. The majority of domestic water supply within the Brantas basin is obtained from sources other than PDAMs; however, only around 12 to 14 percent of the basin's residents are serviced directly by PDAMs (JICA 1998; SRPCAPS 1999). The rest of the residents obtain their domestic water supply from wells, irrigation canals and directly from the river.

Only PDAM abstractions will be included in the preliminary version of the model, however, and only those which are taken from the Brantas, as distinct from springs, wells and other sources not subject to administration by the river basin authority. The locations of these abstraction sites (Surabaya, Sidoarjo and Malang Kota) appear in figure 3.

Industrial demand sites

Approximately 215 million m³ of water are used in industrial production (1996) of which around 130 million m³ are abstracted directly from the Brantas, and the remainder obtained from groundwater, PDAMs and other sources. Around 95 industries abstract significant quantities of water, with sugar and paper industries using the largest quantities (58% and 22%, respectively) and degrading the quality of return flows. In the simplified specification of the

integrated model, these industrial users are grouped into four abstraction sites (figure 3), all in the lower portion of the basin.

Irrigation systems

Classification of irrigated area. Irrigated agriculture is the primary consumptive use of water in the Brantas, and the irrigation sector will be described in somewhat greater detail. Irrigated area in the basin can be characterized in two ways. The first distinction is made on the basis of extent of administrative control over water and the type and extent of physical infrastructure. The categories are a) *technical irrigation areas*, which have relatively well-developed physical infrastructure, and in which water distribution up to the tertiary canal head is controlled by the DPU Pengairan (Irrigation Department); b) *semi-technical areas*, which are also government-managed, but in which physical infrastructure is less well developed; and c) *simple*, village or nontechnical areas, including user-constructed schemes and systems transferred from the government to *HIPPAs* (Water Users Associations). Simple areas tend to have relatively less-developed physical infrastructure, and water may not be available in the dry season, depending on location. Cropping intensity is correspondingly highest (≥ 2.0) on technical areas, and lowest (≥ 1.0) on nontechnical areas. Table 7 summarizes the Brantas basin irrigated area by type according to administrative units (districts, municipalities.) The total net irrigated area in the Brantas basin was estimated at 309,000 hectares in 1996; of which 242,000 hectares are classified as technical, 32,000 hectares as semitechnical, and 35,000 hectares as nontechnical.

A second distinction can be made between areas irrigated directly from the Brantas via one of the 12 primary schemes, and all other irrigated areas. The distinction is significant from the perspective of model development, since only systems which are physically linked to modeled portions of the Brantas hydrosystem and over which administrative control can be exercised can justifiably be included. Net area on direct schemes of Brantas is around 83,200 hectares (1996), nearly all of which are technical. Annual cropping intensities on Brantas direct systems typically exceed 2.0. Direct systems of Brantas included in the integrated model are identified in table 8, along with the cropping pattern for 1995/96. Table 9 presents estimates of system-level efficiency. System or conveyance efficiency is defined as the ratio of the sum of measured flows at tertiary offtakes to the measured system intake volume. Losses in efficiency result from seepage in primary, secondary and tertiary canals, and illegal diversions.

Calculation of evapotranspiration. In the integrated model, water demand is endogenous, and variables describing the composition of cropping in each system (area by crop, planting dates, rotations, etc.) are correspondingly decision variables. Therefore, it is necessary to specify the model such that crop water requirements for an arbitrary cropping pattern in each system can be calculated internally, based on localized coefficient values. The approach used in the current version of the model is based on reference crop evapotranspiration estimates calculated using the FAO Penman-Monteith equation combined with crop and crop-stage coefficients. The method is described in detail in FAO Irrigation and Drainage Papers No. 33 (1986) and No. 56 (2000).

The minimum climatic data needed to calculate ET_0 using the FAO Penman-Monteith are a) daily maximum and minimum temperature ($^{\circ}C$), b) daily mean relative humidity (%)

Table 7. Irrigated area in the Brantas basin, 1996.

Branch Irrigation Service Office	Technical (ha)	Semitechnical (ha)	Nontechnical (ha)	Total (ha)
Malang	13,623	1,433	745	15,801
Kepanjen	16,493	5,420	5,303	27,216
Kediri	20,547	2,060	7,680	30,287
Tulungagung	15,585	6,072	1,747	23,404
Trenggalek I	6,257	2,395	3,721	12,373
Blitar	23,984	2,880	6,086	32,950
Jombang	22,785	0	810	23,595
Mojoagung	22,070	0	1,509	23,579
Pare	18,700	0	1,072	19,772
Nganjuk	33,725	2,864	2,079	38,668
Mojokerto	20,877	7,353	3,315	31,545
Sidoarjo	27,073	765	602	28,440
Wonokromo/ Surabaya	744	725	0	1,469
Total	242,463	31,967	34,669	309,099

Source: DPU Pengairan, in JICA II, table A4-1 p. A4-56, Volume III.

Table 8. Seasonal cropping patterns, direct systems of Brantas (mean 1994/95 and 1995/96).

Irrigation Scheme	Wet Season	Dry Season	Sugarcane (12 mo.)	Polowijo Wet	Polowijo Dry ^b	Other Crops ^c	Gross Irrigated Area
	Paddy (ha)	Paddy ^a (ha)		Season (ha)	Season (ha)		
Brantas Atas	223	248	0	570	1,190	421	2,652
Brantas Bawah	1,069	1,055	183	14	84	0	2,405
Molek	3,347	2,152	279	279	3,745	40	9,842
Lodo Agung	6,900	5,668	3,080	1,725	9,980	616	27,969
Mrican Kanan	12,414	8,494	4,247	1,797	9,310	0	36,262
Warujay-Kerto	10,307	8,170	2,263	377	11,690	0	32,807
Brantas Kediri	422	363	85	0	90	0	960
Jatimlerek ^d	1,456	820	574	21	821	349	4,041
Menturus	848	238	2,476	170	1,390	0	5,122
Jatikulon	563	564	31	0	111	0	1,269
Brantas delta	18,333	13,955	8,482	1,094	7,935	0	49,799
Surabaya	984	749	455	59	426	0	2,673
Total	56,866	42,476	22,155	6,106	46,772	1,426	175,801

Source: JICA table A4-2, p. A4-57 in Vol. III.

^aIncludes both "with permission" and "without permission."

^bIncludes first and second dry seasons.

^cIncludes cotton, tobacco, apples.

^dIncludes Bunder I and II.

Table 9. Estimated system efficiency of irrigation schemes in the Brantas basin.

Scheme	Net Area (ha)	Wet Crop Efficiency (%)	Dry Crop I Efficiency (%)	Dry Crop II Efficiency (%)	Cropping Intensity Gross/Net	Weighted Efficiency (%)
Brantas Atas	1,222	60	55	50	2.30	57
Brantas Bawah	1,901	70	70	50	1.94	70
Molek	3,984	63	62	62	2.07	62
Lodoyo-Tulungagung	12,232	58	54	54	2.34	56
Warujayeng						
Kertosono	12,546	75	69	69	2.06	72
Brantas						
Kiri-Nganjuk	534	65	60	55	1.84	63
Mrican Kanan	16,334	65	54	54	2.45	58
Bunder I & II	334	70	70	50	2.30	67
Jatimlerek	1,716	92	80	80	2.43	85
Menturus	3,392	65	78	78	1.44	69
Jatikulon	619	70	60	50	1.96	65
Brantas Delta	27,762	68	67	55	1.88	68
Surabaya	955	70	70	50	1.10	70
Total	83,531					64 ^a

Source: Based on Table 4.11, SRPCA Main Report, p. 4–44.

^aArea and season-weighted mean of schemes assuming that for a cropping intensity of, e.g., 2.30, weights were 1/(2.3) for each of wet crop and dry crop I, and 0.3 (2.3) for dry crop II.

or alternative measure of atmospheric moisture content, such as dewpoint, c) daily mean wind or sunshine hours, which are more easily measured. These data are routinely collected at ten climatic stations within the Brantas basin. Note that the Penman-Monteith itself need not be solved within the integrated model, once location and period-specific values of ET_0 have been calculated by Penman-Monteith, they are attached to the model as parameters.

Potential evaporation for specific crops (ET_c) differs from reference crop evapotranspiration (ET_0) since various crops differ in physiology, height, degree of development, degree of ground cover, and other factors. In the single-crop coefficient approach, reference crop evapotranspiration is multiplied by the appropriate crop and crop-stage-specific coefficients to obtain evapotranspiration demand by crop for each 10-day period.

Crop production functions. The calculation of crop-specific ET values is only a preliminary step towards the calculation of effective crop water demand, since it cannot be assumed that crop development will take place under conditions of full water supply. The critical trade-off between water delivery and irrigated agricultural output must be made explicit using water production functions, several of which are described in the literature. FAO methodology is based on the yield response coefficient (K_Y) method, described in FAO 33 (1986). The K_Y method describes the fractional reduction in yield relative to its potential (Y_p) resulting from a fractional reduction in actual evapotranspiration relative to reference crop evapotranspiration (ET_0):

$$\left(1 - \frac{Y_A}{Y_P}\right) = K_Y \cdot \left(1 - \frac{ET_A}{ET_0}\right) \quad (5)$$

where,	ET_A	actual evapotranspiration	(mm/day)
	ET_0	reference evapotranspiration	(mm/day)
	Y_A	actual yield	(kg/ha)
	Y_P	potential yield	(kg/ha)
	K_Y	crop yield coefficient	

Although the yield response coefficient method is widely used, the functional form may not be suitable for paddy, the most important irrigated crop in the Brantas basin. On the basis of a meta-analysis of over 30 studies of rice yields obtained under controlled conditions, Bouman and Tuong (2000) have proposed a paddy water production function of the following form:

$$Y_A = Y_P \cdot \left(1 - e^{-\beta \cdot (W - W_0)}\right) \quad (6)$$

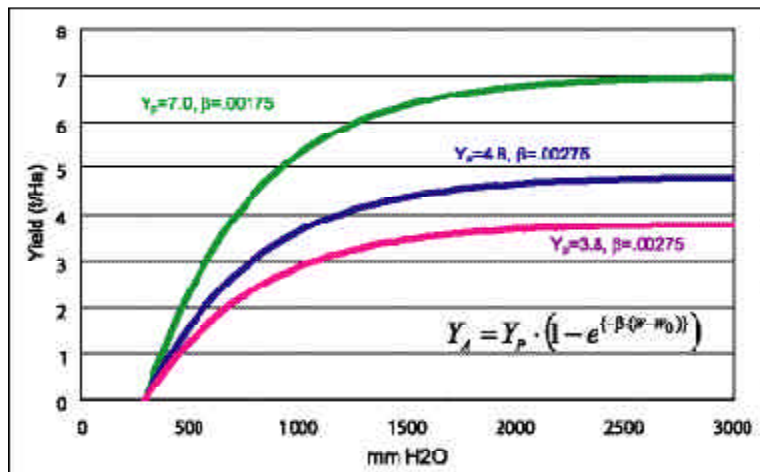
where,	Y_A	actual yield	(kg/ha)
	Y_P	potential or non-water limited yield	(kg/ha)
	β	initial water use efficiency	
	W	water application	(mm)
	W_0	no-yield water application threshold	(mm)

In plotting equation (6) it is observed (figure 4) that there is an extensive region over which significant changes in water application have relatively little effect on yield. This has obvious and important implications for the economic analysis of paddy cultivation when water is a priced input. It is important to note that the level of water demand associated with Y_P is not identical to ET_{paddy} , since optimal paddy production occurs under ponded conditions, which require additional water for land preparation, percolation losses, and maintenance of the water layer (Bouman and Tuong 2000). In equations (5) and (6), it is assumed that Y_P is itself a function of other factors, fixed and variable, which determine and constrain yield:

$$Y_P = Y_P(Cl, S, \dots | Cr, K, L, F, M, \dots) \quad (7)$$

where,	Cl	climatic factors	(units as appropriate)
	S	soil quality	
	Cr	crop variety	
	K	capital (technology)	
	L	labor	
	F	fertilizer	
	M	managerial expertise	

Figure 4. Bouman and Tuong water yield response curves.



Source: Bouman & Tuong 2000

The functional form of (7) is not known ex ante, and will be explored using data collected from the farm survey, described under “Economic Components of the Model, with Emphasis on Irrigated Agriculture,” and aggregate output and water delivery data.

An additional general form of the water production function is described by Dinar and Letey (1996), which is used in the Maipo study (Rosegrant et al. 2000.) The Dinar-Letey relationship is intended to represent the combined impacts of water delivery and salinity on crop yields. It takes the form:

$$(7) \quad Y_A = Y_P \left[a_0 + a_1 \left(\frac{w_i}{E_{\max}^i} \right) + a_2 \cdot \ln \left(\frac{w_i}{E_{\max}^i} \right) \right] \quad (8)$$

where, w_i infiltrated water
 E_{\max}^i maximum evapotranspiration
 a_0, a_1, a_2 estimated coefficients

In the Brantas basin, soil salinity is not believed to have a significant negative influence on crop productivity, and extensive analysis will be required to determine the functional form most appropriate for describing water-yield relationships in the Brantas.

A limitation in most water-production function approaches to estimation of yield is that the distribution of water deliveries in time is seldom explicit. Yet, seasonal yield may largely reflect the period of greatest water stress, as distinct from overall seasonal delivery. FAO 33 (1986) describes a penalty adjustment intended to capture this phenomenon, used in the Maipo study:

$$Y' = Y_A \cdot \sum_i (D_{MAX} - D_{AVG}) \quad (9)$$

where,	Y'	stress-reduced yield	(kg/ha)
	Y_A	Yield predicted by water-production function	(kg/ha)
	D_{MAX}	maximum deficit within the crop growth season	(ratio)
	D_{AVG}	mean deficit within the crop growth season	(ratio)

Equation (9) is assumed to be location- and crop-specific.

Deficits themselves are calculated as:

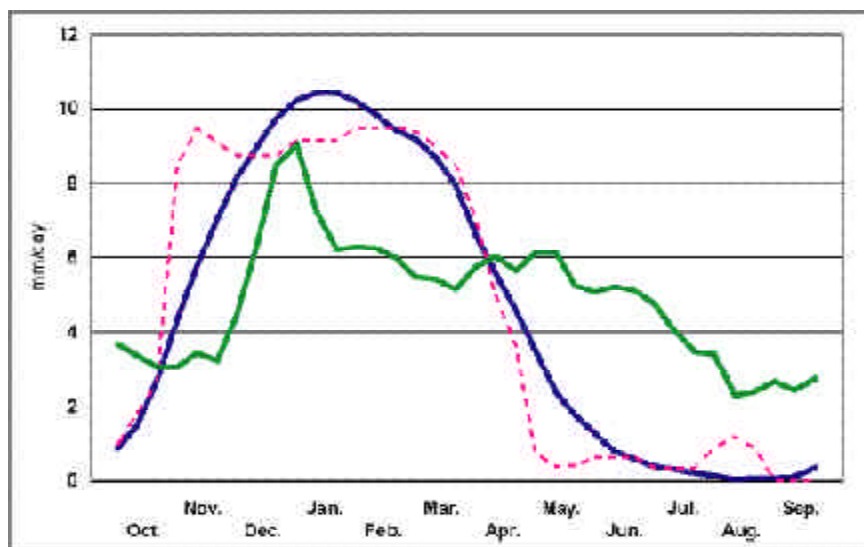
$$D = K_Y \cdot \left(1 - \frac{E_A}{E_{MAX}} \right) \quad (10)$$

where, K_Y is as above and E_A and E_{MAX} are actual and maximum rates of evaporation, respectively.

Cropping patterns and calendars. Given water production and other physical relationships, potential water savings in irrigated agriculture can, in principle, be realized via several mechanisms. These include improved system operation, repair and upgrading of physical infrastructure, more carefully calibrated cropping calendars, substitution of other inputs for water, alternative irrigation technologies, and a shift in cropping composition to less water-intensive crops. The substitution of imports for domestic production (“virtual water”) is also an option. The extent to which any of these can produce significant water savings in a given irrigation system will depend critically upon the current status of that system and, in many cases, the water savings obtainable in theory prove extremely difficult to realize in practice.

Figure 5 depicts the cropping pattern in Lodoyo-Tulungagung (LodoAgung,) a 12,300-hectare irrigation system in the upper Brantas basin, in 1995–96. The system is cropped intensively year-round, and a mix of short- and long-duration crops is present. It is observed that the paddy and polowijo cropping seasons are extremely attenuated, with certain operations, including nursery, land preparation, and transplanting, extended over 90 days. This attenuation of field operations is understood to reflect constraints posed by labor and water, and by economic factors discussed under “Economic Components of the Model, with Emphasis on Irrigated Agriculture.” Figure 6 depicts the corresponding distribution, in time, of system crop-water demand in LodoAgung, inclusive of paddy-land preparation and percolation requirements but excluding conveyance losses and nonutilized (return) flows, calculated using the methodology described above. Demand is compared with direct precipitation, both 50-percent probability values derived from 27 years of data, and data for 1995/96. It appears obvious that by compressing the paddy cultivation cycle, significant water savings will result. A cursory analysis comparing water demand net of precipitation between existing and compressed cropping calendars (maintaining cropping composition) indicates a reduction in ET + percolation demand of roughly 20 percent relative to the observed cropping calendar. However, the desirability of such a shift can be questioned on economic grounds,

Figure 6. Time variation in water demand and direct precipitation, Lodayo-Tulungagung.



since the income effects of such a shift depend critically upon the economics of both water and local commodity price response, as discussed subsequently.

Percolation rates and system efficiency. Strategies to improve agricultural water productivity often focus on irrigation system efficiency, typically defined as the ratio of quantity demanded to quantity supplied (e.g., Xie et al. 1993). To estimate the potential range of water savings obtainable from hypothetical improvements in efficiency, it is necessary to possess defensible estimates of system efficiencies under the *status quo*. Supply is measured, with the appearance of reasonable accuracy, at the tertiary block level for 10-day periods in many technical irrigation systems of Brantas, using calibrated flumes or similar structures.⁸ By contrast, crop-water demand, essentially beneficial ET and percolation (for paddy) less effective precipitation, must be estimated. The FAO Penman-Monteith equation used here has been found to provide the most accurate estimates of ET_0 from among all approaches evaluated by comparison with field measurement, providing estimates within 5 percent of “true” ET in both arid and humid climates (Smith et al. 1992).

Percolation rates are more problematic. References on rice cultivation often recommend the use of percolation rates in the range of 2 to 6 mm/day for puddled alluvial soils, depending on soil conditions (FAO CROPWAT, DeDatta 1981). However, as a component of this study, PJT engineers measured percolation from puddled, flooded paddies at eight locations within the Brantas basin in December 2000 (wet season) using a double-

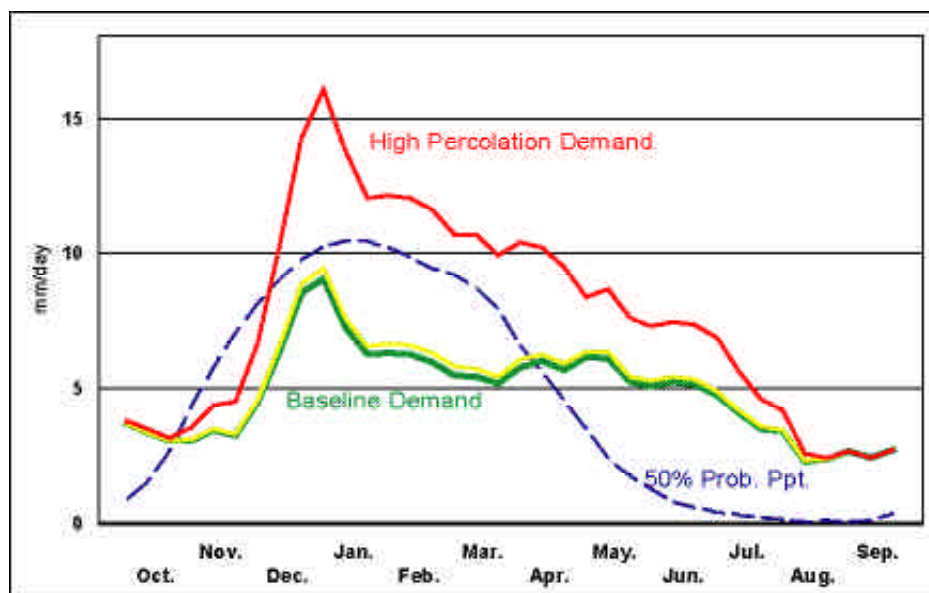
⁸Flumes and weirs were examined at several locations during the process of selecting farm survey samples. Most were well-maintained, although several others were damaged, or occasionally completely absent. All blocks included in the sample survey were required to have well-maintained gates.

ring infiltrometer over 24 hours (Suprpto and Hendradjaja 2000). Observed values ranged from 5 mm/day (2 sites in LodoAgung) to 210 mm/day (Mrican Kiri), with a mean value of 77 mm/day. These are consistent with Armitage (1999) who measured percolation rates of 26 mm/day (wet season) and 103 mm/day (dry season) in the Brantas delta using a single-ring infiltrometer. In similar vein, Bouman and Tuong (2000) report that although land preparation requirements for paddy cultivation are, in theory, around 150–200 mm, amounts as high as 650–900 mm are observed under field conditions, and seepage and percolation account for 50–80 percent of total water inputs to the field. Given that paddy cultivation is by far the most prevalent pattern of cultivation within the irrigation systems of the Brantas basin (table 8), the systematic underrepresentation of percolation rates will lead to nontrivial biases in estimates of crop-water demand and, hence, of current system efficiency and scope for its improvement. While system-wide percolation rates are judged unlikely to equal or exceed 77 mm/day, rates in the 2–5 mm/day range may also be unrealistically low. Figure 7 depicts the increase in crop-water demand for LodoAgung (1995/96) if dry- and wet-season rates are increased to 7.5 mm/day and 15 mm/day, respectively, from the recommended 2.6 mm/day and 4.4 mm/day used in the original calculations.

Interactions between groundwater and surface water

In the Maipo model, groundwater aquifers are fully defined by five coefficients: over-surface area (m²), bottom elevation (m), maximum elevation (m), saturated hydraulic conductivity (m/sec.) and effective yield (m/m). This describes an unconfined, homogenous and isotropic

Figure 7. Impact of differing percolation rates on water demand in Lodoyo-Tulungagung.



aquifer, characteristic of an extensive alluvial formation.⁹ Water balance is calculated in the same way as for a reservoir. For any time period, net change in storage equals the net flux across the aquifer boundary, implicitly vertically (only). Water can be abstracted via pump or recharged via percolation. The upper boundary is flexible, reflecting the extent of storage, and permits the modeling of groundwater overdraft scenarios when combined with information on well depth.

Groundwater data currently available for the Brantas basin include maps of geology and groundwater potential, and detailed data on public irrigation wells, including location, depth of penetration and pump capacities.

Issues and challenges in representing and modeling the physical system

The preceding discussion has identified several issues that represent challenges in the representation of the physical system and the utilization of the integrated model for policy analysis. Several of the most important are summarized below:

Limited reservoir storage. The combined effective reservoir storage in the Brantas is small, relative to both annual discharges and agricultural demand. In addition, most of the storage is in series (Sengguruh, Sutami/Lahor, Wlingi and Lodoyo reservoirs) on the Brantas main stem, thereby limiting the flexibility and independence of operating rules. Reservoir reoperation is, therefore, not likely to play a major role in strategies to increase water productivity at the basin scale, at least given the current infrastructure. This places a disproportionately heavy burden on the agriculture sector to accommodate increasing demand, presumably through increased efficiency and reallocation. The model may prove useful in establishing the economic viability of new storage, since new infrastructure is easily added to the model.

Appropriate level of detail in system representation. We are presently working with a relatively simple representation of the Brantas hydrosystem, which will be modified and expanded as we obtain additional data and experience. In determining what the final model looks like, we need to consider the appropriate balance between the accuracy (or the *appearance* of accuracy) that results from a detailed, highly disaggregated system representation, and the clarity of interpretation and computational efficiency associated with a simplified model. To illustrate, first consider the issue of irrigated area to be included in the Brantas model. The basin contains around 310,000 hectares of irrigated area of which 242,000 are technical. Yet, the 12 systems connected directly to the Brantas and subject to allocation decisions made by the basin authority constitute 83,000 hectares, or only 33 percent of the technical irrigated area within the basin. Can a basin model, particularly one in which the agriculture sector is of central importance, be considered adequately

⁹Definitions of terms relating to groundwater hydrology can be found in Smith and Wheatcraft 1993 and Heath 1991.

specified if two-thirds of the irrigated area subject to regulation is excluded?¹⁰ Or, consider connectivity: if reallocation of water within a tributary does not result in a net change in the discharge to the main stem, it may be more efficient to exclude that subsystem from the integrated model, and possibly to model it separately. The Widas tributary subbasin currently supplies no net inflow to the Brantas main stem during the dry season and, as a consequence, this subbasin has been excluded from PJT's WRMM and RBAM network flow models. It seems relevant to ask whether this would necessarily be the case under an alternative water allocation scenario.

Appropriate level of physical detail in irrigation system modules. An analogous question can be asked concerning the desirable level of physical realism in the simulation of relationships concerning system water supply and agricultural output. Extremely detailed hydrologic-biophysiological models of crop-soil-water relationships have been developed (e.g., Ali et al. 2000; Wopereis et al. 1996) but would the use of detailed physical process models improve the value or accuracy of policy analysis based on integrated model output at the basin scale? In practice, their use would present nearly insurmountable difficulties due to both data availability and computational demand. Moreover, basic principles of error propagation dictate that the highest-variance components of a complex model will dominate the variance of model output. As a result, any putative improvements in accuracy derived from increasingly rigorous specification of individual system components may have little or no real effect on overall model accuracy or the validity of results, unless all components could be upgraded to a comparable level of detail. The challenge here is to balance the level of detail across sectoral simulation modules so that no individual sector dominates the model error or monopolizes computational resources.

Appropriate values for percolation and related parameters. The potential consequences of parameterizing an agricultural water production model with improper percolation values, which can vary by orders of magnitude, are troubling. Field measurement is essential, at the very least for establishing the magnitude of uncertainty. We may choose to develop a stand-alone model at the irrigation system level, and use historical deliveries and sensitivity analyses to arrive at the most plausible range of values for each system.

Groundwater. The specification of groundwater in the integrated model is crude by hydrologic standards, but relative simplicity is required for computational reasons and by virtue of restricted data. Still, we must consider what might be gained by linking the integrated model to an established groundwater flow model (e.g., MODFLOW) to generate improved long-term policy scenarios.

¹⁰If the four major Brantas tributaries—Amprong, Ngrowo, Konto and Widas—are included in the model specification, the percentage of total technical irrigated area of the Brantas basin increases to 50 percent.

Economic Components of the Model, with Emphasis on Irrigated Agriculture

In certain respects, the specification of the economic components of the integrated model presents a greater challenge than the hydrologic specification. The primary reason is an absence of conservation laws analogous to those that govern the behavior of the physical system. Using continuity, we can anticipate how the hydrologic system will behave under a wide range of conditions, including conditions outside of historical observation. In anticipating the economic consequences of hypothetical modifications in policy, however, we must make use of economic models that have been calibrated using data observed under specific historical conditions, and it is never clear how robust the observed (calibrated) relationships are to modifications in policy.

In some sectors, such as power generation, the specification of the benefit (profit) function is straightforward, and rests entirely on published cost and price data. In others, such as the municipal and industrial sectors, further information is required in the form of the demand schedules for water, which may be difficult to derive from existing data, particularly if water has been sold at regulated or subsidized prices. The greatest challenge is faced in the irrigated agriculture sector. Since water has been heavily subsidized (if not free), an explicit water production function approach is used, and the sector is characterized by multiple-input, multiple-output production relationships. The following descriptions of the hydropower and M&I benefit functions are correspondingly brief, and the discussion of the agricultural economy more extensive.

Net benefit function for hydropower generation

Net benefit from the generation of hydroelectric power is simply the gross revenue less costs of production, aggregated over all hydropower plants:

$$Z_{hydro} = \sum_i P_i \cdot (PP_i - PC_i) \quad (11)$$

where, Z_{hydro}	net benefit from hydropower production	(Rp)
i	index of sites	
P_i	power produced at site i	(kWh)
PP_i	marketed price of power	(Rp/kWh)
PC	variable cost of power generation	(Rp/kWh)

The current selling price for hydropower in the Brantas is Rp 13.61 per kWh.

Net benefit function for municipal and industrial water consumption

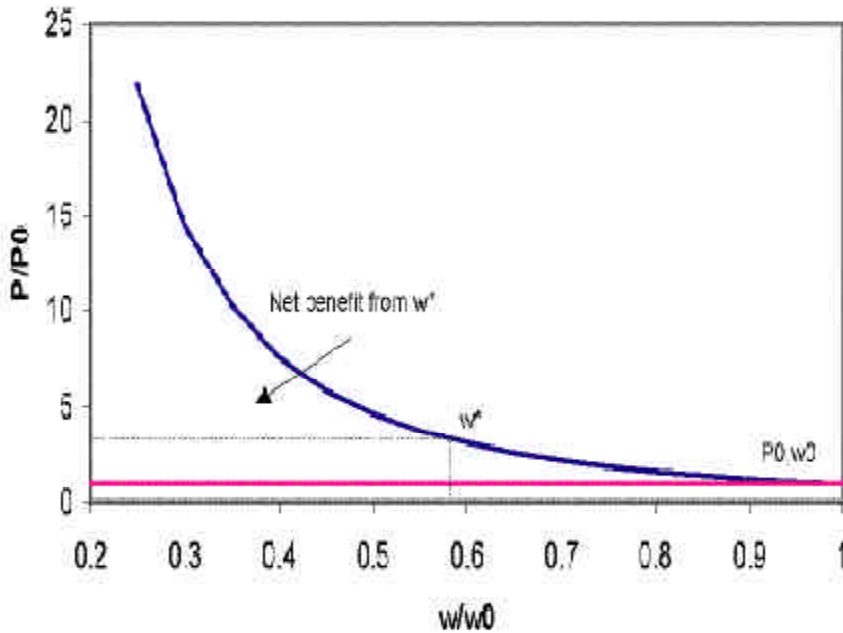
The net benefit function for municipal and industrial users is somewhat less straightforward, since it requires an estimate of the price elasticity of demand in each sector and at each location. The benefit function is an inverse demand function of the form:

$$Z_{mun,ind} = \sum_{m,i} \left[\frac{w_0 \cdot p_0}{(1+a)} \left\{ \left(\frac{w}{w_0} \right)^a + 2a + 1 \right\} - w \cdot wp \right] \quad (12)$$

where, Z_{mun} net benefits to municipal (industrial) consumers (Rp)
 m,i indices of municipal and industrial demand sites
 w_0 maximum withdrawal of water (m^3)
 wp price of water (Rp/ m^3)
 p_0 willingness to pay at full use (Rp/ m^3)
 a reciprocal of the elasticity of demand

The estimation of benefits is illustrated in figure 8.

Figure 8. Inverse demand curve for M&I demand sites.



Net benefit function for irrigated agriculture

Model calibration and constraint. In the agriculture sector module, choice of crop, area by crop, planting dates and level of input use are all potential decision (endogenous) variables at the irrigation system level, resulting in virtually unlimited degrees of freedom. This can pose an extraordinary challenge to optimization solvers, especially in a model containing multiple irrigation systems, and the established practice is to impose constraints, thereby greatly reducing the feasible solution set. Actual, physical constraints are already established by the availability of land and water and the suitability of land to specific crops, and implicit

constraints by labor, capital (e.g., hand tractors), and by the ability of farmers to purchase inputs. While the use of mathematical programming in the agriculture sector policy modeling has an extensive history, characteristic problems associated with calibration and constraint predictably arise:

Programming models should calibrate against a base year or an average over several years. Policy analysis based on normative models that show a wide divergence between base period model outcomes and actual production patterns is generally unacceptable. However, models that are tightly constrained can only produce that subset of normative results that the calibration constraints dictate. The policy conclusions are thus bounded by a set of constraints that are expedient for the base year, but often inappropriate under policy changes. This problem is exacerbated when the model is on a regional basis with very few empirical constraints, but with a wide variety of crop productions (Howitt 1995a).

In the Maipo study (Rosegrant et al. 2000), area by crop was constrained on the basis of historical cropping data. At least two other options are available, although the application of either within the integrated model framework appears at this point to be problematic. The first is to make output prices endogenous, so that any tendency towards overspecialization is countered by the resulting depression of output prices due to oversupply. Additional justification for making output prices endogenous is discussed below. The endogenous price approach has the appeal of theoretical rigor but, in practice, it makes heavy demands of the optimization solver. The second option is to explore the use of Positive Mathematical Programming (PMP). The PMP approach assumes that observed cropping patterns and input use are economically rational given prices, policies, and attitudes toward risk, and uses these observations to infer marginal cost conditions. The method is described by Howitt (1995a, b) and will not be discussed in detail here, beyond noting that certain restrictions are placed on the forms of the production and constraint functions. However, as PMP involves a three-stage estimation procedure,¹¹ it is not yet clear how the method would be integrated within the existing basin model framework.

All of these methods require historical data on cropping patterns, resource use and prices. Data on cropped area by season (by 10-day periods) is archived at the district-level offices of the DPU Pengairan (Irrigation Service) and data at the tertiary-block level are being assembled for several recent years (1995–2000) by PJT staff on the basis of these records. Additional data are required on input use at the farm level, including labor, fertilizer and water, and on input and output (sale) prices. These were collected in a farm-sample survey, described below.

Farm economy-sample survey. To properly specify the physical production and economic benefit functions at the irrigation system level, a farm sample survey was conducted by CASER in October and November 2000. The sample consisted of 160 farm households from each of four irrigation systems chosen to represent different agro-ecological settings within the basin: LodoAgung in the upper region, Mrican Kiri and Kanan in the middle and Porong canal in the Brantas delta. In each system, three tertiary blocks were chosen on the basis of

¹¹In addition, Howitt's most recent work involves the use of maximum entropy estimators.

water delivery infrastructure and composition of cropping, and 40 farm households were selected from within each tertiary block, stratified by location and size of holding, for a total sample size of 480. The tertiary block is the most disaggregated level at which water deliveries are physically measured in Brantas irrigation systems.¹² The sample was further stratified on the basis of the size of landholdings.

The scope of the data collected from sample farm households included a) household characteristics, b) landownership and holding, c) cropping pattern, d) input use, production, price of output, and inputs used, revenue (per crop, per season, per plot of land cultivated), e) irrigation technique and estimated water use, f) further uses of water resources, g) employment and income from other sources (farm income from parcels of land outside of sample blocks, off-farm activities, non-agriculture, others), and h) household expenditures, including food consumption. The data collected from this survey, currently being processed, should permit wide flexibility in the choice of economic models, from simple water production functions to agriculture-sector input-output models.

The survey was additionally structured to learn about the factors that farmers considered important in managing and allocating water. The individual (farm household) interviews were augmented by group interviews with Water User Organizations (WUOs or *HIPPA*) and Farmer's Groups, as well as with local officials from the Irrigation Service. These interviews have provided valuable insight into the formal and informal relationships between individual farmers and local institutions, and between local institutions and district- or basin-level institutions.

Choice of technology. The Maipo basin study (Rosegrant et al. 2000) examined, among other things, the interaction between choice of irrigation technology and price of water. Water application technologies included flood, furrow, sprinkler and drip irrigation, each characterized by the extent of uniformity in application, which is an important dimension of application efficiency. The net benefits component for this study was, therefore, specified as:

$$Z_{irr} = \sum_{cr} A_{cr} \cdot Y_{cr} \cdot PC_{cr} - \sum_{cr} A_{cr} (Cf_{cr} + Ct_{cr}) - \sum_t w_t \cdot PW_t \quad (13)$$

where,	irr	index of irrigation site (implicit on right-hand terms)	
	cr	crop type	
	A	area planted in each crop	(ha)
	Y^{cr}	crop yield	(Mt/ha)
	PC^{cr}	crop price	(Rp/Mt)
	Cf^{cr}	fixed costs	(Rp/ha)
	Ct	technology costs	(Rp/ha)
	w	quantity of water used in period t	(m ³)
	PW	unit price of water	(Rp/m ³)

¹²The quality of water delivery measurement is uneven, and depends on the condition of physical infrastructure. Sample blocks all possess relatively recent, properly functioning flumes or weirs, so that water use as reported by farmers can be compared to deliveries as recorded by the Irrigation Service gate tenders.

A distinct feature of this net benefits function is the inclusion of a technology cost associated with each method of irrigation. In general, the more uniform the water application, the higher the technology cost. In specifying the Brantas basin model, it is not yet clear whether such a range of technologies will be included. The cultivation of paddy, the dominant crop in the Brantas basin, requires ponded water for at least part of the growing season and water redistribution occurs field-to-field, largely driven by gravity, thus mooting the primary justification for high-efficiency application technologies. The choices of crop rotational sequence and planting dates, by contrast, emerge as significant management decisions in the Brantas.

Endogeneity of output prices. In a world of open borders and absence of distorting macroeconomic policies, producers everywhere should, in principle, face the same (world) market prices for generic commodities, adjusted for inland transport and associated marketing and related costs. In practice, there are nearly always distorting interventions, and always spatial and temporal variations in the farm-gate and wholesale prices of agricultural commodities, reflecting corresponding variations in supply. In Indonesia, the primary intervenor in the rice market is BULOG, which has operated a classic buffer stock scheme since the late 1960s, arguably successfully—it is one of several factors that led Indonesia to achieve self-sufficiency in rice in the 1980s—albeit at a high cost (Ismet et al. 1998).

Returning to the observed cropping pattern in LodoAgung for 1995/96 (figure 5), the attenuation of field operations (land preparation, transplanting) are understood to reflect the relative scarcity of labor and water (SRPCAPS 1999). In addition, however, the staggering of plantings appears to be a deliberate strategy to stabilize prices, ensuring that a given season's harvest does not all enter the market in a brief period.¹³ Thus, well-meaning attempts to compress cropping calendars as a water-saving strategy may actually work against price stability and farm income. Consequently, there are two arguments for structuring the integrated model to solve output prices endogenously: the desire to avoid artificial over-constraint of the sector model, and the desire to capture a potentially important component of the set of economic incentives faced by farmers.

Output prices can be treated endogenously by evaluating an additional inverse- demand function appropriate to each site and each commodity, of the general form:

$$\ln(Py) = a + b \cdot \left(\frac{1}{z} \right) \cdot \ln(Y) \quad (14)$$

where,	P_y	output price	(Rp/kg)
	Y	output quantity	(kg)
	β	market share of crop Y	(fraction)
	ζ	price elasticity of demand	(ratio)
	α	estimated coefficient	

¹³Personal conversations with CASER staff. Ismet et al. (1998) note that “In the absence of intervention, prices drop steeply during the main harvests, level off during the second season harvest and rise during the lean season.” (p. 284).

The primary disadvantage of endogenous output pricing is, once again, the demand placed on computing resources.

Issues and challenges in representing and modeling the economic system

The following appear as the major challenges facing us in specifying the economic components of the integrated model:

Availability of data on water demand. The calculation of elasticities requires at least some form of a demand schedule based on observed, historical behavior. While PJT has priced water delivered to municipal (PDAM) and industrial customers, water charges are not necessarily based on marginal productivity values, and it remains to be seen whether existing data are sufficient to estimate proper demand elasticities for these sectors. In the irrigated agriculture sector, it is clear that water has been a free, or at least a heavily subsidized, good. Much analysis will be required using our sample survey data, but it should be possible to construct the appropriate agricultural water demand curves, given what is known about physical water-production relationships.

Model calibration and constraint. Available aggregate data on area, output and prices appear sufficient to permit the calibration of an agriculture-sector model, applicable, at least, to the irrigation systems in the Brantas basin. Questions remain as to how we properly constrain the model. The unconstrained model possesses unacceptably large degrees of freedom, while over-constraint restricts the ability of the model to generate policy analysis. Howitt's PMP approach appears promising, and has been used in both agriculture- and water-sector models, but it will require further investigation and testing in the context of our integrated model.

Endogenous prices. The endogenous specification of agricultural output prices within the model has great theoretical and aesthetic appeal and, indeed, given what we know about the influence of commodity prices on cropping calendar decisions, it could be argued that they are required to generate a truly useful policy simulator. However, the endogenous specification introduces an additional, substantial degree of computational complexity, and only experience will tell us if it can be justified in the present study.

Economic Incentives and Policy Scenarios

A primary focus of the IFPRI study and accompanying modeling effort is the evaluation of various economic incentives and institutional reforms with regard to their impact on water use efficiency and allocation within the Brantas basin. Tiwari and Dinar (2000) define economic incentives as "signal mechanisms that affect the decision-making process and motivate water users to use water more efficiently." Economic incentives include prices, subsidies and taxes, and quotas combined with market allocation mechanisms. Institutional reform includes the creation, strengthening or redefining of property rights and entitlements, decentralization of authority, privatization and turnover of irrigation systems, and the strengthening of local institutions, among others. A substantial recent literature exists

concerning the use of economic incentives in the water sector, as summarized by Dinar and Subramanian (1997), Dinar (2000), Johansson (forthcoming), and Tiwari and Dinar (2000). No attempt will be made here to review this extensive literature or to cite individual case studies, only to summarize key attributes of several instruments and to describe how they can be implemented within the model framework.

Water pricing

Water pricing “denotes any charge or levy that farmers have to pay in order to obtain access to water in their fields, ... and is based on the users’ pay principle (UPP) that those who benefit from the use of scarce resources should pay.” (Tiwari and Dinar 2000:3) The treatment of water as a priced commodity can, in principle, accomplish several distinct purposes: It can directly generate revenues for water management authorities, which are available for reinvestment in the water sector as new capital expenditure and O&M, thereby reducing water sector dependence on general revenues. It can assist in the prioritization of water allocation. It can provide an objective means of resolving conflicts, and it can make the value of environmental services and amenities explicit. Most significant in the context of this study, the pricing of water can regulate demand by providing strong incentives for the efficient use of water. Note that the level of prices, along with the price elasticity of demand, will determine the extent to which these purposes are accomplished. It is possible, for example, to price water at a level that is successful in generating revenue but is ineffective in modifying demand.

Water pricing can take many forms, each of which can be represented explicitly in the integrated model framework. The most straightforward is volumetric pricing, which can be structured to reflect spatial and temporal variation in the scarcity of water, or to discriminate between sources of supply (groundwater, canals and natural channels) if desired. While volumetric pricing, in principle, provides the clearest incentive for efficient water use, in practice, it requires metering, which is difficult and expensive if not entirely impractical at the farm level.¹⁴ It also creates an incentive for the illegal diversion of water.

Alternative, nonvolumetric water charge mechanisms include output-based fees, area-based fees and levies based on both area and crop. Water charges based on output are easier to assess (no metering is required) and, in principle, reflect not only quantity but also quality of water delivery. The strength of the incentive is not as great as that of volumetric pricing, however, and output-based fees may simply penalize efficient farmers. Area-based fees are easy to implement, as neither metering nor assessment of output is required. However, if the same fee is assessed irrespective of quality of delivery (e.g., to both head enders and tail enders) and/or cropping pattern, the efficiency incentive can be undermined, and the equity of the pricing system called into question. An improvement is to base the fee on area and crop.¹⁵

¹⁴Water measurement can and does occur at the tertiary block level in many Brantas irrigation schemes, although the accuracy of such measurements depends both on the condition of the physical infrastructure and on the skill and commitment of the gate tender.

¹⁵H. Lofgren of IFPRI concludes that charges based on crop and area are largely equivalent to volumetric charges in terms of incentive value, subject to assumptions concerning reliability and timing of deliveries. Personal conversation with Ruth Meinzen-Dick, December 2000.

The water charge mechanism in any of its manifestations is represented in the model directly within the net benefit function (equation 2). The appropriate level of prices is determined by repeated simulation over a range of hypothetical water charges, observing the resulting impact on cropping pattern, farm sector income and welfare, and overall water use.

Subsidies and taxes

Subsidy-based policies can provide incentives by both removal and creation. Water delivered to consumers in any sector at below-the-cost-of-supply (with or without capital cost recovery) is subsidized, and a baseline scenario involves the removal of this incentive by the use of O&M-based charges as the basis for water pricing policy. In the Brantas basin, these prices, inclusive of capital cost recovery, are currently estimated at around Rp 25/m³ for irrigation, Rp 10/m³ for municipal supply and Rp 30/m³ for industrial supply given investment through 1997 (JICA 1998; current 1997 prices). A broader objective of this study is to determine how the removal of current subsidies and other distorting factors, if implemented, would affect farm incomes and the welfare of the rural sector.

Subsidy as proactive policy can also be used to promote water-efficient technologies in a variety of ways. Farmer or WUO investment in water-saving technologies, including system repairs and upgrading (e.g., lining of tertiary canals) can be directly subsidized via cost-sharing incentives, subsidized via concessionary credit, or indirectly via knowledge transfer, including training and extension. It can also take the form of institutional strengthening, or via the writing down of outstanding capital costs when state assets, such as irrigation infrastructure, are transferred to WUOs.

Other forms of subsidy to promote water savings can be envisioned, based on the use of targeted price supports to encourage the use of less water-consumptive crops (the inverse strategy involves taxing highly water-consumptive crops). The cost of such programs is minimized if the extent of such support is fixed, and farmers (or WUOs) submit bids to participate.¹⁵ A variation is cross-compliance: if farmers agree to use less water, they become eligible for participation in other subsidy or price-support programs.

Corresponding tax policies can be direct or indirect as well. Direct taxation policies include abstraction taxes, which like water charges can be targeted by type of abstraction (groundwater v surface water) or by season and location. Abstraction taxes, unlike water delivery charges, can be applied to resources, such as groundwater, that are developed by the farmer rather than provided by the government. Direct taxes can also take the form of levies on excess consumption, i.e., withdrawals in excess of the quantity deemed sufficient for the successful cultivation of a particular crop. Indirect taxes can be levied on inputs, such as energy or fertilizer that enter the production process and co-vary with water use.

The implementation of taxes and subsidies within the integrated model is only slightly more complicated than direct water charges, and involves modifying the functional forms of profit functions. In general, for the purposes of policy simulation, taxation and subsidy are less advantageous than direct water charge mechanisms, since the economic incentive effect is often less direct and, hence, more difficult to characterize.

Quotas and rights

Quotas are simply allocation rules or entitlements, enforceable by legal or administrative authority and like water charges they can be made subject to variation in time, space, source and type of use. Quotas can be constructed to ensure that total abstraction within a region (e.g., basin or tributary) or within economic sector remains within limits determined to be environmentally sound or consistent with conservation or other objectives.

It is generally agreed that quotas function as effective tools for demand management when associated rights are established and when all or parts of these quotas (and possibly associated rights) are transferable via market mechanisms. Under these conditions, allocative efficiency can be achieved at a relatively low cost to water-management authorities, and possibly at lower political risk as well. Markets for water and water rights are also subject to a range of economic and physical failures including monopoly power, imprecise information (high transaction costs) and physical losses due to transmission; and water markets must typically be regulated to prevent abuse.

To simulate water trading, based on quotas within the model, the marginal value-water withdrawal relationship is determined for each demand site (aggregated over all crops) over a range of water withdrawal levels. The result is a fitted demand curve for that site, which can be used to evaluate system-wide gains/losses from water trading (Rosegrant et al. 2000). The quotas in the context of the model take the general form of constraints and can be assigned on the basis of landownership or historical levels of withdrawal with transactions costs included. Revenues and costs associated with the sale or purchase of water enter the net benefit function.

Policy simulation v policy advocacy

In Indonesia, as in most regions, there is a history of politically sanctioned subsidy in the irrigation sector, and cheap water has naturally come to be viewed as an entitlement. The discussion of alternative policies, particularly those based explicitly on economic incentives, invariably generates controversy, among those who (correctly or otherwise) perceive themselves as beneficiaries under a “cheap water” policy and those concerned more broadly with distributional justice and the welfare of low-income farmers.

The objective of policy simulation is *not* to advocate for a given set of policy strategies but rather to provide a positive analysis of the likely, relative impacts of proposed policy regimes on total benefits, benefits by sector and location and, ideally, on the distribution of benefits by economic class. A concern for the welfare of the irrigated agriculture sector, currently under stress, is one of the primary motivations for the ADB/IFPRI study, and the analysis of net subsidy/taxation described under “Introduction: Motivation for the Modeling Study” is designed in part to address concerns of distributional equity. We believe that decisions concerning the sustainable, efficient, and just distribution of water resources should be derived on the basis of informed discourse in the social, political and legal arenas, and that the quality of this debate can only be improved by a careful, objective analysis of the likely economic consequences of proposed policies.

Summary of Key Points and Concluding Observations

This paper describes the Brantas basin in East Java, Indonesia. It is a region of major geographic, demographic and economic significance, and one which is subject to the mismatch of water supply with demand, both spatially and temporally, which is a defining characteristic of many river basins in Asia. Specific features of the Brantas, which have significant implications for water management within the basin and policy design include the following:

- Rapid growth in population, economic activity and corresponding water demand
- Strongly seasonal distribution of precipitation and resulting discharge
- Limited surface water storage, ongoing threats to this storage and limited potential for the development of new surface storage
- High cropping intensities, particularly in irrigated areas
- Dominance of paddy cultivation, a highly water-consumptive crop for economic, historical, social and ecological reasons
- History of heavily subsidized water in the agriculture sector
- History of centralized water administration at the river-basin level

Given the current status of hydraulic infrastructure within the basin, it appears evident to the authors of this study that only limited gains in efficiency can be achieved through the reoperation of existing facilities, although significant improvements in system efficiency may be possible to realize through upgrading, repair and maintenance of existing irrigation infrastructure. Barring, or even allowing for expansion of hydraulic infrastructure, it is equally evident that significant changes in practice within the irrigated agriculture sector will be required to meet the challenges of escalating demand for water within the basin. Potential nonstructural strategies include improved system operation, more carefully calibrated cropping calendars, substitution of other inputs for water, a shift in cropping composition to less water-intensive crops, and the substitution of imports for domestic production.

Three related, but distinct, challenges to the irrigated agriculture sector can be identified (Bouman and Tuong 2000): a) to save water, b) to increase water productivity, and c) to produce more output with less water. The first challenge is easily met, for example, by reducing the cropped area, growing less rice, and importing more foodgrain, but we find this approach unacceptable. If many nations in the region followed a similar strategy, the production base would erode and the putative cost savings from imports would be eventually neutralized. It is also possible to meet the second challenge, for example, by the redesign of cropping calendars, as illustrated in this paper. However, it is only by producing more food with less water that food security, economic growth, inter-sectoral equity and the economic health of the agriculture sector can be promoted in the long run.

In the long run, hard or structural solutions will be required as well. Although present and foreseeable storage, within the basin, in the soil, in reservoirs, and groundwater, is limited

relative to current and projected demand, the careful, joint management of this storage can increase the quantity of water available to meet new demand (Keller et al. 2000).

This paper has also described the development of an integrated economic-hydrologic-policy simulation model, which is intended to serve as a tool to investigate means by which the water resources within the Brantas basin can be managed more productively, equitably and sustainably, given the defining basin characteristics noted above. The use of such integrated models represents a relatively recent approach to water policy evaluation, and the present application to the Brantas basin is, in many ways, an experiment.

However, the results of previous applications of the integrated modeling approach (McKinney and Cai 1997; Rosegrant et al. 2000) are promising. The use of an integrated modeling approach permits the exploration of both “hard” and “soft” solutions to the problem of growing water scarcity, and their interaction, within a single framework.

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CHAPTER 10

Water Allocation and Use in the Dong Nai River Basin in the Context of Water Institution Strengthening

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Introduction

Freshwater is becoming an increasingly scarce and vulnerable resource in Vietnam as population and economic growth are demanding a growing share of the country's water supplies. This development is particularly evident in the Dong Nai river basin. The highly productive basin economy depends on water supply for a variety of uses, including drinking water, water for industrial processes, for hydropower production, for irrigation and for combating intrusion of salinity in the dry season. It houses Vietnam's largest population center of Ho Chi Minh City as well as the largest concentration of industrial output. At the same time, the Dong Nai basin continues to diversify its agriculture sector with products ranging from basic staples like rice and maize to raw materials for the local industry, including cotton, rubber and sugarcane to high-valued crops, such as coffee, fruit, grapes, pepper, tea and vegetables.

This development calls for a structured and integrated approach to the management of the basin water resources based on efficient, equitable and environmentally sustainable water allocation mechanisms that support the socioeconomic development in the region. The Government of Vietnam has recognized these challenges and provided a framework of legislation that—if implemented appropriately—will be conducive to the sustainable development of the country's water resources. However, the detailed regulations, water allocation mechanisms and organizational structures have yet to be developed.

The following section introduces the legal and administrative framework underlying the water sector in Vietnam as well as recent reforms in the country's water policy. The third section focuses on the hydrologic and economic characteristics of the Dong Nai river basin while the fourth section suggests an integrated economic-hydrologic modeling framework that accounts for the economic and hydrologic basin characteristics, the temporal and spatial variations in water supply and demand and the economic value of water across its various uses. This framework could assist decision makers at the national and basin levels in developing water-allocation mechanisms and strategies conducive to efficient management

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of water resources in the basin, and would thus facilitate the implementation of the recent water legislation in the country.

Institutional Framework of the Water Sector in Vietnam—Water Legislation

In the time frame of only one year, Vietnam initiated a series of major reforms in the country's water sector—including the Vietnamese framework Law on Water Resources (hereafter called Water Law) of 1999, and the Decision on the Establishment of the National Water Resources Council in June of 2000. The Water Law promotes the establishment of river basin committees and organizations. As a first step, river basin committees for the three largest river basins, the Red river basin, the Mekong delta and the Dong Nai river basin, will be established. As a result of these recent developments, the country is currently in a transition process from a water sector with highly fragmented water authorities with sometimes overlapping responsibilities and little coordination to a more holistic, decentralized and integrated management of the country's water resources at the river basin level.

The Water Law was adopted on May 20, 1998, and went into force on January 1, 1999. According to the law, water resources belong to the people under the management of the state, and organizations and individuals have a right to exploit and use the resources. Water allocation is carried out from a river-basin perspective adhering to the principles of fairness and reasonability. Priority in use is accorded to drinking water in both quality and quantity (Art. 20).

According to the Water Law, MARD is in charge of overall management of the country's water resources, but the government can delegate authority for specific water uses to other ministries. Water management is to be carried out based on river- basin plans that follow the hydrologic catchment (and not administrative) boundaries. MARD, together with provincial governments, is in charge of establishing both flood and drought plans for the country's river basins. Moreover, both water uses and wastewater discharge will be licensed by the provincial government authorities (People's Committees) under the guidance of MARD (Official Gazette 1998). Decree 179/1999/ND-CP of December 30, 1999 assigns specific duties for MARD, other ministries, and provincial people's committees related to water resources management. Additional regulations are currently being drafted to implement the framework Water Law. In addition to the Water Law, several other laws and regulations are important for water resources management in Vietnam. They include the Environmental Protection Law (27 Dec. 1993) and the Ministerial Instruction for Guiding Environmental Impact Assessment for Operating Units by MOSTE (Ministry of Science, Technology, and Environment) (Instruction No. 1420/QD-MTg).

In June 2000, an umbrella organization for the water sector at the national level, called the National Water Resource Council (NWRC), was established, based on Article 63 of the Water Law (Government Decision No. 67/2000/QD-TTg 2000). The NWRC has an office at MARD and a number of permanent members who represent the range of ministries and organizations that are involved in water resources management in the country. The Council is chaired by a Vice Prime Minister, and includes the Minister of MARD, as well as Deputy Ministers from MARD, MOSTE, the Ministry of Fisheries, the Ministry of Planning and

Investment, the Ministry of Finance, the Ministry of National Defense, the Ministry of Construction, the Ministry of Transportation and Communication, the Ministry of Industry and the Ministry of Public Health, and the General Department of Meteo-Hydrology.

Administration of Water Resources

MARD, established in 1995 out of the three former ministries of water resources, agriculture and food industry and forestry (Decree 73/CP of November 1, 1995), is the state agency in charge of water resources management and directly reports to the government. The 1999 Water Law reaffirmed this role, although other ministries are involved in the water sector as delegated by the government. Currently, the water sector in Vietnam is in a transition period and water resources are still largely administrated on a sectoral basis. Different ministries are responsible for the planning and administration of the various water uses. Thus, for example, the Ministry of Industry is responsible for the National Hydropower Plan; the Ministry of Construction is responsible for urban water supply planning; MARD is largely focusing on irrigation-sector development and flood control; and MOSTE is responsible for water quality. Table 1 presents the major ministries involved in water resources planning and management as well as their corresponding organizations.

Irrigation. At the central government level, the Department of Water Resources and Hydraulic Works Management of MARD is responsible for the overall policy framework for the planning and prioritization of new development and for the allocation of inter-provincial water resources. Funding of large capital projects, including investment for main canals of large irrigation and flood control projects is largely provided by the central government. Secondary works and local projects are designed and funded by the provincial government with assistance from the central government.

Irrigation systems are typically managed at the provincial level.² The provincial People's Committee provides policy advice, funds and oversees the work of the Provincial Agriculture and Rural Development Service (PARDS), decides on subsidies for water resources projects, and carries out investments in local infrastructure. The PARDS is responsible for the operation and maintenance (O&M) (through its companies) of public irrigation and flood-control systems and for the design and construction of new works.

In 1984, Irrigation Management Enterprises (IME) at the district or sub-province level were established to operate and maintain the irrigation systems. They are responsible for managing both the irrigation headwork and the main and secondary canals. Typically, they contract with the commune-based agricultural cooperatives and, in some cases, with Village Administrative Boards to provide irrigation water to the tertiary canals via the Water User Groups/Organizations at the village level. The substation has the task to collect information on the following year's cropping plan (established by the cooperatives with the assistance

²The head-works of two large irrigation systems are directly managed by MARD as they cover more than once province. These are Dau Tieng in the Dong Nai river basin and Bac-Hung-Hai in northern Vietnam.

Table 1. Water management administration in Vietnam.

National Water Resources Council	Advice to Government
<i>Ministry of Agriculture and Rural Development</i>	Surface water, groundwater protection
<ul style="list-style-type: none"> • Department of Water Resources and Hydraulic Works Management 	Legislation, licensing and policies for water resources management, hydraulic modeling, infrastructure management
<ul style="list-style-type: none"> • Department of Flood Control and Dike Management 	Flood control, dike management
<ul style="list-style-type: none"> • Vietnam National Mekong Committee 	Coordination, Mekong river basin
<ul style="list-style-type: none"> • Institute for Water Resources Planning 	Water resources planning for basins
<ul style="list-style-type: none"> • Institute for Water Resources Research 	
<ul style="list-style-type: none"> • Hydraulic Survey & Design Company 	
<ul style="list-style-type: none"> • Central Rural Water Supply Project Office 	
<i>Ministry of Science, Technology and Environment</i>	Environmental conservation and environmental quality standards
<i>Ministry of Industry</i>	Groundwater
<ul style="list-style-type: none"> • Vietnam Power Corporation (VPC) 	Energy/hydropower supply
<i>Ministry of Construction</i>	Urban water supply and sanitation
<ul style="list-style-type: none"> • Design Company for Water Supply and Sewerage 	
<ul style="list-style-type: none"> • Water Supply Construction Companies 	
<i>Ministry of Fisheries</i>	Fish production
<i>Ministry of Public Health</i>	Drinking water quality and hygiene
<i>Other Organizations</i>	
General Department of Geology	Groundwater
<ul style="list-style-type: none"> • General Department of Meteorology and Hydrology 	
Provincial Government and Local Organizations	Irrigation water supply, industrial water supply, fisheries, infrastructure O&M, urban and rural water supply and drainage

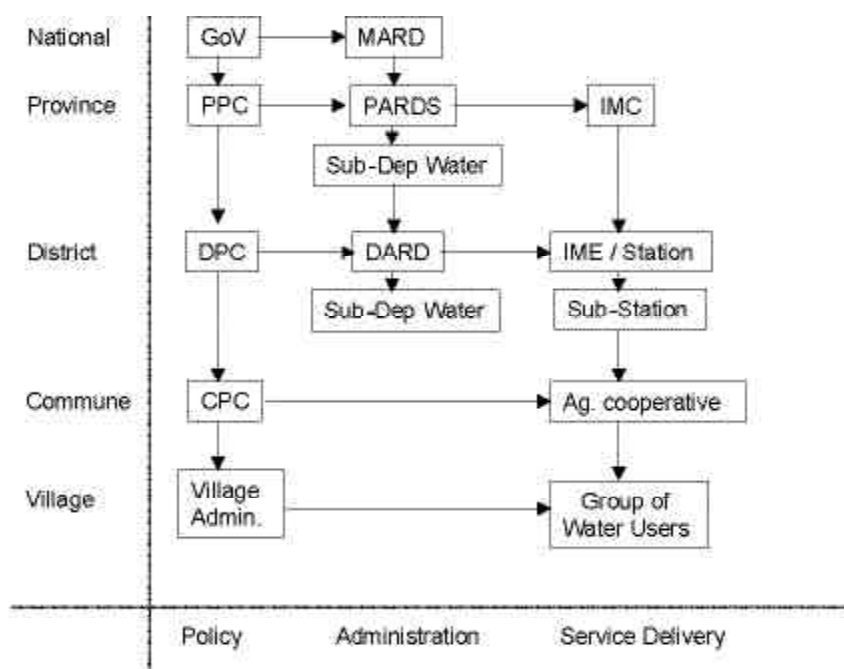
of agricultural extension workers), as required by the (district) station to draw up the water-delivery contracts (Small 1996; ADB/MARD n.d.).

The IME have been supplemented, beginning in 1991, with state-owned Irrigation Management Companies (IMC), which operate at the provincial level and oversees the IME. IME are now effectively subunits of the provincial IMCs. The general functions of IMC are a) provision of water, b) collection of irrigation service fees (ISF), and c) maintenance of irrigation facilities. IMCs are supposed to be run as autonomous, self-financing enterprises.

However, in practice, only part of their income is derived from the collection of water fees while the remainder is allocated from state subsidies. Moreover, the power to set the ISF resides with the provincial People's Committee, based on the recommendation of the IMEs and the Provincial Irrigation Departments, and in line with the broad guidelines issued by MARD. Figure 1 provides a schematic overview of the administration of irrigation systems.

The ISF is area-based and is typically differentiated by crop and by season. It is set in terms of kilograms of paddy to maintain its real value in the face of inflation and can vary substantially by province.³ Costs and equity factors as well as province-specific policies are taken into account in considering the fee schedule. Compared to other (southeast) Asian countries, the water fees in Vietnam are quite high (Small 1996). Water fees average US\$30 per hectare and year but vary substantially across province and season. The total annual fee

Figure 1. Administration of irrigation systems at different levels.



CPC: Commune People's Committee

DPC: District People's Committee

IMC: Irrigation Management Company

MARD: Ministry of Agriculture and Rural Development

PPC: Provincial People's Committee

DARD: District Unit of Agriculture and Rural Development

GoV: Government of Vietnam

IME: Irrigation Management Enterprises

PARDS: Provincial Agricultural and Rural Development Service

Note: A large share of agricultural cooperatives has been abolished since responsibility for agricultural production was turned over to the responsibility of individual households. Some have been replaced by other organizations that also provide some irrigation services, including agriculture service cooperatives, water user cooperatives, inter-commune water user cooperatives (Tiep and Chinh 1999).

³See also table 3.

collection is estimated at 50 percent of the actual water fees assessed or VND 500–600 billion (US\$36–43 million; US\$1=VND 14,000). Thus, water fees only cover about half of the total annual O&M costs, estimated at VND 1,200–1,500 billion (US\$86–107 million) for approximately 3 million hectares of irrigated area (MARD 1998).

Urban water supply. Whereas MARD has the overall responsibility for water resources supply, the Ministry of Construction (MoC) is directly responsible for the planning, design and construction of urban water supply. Planning and design of water supply projects are managed by ministerial companies, for example, the Design Company for Water Supply and Sanitation Works (DCWSS), as are the actual construction of water supply projects, for example, through the Water Supply and Sewerage Company Nos. 1 and 2 (WASECO 1 and 2). Water supply projects are implemented at the district and provincial levels. Following construction, management is transferred to the public water company.

In addition to the MoC, the Ministry of Public Health is involved in the monitoring of drinking water quality. MARD is in charge of water resources licensing for both surface water and groundwater. The Ministry of Industry carries out activities related to groundwater surveys and exploitation.

Rural water supply. Several organizations are involved in rural water supply. Whereas MARD is directly responsible for water supply to rural areas, the MoC is responsible for water supply to small towns (less than 15,000 persons), and the Ministry of Public Health is responsible for sanitation (Socialist Republic of Vietnam/DANIDA 1997).

At the national level, it is estimated that open dug wells serve about 40 percent of the rural population, 40 percent use unprotected water sources and 20 percent use rainwater and tube wells. Only half of all rural households have sanitation services. Household wells and piped schemes cost about US\$35/capita, and existing rural water tariffs are about US\$0.1/m³ (Socialist Republic of Vietnam/DANIDA 1997).

Hydropower. In Vietnam, electricity is under the Ministry of Industry, which is responsible for the planning of national hydropower development. However, sectoral plans for hydropower do not always take into account the needs of overall water resources as promoted in the Water Resources Law. The electric power supply regime is divided by region into a northern Power Company No. 1, a southern Power Company No. 2 and a central Power Company No. 3 (Nippon Koei 1996b, Vol. VI).

Fisheries. The Ministry of Fisheries is responsible for the management of fisheries resources. Water supply for on-farm fisheries, however, belongs to MARD and is supplied through IMCs and IME.

Environmental uses. Whereas MARD has the overall responsibility for water quality as laid down in the Water Law, MOSTE is the ministry directly responsible for issuing water quality standards. It also supplies water quality certificates and enforces water quality standards while cooperating with the Ministry of Public Health for the quality of urban and rural water supply. No agency is currently directly responsible for determining minimum flows in rivers to

maintain the natural habitat. Minimum in-stream flow levels are calculated on a case-by-case basis by infrastructural and design companies.

Ongoing Water Policy Reforms

Coordination of water resources management at the central level. The recently established National Water Resources Council (NWRC) has the objective of facilitating coordination among the various ministries and agencies involved in water resources management. Its role is to advise the government on important decisions related to water resources management, including a) strategies and policies on national water resources, b) major river-basin plans, c) plans for major interbasin diversions, d) projects for protection, exploitation and utilization of water resources and projects for flood control and water damage control, e) management, protection, exploitation and utilization of international water sources and dispute settlement, and f) conflict resolution between ministries and branches and between ministries, provinces and cities under central control.

Water resources management at the basin level. According to the 1999 Water Law, the water resources in Vietnam will be managed at the basin level. In June 2000, the Government of Vietnam wrote to the ADB (ADB) about its intention to establish River Basin Organizations (RBOs) for the Red river basin, Mekong delta, and Dong Nai river basin by June 2001.⁴ These are the pilot sites for implementing the basin concept stipulated in the Water Law. All three RBOs were approved by the Government of Vietnam in April 2001.

As the Water Law does not provide any specific guidance on the structure of the RBOs that are being set up in the country, the Dong Nai basin organization could either follow the model of the Red River Basin Organization (RRBO), which has been developed under an ADB-financed project, or refer to international experiences. In the following, some features of the RRBO are presented. The RRBO is being established as an advisory body to MARD and the government on water resources issues concerning the Red river basin. It has no executive powers but all plans and policies related to water resources planning and management within this basin should be submitted to the RRBO for consideration and comment prior to their approval by whichever agency has the power of approval. The RRBO consists of a Commission,⁵ which meets at least once a year, and a technical office, which will be located at the Institute for Water Resources Planning (IWRP). As the RRBO Commission includes not only representatives of the various ministries involved in water resources management at the director level but also representatives of all 25 provinces in the Red river basin, a Standing Committee has been proposed to be responsible for the major ongoing activities of the RRBO. The technical office at IWRP is expected to have the status of a separate division and a staff of about 20 people with expertise in all water-related sectors and functions

⁴Letter by Dr. Nguyen Dinh Thinh, Deputy Minister, MARD to the ADB on June 8, 2000.

⁵The Commission has no specific meaning in Vietnamese, whereas both the terms “Council” and “Committee” are related to very specific functions and levels of power. In Vietnam, the term “Council” is, therefore, usually used for a River Basin Commission.

of planning, operation and administration. As a first step, an integrated river basin plan will be developed for the Red river basin (WRCS 2000). In the Dong Nai basin, the technical RBO office is being established at the Sub-Institute for Water Resources Planning in Ho Chi Minh City (HCMC).

One of the major challenges of the RBOs will be their financing. The consultants for the RRBO proposed that external donors will finance the establishment costs, whereas the operational and implementation costs would need to be financed through a variety of means, including penalty fees for wrongful water uses; a portion of the license or permit fees paid for access to the resource; a royalty or resource tax on resources exploited for commercial sale (for example, hydropower, minerals, coal); government contributions; and international donor contributions (WRCS 2000).

According to WRCS (2000), the major concern related to the proposed structure of the RRBO is the potential bias towards MARD, as the level of membership of the Commission is highest for MARD at the Vice-Minister-level (compared to director level for other ministries), as the Chairperson of the Commission will be appointed by MARD, and as the technical body of the RBO will be located at IWRP, which falls under the responsibility of a Vice-Minister of MARD.

Participation of the private sector in water resources development. Altogether, three water supply BOT (Build-Operate-Transfer) projects have been licensed in Vietnam. The Binh An water supply scheme for HCMC was the first approved BOT project under the BOT law of 1993 (Decree No. 87-CP). The BOT company, the Binh An Water Corporation Limited (BAWC), a consortium of Malaysian companies, entered a 20-year contract with the People's Committee and the Water Supply Company of HCMC. The treated water will be sold to the city's Water Supply Company. The International Finance Corporation provided a loan of US\$25 million for this first private water-treatment facility in Vietnam. At 100,000 m³/day, the company is expected to contribute an estimated 11 percent of HCMC's water supply (IFC 1998). In the hydropower sector, the US\$86 million Can Don hydropower station in the Dong Nai river basin is the first privately held BOT power project in Vietnam. Here, the BOT company is the Song Da Hydropower General Company. Once completed, it will generate 300 million kWh per year and irrigate about 4,800 hectares. All in all, the BOT experience is very recent in Vietnam and few projects have been implemented successfully so far.

Participation of end users in irrigation management. In order to decrease the budgetary burden of irrigation systems, the Government of Vietnam has been supporting the transfer of small- and medium-scale irrigation systems to farmers at the commune or district level on a pilot basis. Tiep and Chinh (1999) report on the results of the establishment of water user cooperatives to manage the O&M of previously company-managed secondary or tertiary inter-commune canals. The joint management by the water users has led to more reliable water supply, a higher irrigation service fee collection rate, a quicker fee remittance, reduced cost and time spent on maintenance, a more equitable water distribution between upstream and downstream portions of the canals, expanded production areas (100% of designed area up from 60%–70%), higher yields at the tail end (by 8–20%), as well as inter-commune unity along the canals. Dinh (1999) reports on the results of the turnover of both the management and the collection and use of the irrigation service to cooperatives and communes in Tuyen

Quang province in northern Vietnam. After the turnover of a total of 13,000 hectares of largely small irrigation systems, water fee collection increased from 750 tons of paddy in 1996 to 2,740 tons in 1997, and 3,000 tons of paddy in 1998. As results have been largely positive, the participation of end users in irrigation management is being widened to include additional schemes and provinces.

On an even smaller scale, according to the Farm Enterprise Law passed in 2000, farm owners are encouraged to construct their own on-farm water infrastructure for irrigation and domestic uses. These uses are then exempted from irrigation and domestic service fees.

Basic Characteristics of the Dong Nai Basin

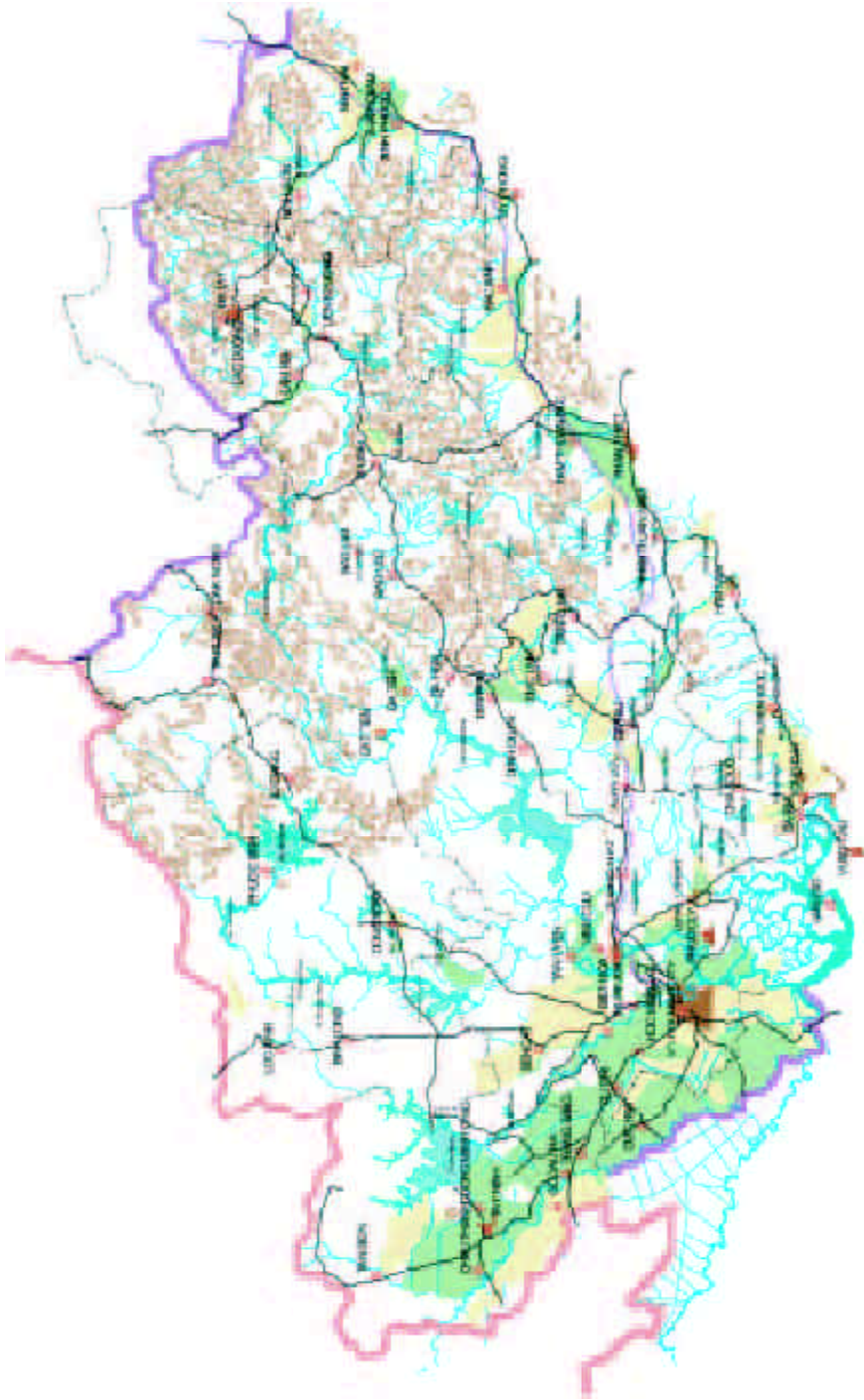
Hydrologic characteristics. The Dong Nai basin has a total catchment area of 40,683 km², 90 percent of which is located within Vietnam.⁶ For purposes of analysis, the Dong Nai basin is typically combined with several smaller basins on the coast, adding to a total surface area of 48,471 km² within Vietnam, or about 15 percent of Vietnam's land surface area (see also figure 2). The Dong Nai mainstream has a length of 628 kilometers. Important tributaries include the Be, the Sai Gon, the La Nga, and the East and West Vam Co. The total runoff amounts to 37.4 BCM (billion cubic meters), 14 percent of which is contributed from the coastal basins. The Dong Nai basin has several distinct hydro-geological regions, ranging from the lowland areas in the Vam Co Dong river system, that are inundated from the Mekong floods during the rainy season, to the Central Highland areas of up to 1,600 meters. The lower basin reaches are subject to tidal influences, particularly during the dry season, with substantial saltwater intrusion. Precipitation averages 2,000 millimeters, ranging from 1,200 millimeters in the lowlands to 2,800 millimeters in the highlands and 700–1,000 millimeters in the coastal area. The basin exhibits marked seasonal variations in flow with 87 percent of total precipitation concentrated during the rainy season from April/May to July/August. In addition, there are large temporal variations in flow with low inflows of 27 BCM in 1977 compared to very high inflows of 48 BCM in 1985.

Total reservoir storage capacity in the basin amounts to 5,068 MCM or 14 percent of total annual runoff. In 1999, total installed hydropower capacity was 710 MW and the annual energy output was estimated at 3,315 GWh.

Socioeconomic characteristics. The Dong Nai basin includes part or all of 11 provinces in southern Vietnam. About 13.6 million people—18 percent of the national total—live in the basin area. At the beginning of 1999, the population was split roughly equally between rural and urban areas, down from a 60 percent (rural) to 40 percent (urban) split in 1993. Whereas overall population growth in Vietnam has been projected at 1.3 percent/year during 1995–2020 (UN 1998), population growth in the Dong Nai basin has been estimated at 2.8%/year during 1989–93. The Dong Nai basin has received substantial—in part government-promoted—in-migration from northern regions, particularly to the central highlands, the Mekong river delta, and the south central coast (Nippon Koei 1996a, Vol. III). In addition, there is substantial illegal migration into the HCMC area fueled by the large urban-rural

⁶Part of the upstream area is located in Cambodia.

Figure 2. The Dong Nai river basin.



income gap. In 1989, 90 percent of the population in the study area belonged to the Kinh (Viet) group. The remainder was made up of a wide variety of ethnic minorities. The major share of minority population resides in the central highland provinces of Dac Lac (30%) and Lam Dong (24%) (Nippon Koei 1996a, Vol. III).

In 1998, the Dong Nai basin accounted for 15 percent of the national gross agricultural output and 51 percent of total industrial output, and contributed 39 percent to the country's service sector (GSO 2000). Economic growth is expected to continue at 7–10 percent per year. The industrial powerhouse is located chiefly in the HCMC-Bien Hoa-Ba Ria Vung Tau-Binh Duong economic zone. In 1993, GDP per capita in the Dong Nai basin reached VND 936,000 (about US\$88), almost twice the country average (WB 1995 cited in Nippon Koei 1996a, Vol. III). In 1999, per capita GDP in the richest province, HCMC, at US\$990 was almost 5 times the level of per capita income in the poorest region, the coastal province of Ninh Thuan (Statistical Office of HCMC 1999; Ninh Thuan Statistical Office 2000).

Water Allocation and Use in the Dong Nai River Basin

Similar to other basins all over the world, irrigated agriculture is still a major water user in the Dong Nai river basin. Irrigation water withdrawals are estimated at about 2.5 BCM, whereas urban water supply companies distribute about 0.5 BCM per year. Total domestic water withdrawals have been estimated at 1 BCM in the basin and total industrial withdrawals at 2.5 BCM. This makes the Dong Nai basin the largest urban-industrial water consumer in the country although the estimates for industrial withdrawals need to be treated with caution (Boggs 1996) citing values from the Ministry of Water Resources). In any case, the rapidly growing urban-industrial sector is increasingly channeling the basin natural resources, including water, into industrial and urban uses. How this transfer can be managed efficiently, equitably and in a sustainable fashion, is one of the major challenges in the Dong Nai river basin.

At present, water allocation in the Dong Nai basin is still largely managed following sectoral lines. Moreover, there is little coordination for inter-provincial water allocation. Coordination exists, however, during severe flooding events, when the southern Damage Management Board is called upon. This board includes the Vice Minister, the Director of SIWRP and other line agencies, as well as representatives of the southern provinces. The board can exert influence on the three boards overseeing the major reservoirs controlling the downstream flow to HCMC: Dau Tieng, Tri An, and Thac Mo reservoirs. The boards of the reservoirs are first and foremost concerned with flow releases for dam safety, but once dam safety is assured, they have to follow the calls from the southern Damage Management Board. In addition, each province has its own Damage Management Unit, mainly concerned with warning people close to reservoirs and evacuation procedures. So far, no protocols have been developed for drought events.

Irrigation

Gross agricultural area has increased from about 1.2 million hectares in the late 1980s to 1.6 million hectares during the late 1990s. In 1998, 43 percent of the area was planted to

rice, 39 percent to multiyear industrial crops, including coffee and rubber, 13 percent to annual industrial crops (including sugarcane, peanut, tobacco and soybean), and 5 percent to annual crops other than rice, chiefly maize and cassava (GSO 1996). Coffee and rubber have been expanding particularly rapidly in large areas of the basin, with growth in area averaging 17%/year and 3%/year, respectively, during 1985–99. In 1998, these two crops alone accounted for 25 percent of total gross agricultural area in the basin.

The low rainfall during the dry season (with as little as 10–50 mm) and the low water availability during dry spells in the rainy season make irrigation indispensable for the cultivation of many crops. In 2000, the designed net irrigated area was estimated at around 278,000 hectares, whereas the actual gross irrigated area reaches around 242,000 hectares, about 15 percent of the gross agricultural area (table 2). Currently, there are four irrigation projects with more than 10,000 hectares in the basin, and four additional schemes are planned. In addition to the areas managed by IMCs and Provincial Irrigation Departments, about 70 percent of the coffee area (or about 120,000 hectares in 1998) is irrigated from private wells. Pepper and fruit trees are also typically irrigated directly from wells and streams and thus do not figure in official irrigation system accounts.

Table 2. *Designed and actual irrigated areas by province and subbasin, 2000.*

Province	Subbasin	Designed Area	Actual Area		
			W/S	S/A	Wet S.
(in hectares)					
Lam Dong	Dong Nai	10,709	4,336		
Dac Lac	Be	120			
Ninh Thuan	Coast (Cai/Da)	21,442	10,189	4,125	11,729
Binh Thuan	Coast (various)	25,033	2,625	9,164	14,156
BaRia-VungTau	Coast (various)	8,080	2,764	290	82
Tay Ninh	Sai Gon/Vam Co	82,090	46,500	500	3,300
Binh Phuoc	Sai Gon/Be/others	3,550	1,475	1,600	1,812
Binh Duong	Dong Nai/Sai Gon	9,054	4,015	4,325	4,829
Dong Nai	Coast/Sai Gon/Dong Nai/La Nga	16,930	8,104	1,800	6,855
HCMC	Sai Gon/Vam Co/Dong Nai	41,635	16,360	18,000	8,500
Long An	East/West Vam Co	59,200	28,230	16,670	9,920
Total		277,843	124,598	56,474	61,183

Note: W/S = Winter-Spring season; S/A = Summer-Autumn season; An estimated 19% of Dac Lac Province, 51% of Long An Province, and 90% of Lam Dong Province are included in the Dong Nai basin. Irrigated areas at the province level refer to basin areas only. The irrigated areas in the table are those falling under provincial/government authority.

Source: Based on Nippon Koei 1996, updated by Dong Nai Division, SIWRP 2000.

The largest irrigation system in the Dong Nai basin is the Dau Tieng irrigation scheme on the Sai Gon river, completed in 1985 and financed by a World Bank loan. The Dau Tieng reservoir has an effective live storage of 1.1 BCM and a maximum surface area of 27,000 hectares. It supplies irrigation water to more than 60,000 hectares commanded by the East and West canals (including 15,000 hectares in the HCMC province) and to 40,000 hectares of downstream riparian abstractors in the Sai Gon and Vam Co Dong river basins, and for domestic water supply to the HCMC. A third canal, Tan Hung, commenced operation in 1998, largely to supply water to industries in the area and to irrigate up to 10,000 hectares. These areas fall short of the 172,000 net irrigated area envisioned in the original feasibility project of 1979, which can be traced in part to the inclusion of urban water supply into the functions of the Dau Tieng reservoir. Dau Tieng also regulates the position of the saline boundary between the seawater and freshwater in the lower-lying reaches of the Sai Gon and Vam Co Dong rivers. Moreover, due to the substantial percolation from the dam and canals, the groundwater table in the area rose from 10–12 m to only 4–5 m, facilitating the establishment of groundwater pumping in areas not serviced by irrigation canals. The planned urban water supply withdrawal capacity on the Sai Gon river relies on the salinity control exerted by Dau Tieng. However, competition between water uses in the Sai Gon river is set to increase due to planned additional upstream irrigation pumping schemes and industrial projects that will help develop the full potential of the Dau Tieng reservoir.

There are various reasons for the relatively small share of irrigated agricultural area in the basin. First, the irrigation-system costs on a per hectare basis are substantially higher than in the Mekong or the Red river deltas, as irrigation in the Dong Nai basin has to rely, to a large extent, on reservoir infrastructure. Whereas irrigation infrastructural costs (including capital costs) in the Mekong delta are typically about US\$1,800/ha they can be as high as US\$3,000–4,000/ha in the Dong Nai basin, with an average of US\$2,000–3,000/ha. In addition, highland irrigation of coffee or pepper typically requires pumping water out of irrigation canals or wells at a substantial cost. Second, crop water demand for dry-season rice is about 4,800–5,000 m³/ha in the Mekong delta while it is 7,800–8,000 m³/ha in the Dong Nai basin due to the much higher soil percolation rate in the latter basin.⁷ Third, a substantial share of the irrigable areas in the Dong Nai river basin has been planted with perennial rubber or cashew plantations. These crops constitute long-term investments that do not rely on irrigation water. Moreover, some crops typically irrigated in other areas of the world, like sugarcane, cotton and tea are not irrigated in the Dong Nai basin, as yields would only marginally increase following the irrigation investment. However, the risk of crop failure during the dry season could be reduced significantly with irrigation facilities.

There are various types of irrigation in the Dong Nai river basin. These include not only gravity/flood irrigation, largely for paddy, but also sugarcane and vegetables; pump irrigation from canals for cereals other than paddy and industrial crops; individual pump irrigation from rivers and streams, particularly for fruit trees; individual groundwater pumping, particularly for coffee; individual, controlled irrigation with buckets and hoses, particularly for vegetable and fruit trees; and tidal irrigation (water is delivered to the field whenever the

⁷Personal communication, Dr. Hoang Quoc Tuan, Head, Planning Division, Sub-Institute for Agricultural Planning and Projection, November 2000.

tide increases the water levels in canals and streams), largely for paddy. Most of the gravity irrigation and some of the pump irrigation from canals comes under the Provincial Irrigation Departments or IMCs and farmers in these systems need to pay an ISF. Fees vary substantially across provinces, depending on the availability of water in a particular area and season, the importance of agriculture in the region, and the specific policies of the provincial government. Table 3 provides the ISF for selected provinces in the Dong Nai river basin.

Table 3. ISF, selected provinces in the Dong Nai river basin.

Province	Fee Structure			
	For rice:	Winter-Spring	Summer-Autumn	Wet season
Lam Dong Province	Irrigation by gravity			
	Irrigation by pumping or or gravity with drainage	200 kg	120 kg	105 kg
	(includes all pump costs)	420 kg	280 kg	240 kg
	For industrial crops (coffee, tea, flowers, etc.) the price is double that of rice.			
	For vegetables, the price is half as they are promoted.			
Ho Chi Minh City	300 kg paddy per year, irrespective of crop.			
Ba Ria-Vung Tau	200,000 VND for rice, only dry (winter-spring) season			
	230,000 VND for coffee per year			
	All other crops are free.			

Note: The price of rice in 2000 is approximately 1,000-1,400 VND/kg; US\$1.00=14,000 VND.

Source: Data collected by SIWRP and Sub-NIAPP from provincial authorities.

Urban-Industrial Uses

The current urban-industrial water supply capacity in the Dong Nai Basin is estimated at 1.5 million m³/day, which would translate into 61 liters per capita per day if the total basin population would be served (table 4). Eighty-one percent of the urban-industrial capacity is provided by surface water. Moreover, almost all of the additional future urban-industrial water supply capacity (97%) is expected to be met from surface sources. This requires sufficient water available at suitable water quality levels during the dry season, including low saltwater concentration.

HCMC is by far the largest urban-industrial water consumer with an existing supply capacity of 945,505 m³/day or 188 liters per capita per day. However, in 1995 only about 66 percent of the people living in HCMC had access to public water supply, 52 percent through own connections with water meters, and 14 percent through public standpipes. Other important industrial centers, including Ba Ria Vung Tau and Dong Nai provinces also have high per capita urban-industrial water supply levels.

HCMC manages its domestic and industrial water supply on its own from planning to operation, albeit in close coordination with the Ministry of Construction (MoC). Urban-industrial water fees in HCMC, which are set by the People's Committee, have been raised

several times over the last few years. The latest increase, which came into force in March of 2000, raised the domestic water price by between 24–69 percent. The recently refined block tariff structure is shown in table 5. The recent price increase will help finance the Binh An BOT water plant, which started operations in August 1999. Before this, the city's Water Supply Company (WSC) had to buy 80,000 m³ of water daily from Binh An plant at 2,800 VND/m³ and then sell it to users at 1,300 VND/m³ because of the government policy to subsidize water supply to residents. In addition, the new fees will help to pay back the loans incurred for the upgrading of HCMC's water supply system (Tradeport 2000). Unaccounted-for-water rates in HCMC have been around 32–37 percent over the past few years.

Table 4. Municipal and industrial water use in the Dong Nai basin, current status and future plans.

Province	Population	Surface	Existing Ground (m ³ /day)	Total	Planned		Total	Existing	Planned
					Surface	Ground			
HCMC	5,037,200	750,000	195,505	945,505	1,800,000	54,140	2,799,645	188	556
Dong Nai	1,989,500	167,000	11,905	178,905	549,000	9,400	737,305	90	371
Long An	830,049	0	4,140	4,140	0	4,000	8,140	5	10
Tay Ninh	965,200	136,600	5,090	141,690	5,000	9,010	155,700	147	161
Binh Duong	716,400	14,000	16,632	30,632	340,720	0	371,352	43	518
Binh Phuoc	653,600	6,400	276	6,676	10,000	0	16,676	10	26
Dak Lak	344,600	700	0	700	0	1,000	1,700	2	5
Lam Dong	996,200	35,000	10,440	45,440	43,000	9,160	97,600	46	98
Ninh Thuan	505,200	12,800	4,200	17,000	12,000	0	29,000	34	57
Binh Thuan	1,047,000	29,300	1,970	31,270	7,700	0	38,970	30	37
Ba Ria VT	800,600	30,000	33,771	63,771	554,000	6,780	624,551	80	780
Total/Average	13,885,549	1,181,800	283,929	1,465,729	3,321,420	93,490	4,880,639	61	238

Note: Population data for 1999, for Long An from 1998 and for Dak Lak estimated (only basin areas included). Values for liters/capita/day are for total basin population, rather than population actually served by urban water supply companies.

Source: WASE 1999; Population Data: GSO 2000.

Table 5. Water tariff structure, HCMC, 1999 and 2000 (in VND/m³/month/person).

Year	Administration		Households			Production	Business/Services	
	0-1 m ³	>1 m ³	0-4 m ³	5-6 m ³	7-10 m ³	>10 m ³	No stand.	
1999	1,300	1,300	1,000	1,500	1,500	1,500	2,500	4,700
2000	2,200	3,000	1,700	2,500	3,200	4,000	4,000	6,500

Source: Data provided by Water Supply Company, and Tradeport 2000.

Hydropower

The Dong Nai river has the second highest rank in terms of hydropower potential in Vietnam after the Da river and planned hydropower projects are expected to meet one-third of the electricity demand of southern Vietnam by 2010 (EVN 2000). Information on planned and existing hydropower stations and irrigation reservoirs is provided in table 6. As can be seen, extensive additional capacity is currently planned or under construction. The focus of new hydropower projects in the Dong Nai is on multipurpose schemes, which include the functions of flood control, water supply and irrigation in addition to hydropower production. Furthermore, several projects include interbasin transfers. The maximum total planned (and existing) capacity adds up to 3,059 MW and active storage to 9,289 million m³ or 25 percent of total annual discharge. However, if environmental protection concerns are accounted for, in particular, Cat Tien National Park, the total potential is reduced to 2,830 MW. Although electricity demand in Vietnam has been growing at 15 percent per year during 1992–98, Dapice and Quinn (1999) voice concerns that excessive hydropower construction in Vietnam could cost the government as much as US\$2.7 billion or roughly 10 percent of the current GDP. Whereas the financial costs of total planned hydropower capacity are well known, the impacts of the existing and planned systems on the basin water economy have been studied to a lesser extent.

Environmental Uses

Intrusion of salinity is one of the major adverse factors concerning agricultural development and water supply in the areas lying in the downstream reaches of the Dong Nai, Saigon, and Vam Co rivers. The tidal effect reaches the confluence of the Be and Dong Nai rivers, as well as up to the downstream area of the Dau Tieng reservoir (Sai Gon river) and the lower part of the East and West Vam Co rivers. According to Nippon Koei (1996d, Vol. VIII), a maintenance flow of 100 m³/sec. at Hoa An in the Dong Nai river and of 25 m³/sec. at Thu Dau Mot (Phu Cuong) in the Sai Gon river are needed to keep the salinity level at 0.25 g/l or less to enable water supply abstractions for drinking water in HCMC. Several other studies have been carried out to estimate minimum flow requirement at different reaches in the Sai Gon river: according to the Black and Veatch Inception Report (BVI 1999a), a flow of 30 m³/sec. is required to control salinity at the planned water-supply facility at Ben Than; according to WRCS (1997), 40 m³/sec. are required at Ben Than; and according to a HEC-2 (1997) pre-feasibility study of Phuoc Hoa multipurpose project, 15 m³/sec. are required. at Ben Than.

Challenges for Dong Nai River Basin Management

The challenges facing water management in the basin include rapid industrial development and urban growth, which are placing growing pressure on urban-industrial water demands and hydropower production. At the same time, these uses are in direct competition with the agriculture sector. The problems are compounded by increasing industrial effluents and domestic wastewater that are discharged directly into the water bodies without prior treatment.

Table 6. Existing and planned reservoir projects in the Dong Nai basin.

Name	Catchment (km ²)	Year	Uses	Capacity (MW)	Annual Output (GWh)	Active Storage (Million m ³)	Net Head (m)
Dong Nai river							
Da Nhim ^a	775	1963	HP	160	1,025	156	800
Dai Ninh ^b	1,158		HP/IR/ WS	300	1,043	230	550
Dong Nai 1	2,804		HP	45	188	250	60
Dong Nai 2	3,141		HP	75	299	220	82
Dong Nai 3	3,612		HP	170	545	440	120
Dong Nai 4	3,782		HP	220	705	208	140
Dong Nai 5	54,62		HP	150	607	139	67
Dong Nai 6	6,272		HP	171	651	585	54
Dong Nai 8	9,050		HP	250	1,040	582	48
Tri An	14,800	1989	HP/FC	400	1,700	2,542	50
Be river							
Thac Mo	2,200	1995	HP	150	590	1,260	
Can Don (BOT)	3,440	Const.	HP	72	285	80	30
Fu Mieng ^d	4,110		HP	60	281	175	43
Phuoc Hoa ^e	5,420		HP/IR	10	75	32	
Smaller Dong Nai tributaries							
Da M'Brie ^f	234		HP	66	295	60	350
Dak R'Tih-Da Anh Kong	868		HP	210	773	244	370
Da Siat	115		HP	16	80	304	255
Song Luy	554		IR			132	
La Nga river							
Ham Thuan	1,280	Const.	HP	300	957	522.5	250
Da Mi	83	Const.	HP	172	595	17.3	142
La Nga 3 (Ta Pao)				IR	62		
Sai Gon river							
Dau Tieng		1985	IR/WS			1,110	
Total (pl+ex)				3,059	11,734	9,289	

^aDa Nhim transfers water to the Cai river in the coastal basin for irrigation and water supply. ^bThe Dai Ninh project will divert water from Dong Nai to the Luy river in the coastal zone for irrigation and domestic water supply. ^cIt is highly unlikely that Dong Nai 5 and 6 will be built due to large negative environmental impacts. ^dFu Mieng could divert water from the Be river to the Sai Gon river. However, a transfer from Phuoc Hoa to the Sai Gon river seems more likely. ^eThe hydropower component of Phuoc Hoa is unlikely to be realized. ^fOne version of Da M'Brie considers diverting water from the Da M'Brie river to the Da Te river through an approximately 6,600-m long water way to create an available static head of 460 m. ^gLa Nga 3 could be used to transfer water for irrigation development to Ham Tan-Song Ray. However, this would decrease the energy output at Tri An.

Despite several large investments in multipurpose reservoirs, the full irrigation potential of the command area has not been achieved because of the following reasons: lack of financial resources, increasing downstream demands, growing salinity problems, poor management of irrigation systems, lack of coordination among water resources projects in the region and other conditions unfavorable to irrigation development as described above.

There are several conflicts concerning water allocation in the Dong Nai river basin. On the one hand, salinity intrusion during the dry season is directly related to increased water abstractions upstream—for additional irrigation development and more and more to accommodate the increasingly urban and industrial development in the lower basin area. Water transfers out of the Dong Nai basin to increase irrigation and economic development in the dry coastal areas, as well as in the lowlands of the Vam Co Dong system might further aggravate the situation. However, the construction of several large-scale reservoirs has counterbalanced the increasing water shortages and has also helped improve flood control during the rainy season.

The lack of integrated water management in the Dong Nai river basin can be seen at various examples. During the large precipitation events in the Dong Nai river in October, 2000, all three large reservoirs needed to spill water at the flood peak, causing flooding in the downstream areas with a probability level of only 4 percent at a time when the reservoir inflows occurred at a probability level of 25 percent. Coordination between the reservoirs and a quicker change of operational rules from hydropower production to flood control could have prevented such a large downstream flooding event (Ngoc Anh 2000a). Second, the sum of all the individual, long-term plans for future withdrawal capacity from the Sai Gon river actually surpasses the water availability in the river, and these plans can only be implemented if interbasin transfers from the Be river materialize (BVI 1999b). The potential conflicts between irrigation, urban water supply, hydropower development, navigation and environmental uses are clear. Therefore, a more holistic approach will be necessary to develop the optimal water allocation strategy for the basin. Finally, both the ISF and the municipal and industrial water tariffs are subsidized at the provincial and national levels and the compensation for water transfers from irrigated agriculture to urban areas is inadequate. Again, a more integrated water management approach at the basin level could help devise adequate compensation measures by the various water users and for interbasin and inter-sectoral water transfers.

According to Ngoc Anh (2000b), deforestation is increasingly affecting the Dong Nai basin. Soil erosion is estimated to have increased from about 50 tons per kilometer per year (t/km/yr.) to 200 t/km/yr. over time, equivalent to an annual soil loss depth of 0.072 mm and a total sediment transport in basin rivers of 3.5 million tons, part of which is likely accumulating in reservoirs.

On the institutional side, linkages need to be created between the various provinces to tackle cross-provincial issues like upstream and downstream water usage. At the same time, the coordination between the various line agencies at the national and provincial level needs to be strengthened. In particular, the PARDS, which has so far been largely focused on irrigation and drainage management, will need to assume a broader role to achieve coordination among the various water uses in the basin to live up to the role of MARD in overall water management as envisioned in the 1999 Water Law.

To support coordination of management in the Dong Nai river basin, a better understanding of water supply, demand and its value in various uses is needed. Moreover, an understanding of the complex trade-offs involved in future growth and water development in the basin is necessary to allocate scarce resources across irrigation, hydropower development and demands of urban water supply. The development of appropriate policies for water allocation and management requires the modeling of inter-sectoral water allocation in the basin.

Modeling of Water Allocation and Use

The complexities involved in water allocation and use in the Dong Nai river basin—or any other river basin in the world—require a holistic approach to the planning and management of its water resources to achieve an optimal utilization that is, at the same time, sustainable, efficient and equitable. Modeling tools at the river basin level allow integrating the complexities involved in water resources management into a comprehensive framework of analysis that can provide objective and flexible decision support to decision makers in the water sector (McKinney et al. 1999; Rogers and Fiering 1986).

The two principal approaches to river basin modeling are simulation—to simulate water resources behavior based on a set of rules governing water allocation and infrastructural operation; and optimization—to optimize allocation based on an objective function and accompanying constraints. Although simulation and optimization models have differing objectives they are, in fact, complementary tools to address problems related to the competition over scarce water resources and the design and assessment of alternative systems of water allocation.

Inventory of Models Applied in the Dong Nai River Basin

Several river basin simulation models have been applied in the Dong Nai basin for specific projects. The MIT Basin Simulation Model, MITSIM, has been applied to the Dong Nai river basin to determine an optimal water use strategy for the lower basin and to analyze the joint effects of planned hydropower projects on irrigation, hydropower production and availability of water downstream. Resulting water-availability levels downstream were then included into VRSAP (see below) to calculate intrusion of saltwater. The simulation time step was 5 years. Based on the simulation results, a series of favorable hydropower projects were identified. This research has been carried out as a joint activity under the Ministry of Water Resources (now MARD) and MOSTE (SIWRP 1994, 1995).

The SSARR Streamflow Synthesis and Reservoir Regulation Model has also been adapted to the Dong Nai river basin. The model incorporates a rainfall-runoff component, a reservoir-regulation component and a river-system component. The objective of this model application was the determination of optimal reservoir releases of Dau Tieng (used for irrigation, administered by MARD), and Thac Mo and Tri An (used for hydropower production, administered by the Ministry of Industry) in order to minimize inundation and floods in the HCMC region during the flooding season. Dry-season flows and saltwater intrusion were not considered (SIWRP 2000).

Nien (1995, cited in Duc 2000b) developed the KOD-01 model to investigate and establish water release policies from the Dau Tieng reservoir in combination with Tri An, Thac Mo and the planned Phuoc Hoa reservoir. The objective of this study was to determine the effects of the release policies, if any, on the flow and salt intrusion in the Sai Gon-Dong Nai network. Nien (1996) analyzed the forecasting of saltwater intrusion based on the computation of hydrodynamic flow and salt transport in the lower Sai Gon and Dong Nai rivers to serve as the feasibility study of the Ben Than water treatment plant on the Sai Gon river. Alternative reservoir release policies were implemented to determine the resulting salt concentration at the Ben Than offtake point to be used for future water supply of HCMC.

The Vietnam River Systems And Plains (VRSAP) model has been applied in the Dong Nai river basin to account for the tidal effects and saltwater intrusion in the lower basin. The surrounding basins have not been included in VRSAP. In the Dong Nai basin, VRSAP includes a total of 451 nodes, 528 segments and 259 cells (Ngoc 2000).

Nippon Koei (1996e, Vol. X) used a mixed integer programming model to determine the optimal solution of the joint objectives of hydropower generation, irrigation development and water supply for specific development projects in the Dong Nai basin. Total costs included the construction costs for the proposed dams, irrigation development, diversion channels and water-supply facilities. The O&M costs were also included. The constraints on saltwater intrusion at the extraction points were considered using the minimum monthly discharges derived based on historical data.

Duc (2000a, b) developed the IMMCWRS or Integrated Management Modeling for a Complex Water Resources System for the Lower Dong Nai basin. The objective of the model is to optimize the operating policy of linked reservoirs, water treatment plants and irrigation systems to attain optimum benefits from joint utilization of these uses. IMMCWRS includes five models: an Artificial Neural Network Model (BPNN), a Hydrologic Model (HM), an Optimization Model (Extended Lingo System), a Hydrodynamic Flow and Transport Model (VRSAP) and a Compromising Model (CM). The Linked Extended-Lingo-Excel-HFTM software (referred to as LELEH) tool was used to overcome the nonlinearities involved in the salinity constraint and to improve the efficiency in the execution processing and graphical presentation of the results. An Analytical Hierarchy Process is used through the Expert Choice software for determining the best choice among various alternative solutions.

Most of the models applied in the Dong Nai river basin to date are concerned with hydrologic flow simulation to identify optimal reservoir release and investment strategies to avoid extreme flooding and drought events (here related to salinity intrusion). Models have been developed for the dry or the wet season and they focus on the lower Dong Nai basin, excluding both the upstream areas and the coastal region. With the exception of the identification of suitable hydropower projects based on MITSIM, no model developed and applied to date in the Dong Nai basin has been used for strategic decision making. With the exception of the model of Duc, previous models do not include economic optimization or cost-benefit analyses. No model is currently used in the Dong Nai basin for real-time water resources management and none is used to support strategic decision-making processes based on alternative policy scenarios. Currently, the Sub-Institute for Water Resources Planning in collaboration with IFPRI is developing an integrated economic-hydrologic river basin model as one component of the ADB-funded project "Irrigation Investment, Fiscal Policy, and Water Resource Allocation in Indonesia and Vietnam." The general objective of the project

is to assist the ADB, as well as national and regional policymakers and river-basin authorities, to make appropriate policy decisions for the development and allocation of water resources, and to establish priorities for reform of institutions and incentives that affect water-resource allocation, particularly in the irrigation sector.

The model to be developed under this project will cover the entire Dong Nai and surrounding basins, will take an entire year and will be geared towards the development of alternative water allocation strategies and policy analysis based on the economic value of water in alternative uses. In the following, the basic components of such an integrated economic-hydrologic modeling framework will be presented.

Modeling Framework

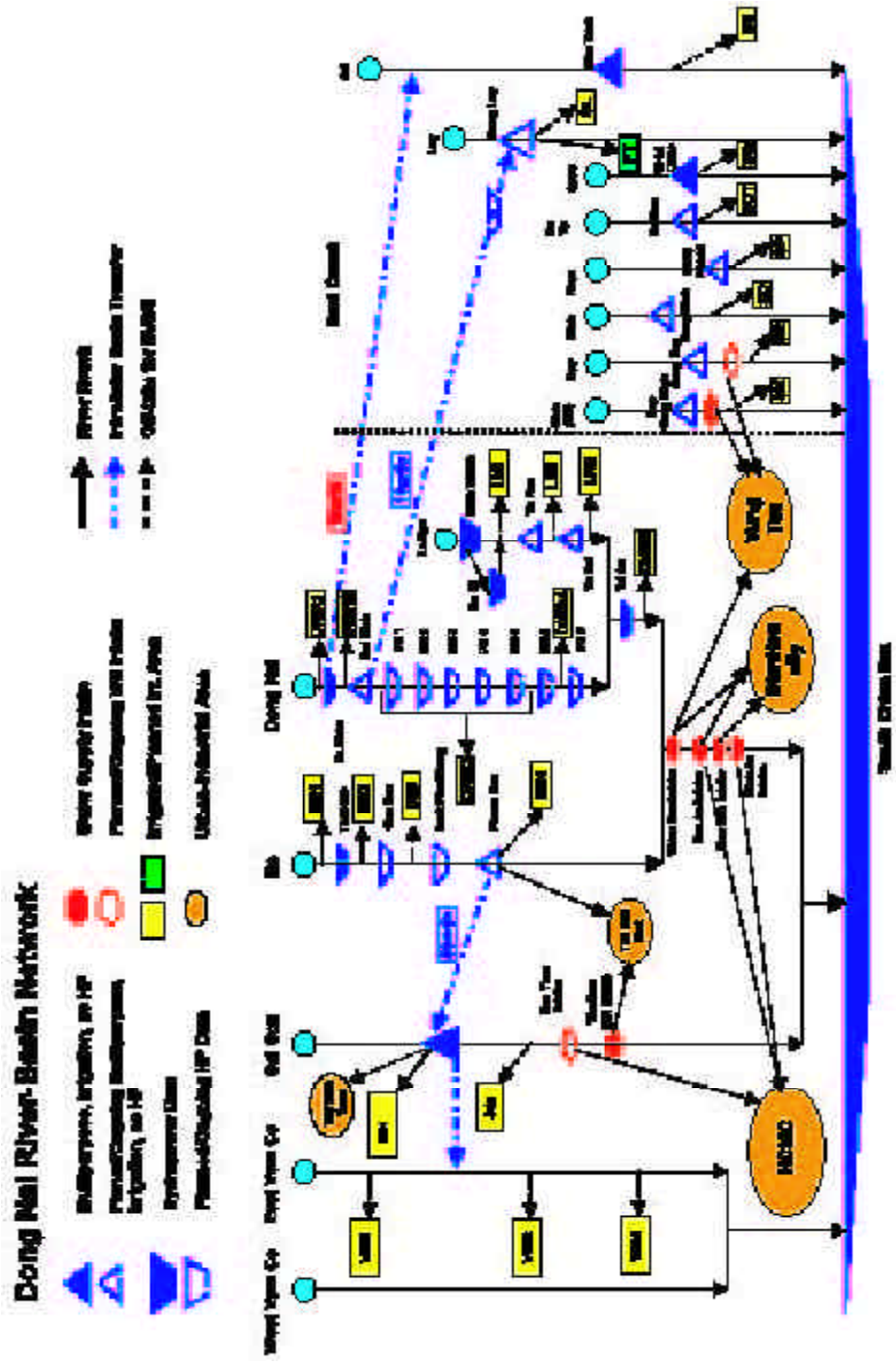
The river basin model will be adapted from a model developed by IFPRI for the Maipo river basin in Chile (Rosegrant et al. 2000). The modeling system is developed as a node-link network, in which nodes represent physical entities and links represent the connection between these entities (figure 3). The nodes included in the network are a) source nodes, such as rivers, reservoirs and groundwater aquifers; and b) demand nodes, such as irrigation fields, industrial plants and households. Each distribution node is a location where water is diverted to different sites for beneficial use. The inflows to these nodes include water flows from the headwaters of the river basin and rainfall drainage entering the entities. No prior storage is assumed for the river nodes. A number of agricultural and municipal and industrial (M&I) demand sites or nodes have been spatially connected to the basin network. Agricultural demand sites are delineated according to the irrigation districts. At each agricultural demand site, water is allocated to a series of crops, according to their water requirements and economic profitability. Both crop area and yield will be determined endogenously in the model.

Water demand is determined endogenously within the model, based on functional relationships between water and productive uses in irrigated agriculture, households, industries and hydropower. Water supply is determined through the hydrologic water balance in the river system. Water demand and water supply are then integrated in an endogenous system, and are balanced, based on the economic objective of maximization of economic benefits from water use.

Model Components

Thematically, the modeling framework includes three components: a) hydrologic components, including the water balance in reservoirs and river reaches, deep percolation, and return flows, and in-stream and off-stream water demand components, b) economic components, including the calculation of benefits from water uses by sector and demand site, and c) institutional rules and economic incentives that impact upon the hydrologic and economic components. Thus, the river basin model provides a description of the underlying physical processes and the institutions and rules that govern the balance of flows, the flow regulation through surface water and the water allocation to both off-stream and in-stream demand sites.

Figure 3. The Dong Nai river basin network.



Hydrologic relations and processes are based on the flow network, which is an abstracted representation of the spatial relationships between the physical entities in the river basin. The major hydrologic relations/processes include: a) flow transport and balance from river outlets and reservoirs to crop fields or urban-industrial demand sites, b) return flow from irrigated areas and urban-industrial areas, c) evapotranspiration in the crop field, d) reservoir releases, and e) in-stream water uses.

The agronomic component focuses on the establishment of a relationship between crop yield and water. In order to develop this relationship an agricultural input-output survey is currently being implemented by the Sub-Institute for National Planning and Projection in HCMC. Based on this survey, regression equations will be determined for the various (irrigated) crops in the basin. The regression analysis can then be linked with a crop-water simulation model.

The economic component is driven by the maximization of net profits to water use. The objective of the model is to maximize the annual net profits from water uses for irrigation, households, power production and industries.

The model optimizes water allocation following the economic efficiency principle. In the baseline, an omniscient decision maker will be assumed who maximizes total net profits for the entire basin. Minimum flows to keep saltwater intrusion at bay will be included as constraints. Initially no other water rights and institutional rules will be incorporated, as no specific protocols have been set up for the Dong Nai river basin. Alternative simulations will then vary levels of inflow and development as well as institutional rules to help devise strategies for optimal inter-sectoral allocation of water resources in the basin.

Conclusions

This paper described the institutional setting of Vietnam's water sector and outlined the current transition process towards a more coordinated management of the water sector at the national and regional levels under the guidance of the Ministry of Agriculture and Rural Development. The management of water resources at the river basin level as envisioned in the 1999 Water Law will likely bring about substantial benefits to both the agriculture and economic sector in the country through the avoidance of inefficiencies in water allocation processes, the development of more effective institutions under MARD, the protection of the country's water resources and the facilitation of a more holistic and thus sustainable management of the country's water resources.

Establishing water allocation mechanisms conducive to both agricultural and economic growth is of particular importance in the Dong Nai river basin in southern Vietnam due to its preeminent role in Vietnam's development process. Water withdrawals, estimated at 16 percent of annual discharge, are already high, and will likely continue to rapidly increase over the coming decades. At the same time, the large reservoir storage in the basin, currently standing at 14 percent of annual discharge, and set to increase, will help counteract the increasing dry-season water shortages. However, the costs and benefits of additional infrastructure in the basin—be it for irrigation, urban and industrial water supply or hydropower—need to be carefully balanced to achieve an efficient, equitable and environmentally sustainable development of the basin water resources. Even more emphasis

needs to be placed on the institutional side of basin development in the Dong Nai, particularly as more multipurpose reservoirs are coming online with competing responsibilities for hydropower, irrigated agriculture and urban-industrial water supply exerted by several ministries and provincial authorities. The establishment of a River Basin Organization in the Dong Nai river basin will be a first important step to overcome some of the obstacles to sustainable, integrated and comprehensive development of the basin water economy.

To analyze the various water allocation mechanisms, and the costs and benefits involved in water allocation across time (dry and wet seasons) and space (upstream and downstream areas) as well as water use (industry, households, agriculture, environment) an integrated economic-hydrologic river basin model is currently being developed as a collaborative effort of the Sub-Institute for Water Resources Planning in HCMC, Vietnam and IFPRI in Washington, D.C., supported by the ADB.

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Part IV
Lessons from Some Best Practices in
River-Basin Management

CHAPTER 11

Institutional Arrangements in the Murray-Darling River Basin

*Darla Hatton MacDonald and Mike Young*¹

Overview of the Basin

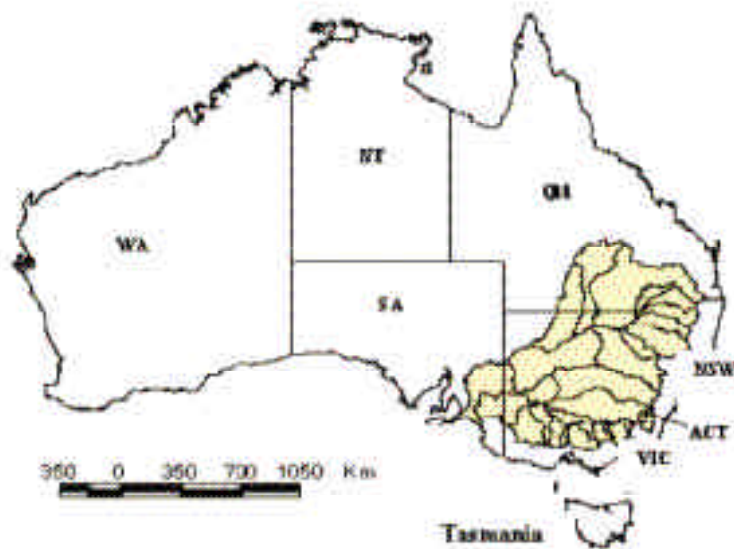
Managing water resources in the Murray-Darling basin is a lesson in resolving conflict across jurisdictional lines. Often, it is assumed that the water resources of the basin are managed by one body, which is not a full picture. Australia is a commonwealth of states and territories and works under a model of cooperative federalism. The Murray-Darling basin is managed in a framework that involves the commonwealth (or federal) government, four states and one territory. The framework involves layers of representative bodies that consist of a Ministerial Council, the Murray-Darling Basin Commission (MDBC), and series of high level groups interspersed with community representatives. These layers make up the fora where strategies and policies are set out for sharing the water and managing the serious problems of water quality in the basin. Water is fundamental to Australia's economy and a strong commitment to using water according to its highest and best use has emerged in Australia. As part of a National Competition Policy, Australia has embarked on major reforms, which include expanding water trading and moving to full cost pricing of the resource.

The two rivers, the Murray and the Darling, which give the basin its name, are hydrologically very different. The Murray river flows out of the mountains in southeast Australia and has a relatively reliable flow, whereas the Darling drains the northern half of the basin and displays the erratic flow patterns of a river in a semiarid area. The two rivers come together quite far downstream some 250 kilometers from the sea. The Murray-Darling river basin comprises a large geographical area, approximately one million square kilometers or approximately one-seventh of the landmass of Australia. With a total length of 3,780 kilometers, it is the fourth longest river system in the world. The total area is roughly equivalent to the area of France. An overview of the Murray-Darling basin can be seen in figure 1.

The Murray-Darling river basin contains half the Great Dividing Range and some of Australia's highest mountains. The high catchments provide a significant amount of water to the system. However, much of the basin is flat, with extensive plains or low undulating areas

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Figure 1. Map of Australia with state lines and the outline of the Murray-Darling basin.



Notes

WA – Western Australia

NT – Northern Territory

Qld – Queensland

VIC – Victoria

NSW – New South Wales

SA – South Australia

ACT – Australian Capital Territory

Source: CSIRO

less than 200 meters above sea level. The basin covers 75 percent of the State of New South Wales, 56 percent of the State of Victoria, 15 percent of the State of Queensland, 8 percent of the State of South Australia and the entire Australian Capital Territory (MDMBC 1987). The Murray river system consists of the main course of the Murray river and all its branches, tributaries entering the Murray river upstream of Albury, as can be seen in figure 2.

Due to the relatively low rates of runoff in much of the basin, and the existence of a substantial amount of salt of geological origin present in the landscape, salinity is a significant issue in the basin.

The Murray-Darling basin has been transformed by the construction of major water weirs, locks and storages on the rivers over the last 100 years. A number of works have been put in place: Dartmouth dam, Hume dam, Yarrowonga weir, Lake Victoria storage, the Menindee lakes storage, the weirs and locks along the Murray river and lower Murrumbidgee, as well as the barrages near the mouth of the Murray river. Further, a major hydroelectric power station, the Snowy river scheme, was constructed over a 25-year period beginning in 1949. The scheme diverts water from the Snowy and Eucumbene rivers and adds about 1,140 GL (giga-liters: million m³) of water to the Murray and Murrumbidgee valleys making more water

Figure 2. Branches and tributaries of the Murray-Darling basin.



Source: <http://www.mdbc.gov.au>

available for irrigation. People living in the Snowy catchment are now arguing for some of this water to be returned to them.

The total volume of water-storage capacity in the basin is just less than 35,000 GL. The major storages, especially Dartmouth, Hume, Lake Victoria, and the Menindee lakes and other river regulatory structures have made it possible to store water during wet periods and release it as needed during summer or in droughts.

The basin has been populated for an estimated 40,000 years and there are significant sites where cave paintings and artifacts of aboriginal culture have been found. The basin is also important as a place of recreation and tourism. The Adelaide city with a population of over 1 million people draws an average of 40 percent of its water needs from the Murray system. There are a large number of wetlands throughout the basin some which are considered to be of international significance and listed as Ramsar wetlands. The basin provides the breeding habitats for many species of water birds, fish, invertebrates and plants.

The importance of the basin to Australian agriculture is evident by the fact that 43 percent of the total number of farms in Australia are in the basin, representing 45 percent of the crop area. Within the agriculture sector, crops, pastures and grasses are the largest-value components of agricultural production in the basin, with a gross value of production of A\$7.9

billion (Australia Bureau of Statistics) (US\$1.00=A\$1.54). Irrigation dominates the landscape of the basin. Irrigated crops and pastures in the basin represent 72 percent of Australia's total area of irrigated land. Irrigation is essential for improved dairy, cotton, rice and horticulture, in particular viticulture.²

Water Resources in the Basin

One of the more remarkable features of the Murray-Darling basin is the climatic variability. Within the basin, rainfall varies from 1,400 mm/yr. in the highlands to 300 mm/yr. in the northwest (MDMBC 1987). Australia's climate, compounded by the variability of its rainfall, means that virtually all of Australia's river systems are subject to considerable variability of flows from one year to another. According to Brennan and Scoccimarro (1998), annual variations from maximum to minimum flows range from 300:1 to 1,000:1 in Australia. Extremes of 10,000:1 have been reported for the Darling river. The northern "Darling" system is essentially a summer rainfall system, while the southern "Murray" system is essentially a winter rainfall system.

The Murray and Murrumbidgee rivers experience relatively more reliable precipitation and, as a result, streamflow is much more reliable than in other parts of the basin. The largest variability seems to occur with the Darling river and its tributaries where massive floods can occur as well as times when the rivers cease to flow.³ The Murray-Darling basin has a relatively low mean annual discharge in proportion to runoff and in comparison with the other river systems in the world.

Geopolitical Organization of the Basin

The previous section highlighted the unique physical characteristics of the Murray-Darling basin. Due to the geographic size of the basin, it crosses the boundaries of states and one territory. The Murray-Darling river basin is managed by individual states but there are overarching bodies that coordinate many of the efforts of state and territory governments at the basin level. Australia is a commonwealth of states and territories. Water resources are largely under the jurisdiction of the states and territory governments. Rather than amending the Constitution, a MDBC has been formed to manage interjurisdictional processes and conflicts in an organized manner.

The commonwealth (or federal) government does participate in water and water-resources management through other means such as legislative and executive capacity. In particular, the commonwealth government gives financial assistance to the states and territories under section 96 of the Commonwealth Constitution (Fisher 2000, 35). However, these financial incentives must not be shown to discriminate between states. This is a form of cooperative federalism where the commonwealth and state governments come to

²See Crabb (1997) or <http://www.mdbc.gov.au/tour/irrigation.html>.

³Water flow becomes an issue later in the report when we discuss security of water allocations.

agreements and the commonwealth relies on the states to implement agreements within their respective jurisdictions.

As a result of the constitutional framework, different bodies of legislation and institutional arrangements have evolved in each of the states. To follow the elaborate layers of committees, management groups and other arrangements that are necessary to manage the basin (and other resources in Australia), it is necessary to introduce the key bodies that shape commonwealth, state and territorial government policy on water. The institutional arrangements in the basin are in a process of evolution as the states and territories move towards market-based systems of allocation of resources.

An overarching policy, which affects most sectors of the Australian economy, is the National Competition Policy. Under this policy, the states, territories and the commonwealth have committed to a process of creating a level playing field for all by facilitating effective competition. The goal of this process is to promote economic efficiency and economic growth. The policies are articulated in what has become known as the Hilmer report on National Competition (Hilmer 1993).

To facilitate these competitive reforms, the commonwealth government has placed funds in a pool to be distributed among states and territories on the basis of progress in implementing reform (each step is known as a tranche). Thus, states and territories have a financial incentive to implement the policy framework. The size of payments promised varies among states. Payments are not large enough to fully finance reform but have been sufficient to ensure that serious steps are taken to implement the required reforms.

Council of Australian Governments

The Council of Australian Governments (COAG) comprises heads of federal (Commonwealth of Australia) and state/territory governments plus a representative from each local government. Water is one of many sectors that come under the purview of the COAG.

The COAG has developed a national policy called the COAG Water Reform Framework for the efficient and sustainable reform of Australia's rural and urban water industries. Many of the states and territories had been moving in these directions prior to the COAG. In developing its framework, COAG adopted a position that required a consistent approach to water reform throughout Australia. The key elements of COAG's water reforms are the following:

- All water pricing is to be based on the principles of full cost-recovery and cross-subsidies must be made transparent.
- Any future new investment in irrigation schemes, or extensions to existing schemes, are to be undertaken only after appraisal indicates it is economically viable and ecologically sustainable.
- States and territorial governments, through relevant agencies, are to implement comprehensive systems of water allocations or entitlements, which are to be backed by the separation of water property rights from land and include clear

specification of entitlements in terms of ownership, volume, reliability, transferability and, if appropriate, quality.

- The formal determination of water allocation entitlements, including allocations for the environment as a legitimate user of water, is to be undertaken.
- Trading, including cross-border sales of water allocations and entitlements, is to be allowed within the social or physical and ecological constraints of catchments.
- An integrated catchment management approach to water resources management is to be adopted.
- Resources management and regulatory roles of governments are to be separated as far as possible from water-service provisions.
- Greater responsibility is to be given to local areas for the management of water resources.
- Greater public education about water use and consultation in the implementation of water reforms and appropriate research into technologies of water-use efficiency and related areas should occur.⁴

Each state and territory was given the flexibility to adopt its own approach to implementation depending on its own unique institutional and natural characteristics, but agreed that the full framework would be implemented by the year 2001. A key feature of the COAG framework was the state and territory agreement to a tranche payment system, where access to very large payments was conditional upon delivery of reform milestones. The tranche payment system was instrumental in achieving the degree of economic reforms that has occurred across the states.

The reform process has not led to universal or even uniform changes in policies and practices across the states and territories. Governments have tended to tackle the reforms that are most easily achieved. In some ways, South Australia was furthest along the track, as the state had already introduced many of the reforms in a single piece of legislation, the *Water Resources Act 1997*. South Australia has the most comprehensive planning process where catchment boards undertake community consultation as part of the water management plans and this process is made consistent with a State Water Plan. However, South Australia has made only partial progress towards full cost pricing of water because of the state-level commitment to one price for reticulated water throughout the state. Arguably, New South Wales has made the greater strides towards full cost pricing because the state already had a process in place through the Independent Pricing and Regulatory Tribunal (IPART). Musgrave (2000) reports on the transparent public process that IPART uses to navigate through the conflicting interests.⁵ Many of these more successful aspects of water reform do not appear to be transferred easily even to other states, as the process of reform is constricted by

⁴Source: <http://www.affa.gov.au/water-reform/facts2.html>.

⁵Pricing issues will be described in more detail in the water pricing section.

institutional settings already in place. Generally, in the area of water reform, Queensland has the “longest way to go,” which has required the state to undertake an extensive consultation process on water pricing, water trading and the system of water allocation. A new insight beginning to emerge is that states that are slower to implement reforms can learn from others. Those states that were last to implement reforms are now beginning to pass those who were the first movers in the reform process.

The COAG Water Reform process has been further developed by the High Level Steering Group on Water. This group consisted of the chief executive of each state and territorial and commonwealth department directly responsible for water. The head of the Murray-Darling Basin Ministerial Council (MDBMC) is not represented on the High Level Steering Group **on Water but its members with a few exceptions, are members of the commission.**

MDBMC

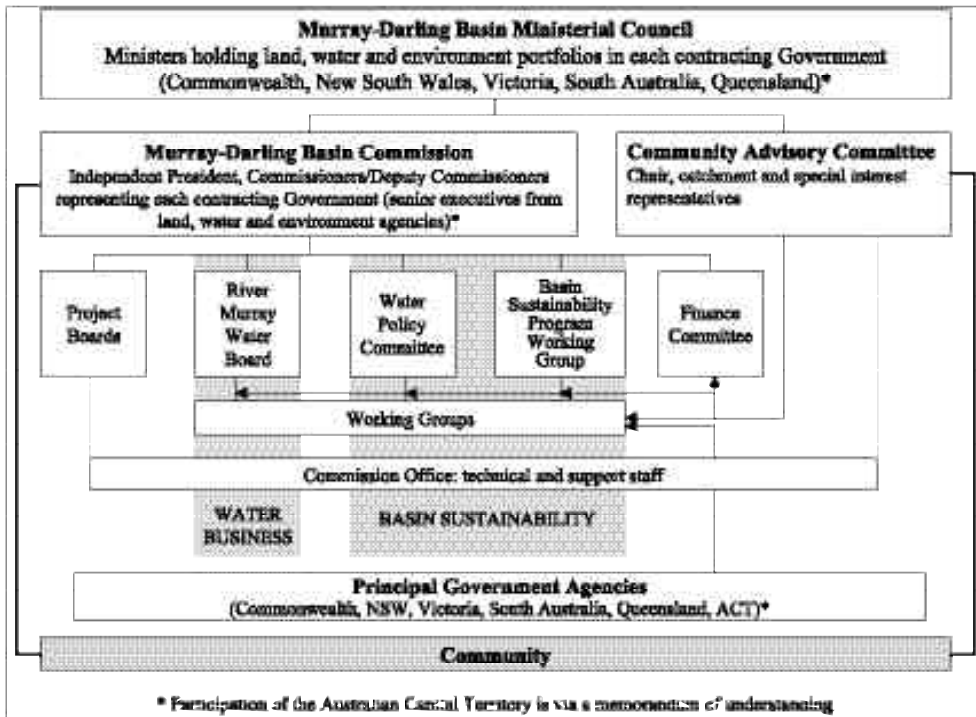
The MDBMC was established in 1985 with amendments to the Murray-Darling Basin Agreement. The MDBMC advises the council of Australian Governments as appropriate on matters relating to the implementation of the framework for water reform. The MDBMC consists of the ministers responsible for land, water and environmental resources in each of the signatory or contracting governments, the Commonwealth, New South Wales, South Australia, Victoria and Queensland, with each government limited to a maximum of three members. Its prime functions are:

- a. Generally, to consider and determine major policy issues of common interest to the contracting governments concerning effective planning and management for the equitable, efficient and sustainable use of the water, land and other environmental resources of the Murray-Darling basin.
- b. To develop, consider and, where appropriate, authorize measures for the equitable, efficient and sustainable use of such water, land and other environmental resources (Murray-Darling Basin Agreement 1992, Clause 9).

Being a political forum, the MDBMC has the power to make decisions for the basin as a whole because of the presence of ministers representing each state and territory. Resolutions of the council are arrived at through consensus. This means that decisions taken by the council represent, in theory, a consensus of governmental opinion and policy across the basin at a point in time. However, the MDBMC relies on the states to implement any decisions taken. An overview of the high-level organization of the Murray-Darling basin can be seen in figure 3 and details concerning the MDBC are discussed below.

⁶A decision to rationalize the number of high level institutional arrangements in Australia has resulted in the recent transfer of the functions of this group to a new Natural Resources Management Council and its subsidiaries. At the time of writing, it is still too soon to see if this group will conclude that all water and natural resources management issues can be managed under a single structure or if there is an ongoing need for separate water-focused meetings. In most states, the CEOs responsible for water policy are the same people responsible for natural resources management.

Figure 3. Organization of the MDBC.



This organization chart highlights how the state and commonwealth governments coordinate their efforts to provide a high-level structure that is responsible for the basin. It is interesting to note that within this high-level structure, a place has been made for a community advisory committee, which reports to the MDBMC. The committee serves as a two-way communication channel between the MDBMC and the communities living in the basin. In the last few years, the community advisory committee has considered a number of controversial topics, such as dryland salinity, implementation and monitoring of the cap on water diversions, and floodplain management. The committee was able to communicate the issues to the community and provide a “reality-check” concerning the human dimensions of problems. The committee has also been considering issues relating to aboriginal involvement in natural resources management and recognition of cultural heritage in the basin (MDBC 2000). The first two tiers of the structure have been stable for many years, but the third tier of project boards, policy committees, etc., changes regularly. The commission’s staffing structure was changed radically in 1999.

MDBC

The MDBC is the executive arm of the MDBMC. It also works cooperatively with the states. The MDBC is responsible for managing the Murray river and the Menindee lakes system of the lower Darling river, and advising the MDBMC on matters related to the use of the water, land and other environmental resources of the Murray-Darling basin.

The MDBC comprises an independent president, two commissioners from each contracting government (i.e., the Commonwealth, New South Wales, Victoria, South Australia and Queensland) and a representative of the Australian Capital Territory Government. Each contracting government also has two deputy commissioners. The Australian Capital Territory has one deputy representative. Apart from the president, commissioners are normally chiefs and senior executives of the agencies responsible for management of land, water and environmental resources.

The MDBC is an autonomous organization equally responsible to the governments represented on the MDBMC as well as to the council itself. It is a rather unusual entity in that it is neither a government department nor a statutory body of any individual government.

The MDBC has a couple of key functions that include:

- advising the MDBMC in relation to the planning, development and management of the basin's natural resources;
- assisting the council in developing measures for the equitable, efficient and sustainable use of the basin's natural resources;
- coordinating the implementation of those measures, or where so directed by the council directly implementing measures; and
- giving effect to any policy or decision of the MDBMC.

The MDBC must balance equity considerations as well as manage and distribute the water resources of the Murray river in accordance with the Murray-Darling Basin Agreement. The MDBC began with a mandate to manage the water quantity that has gradually extended to include water quality issues and, to a limited extent, related issues on land-resources management. In the late 1980s, it was given a mandate to initiate, support and evaluate integrated natural resources management across the Murray-Darling basin.

The MDBC must work in cooperation with the contracting governments, committees, and community groups to develop and implement policies and programs. As a result, it tends to work on a consensus basis. This cooperative approach reflects the constitutional reality and the importance placed on government-community partnerships, brings to participants and end users the benefit of shared concerns and expertise, jointly developed and integrated solutions and avoids duplication of effort.⁷

Other Committees Involved in Water Reforms

There are a couple of key ministerial committees⁸ that have been charged with putting the policy framework in place in each state and territory in line with COAG reforms. Two groups,

⁷www.mdbc.gov.au/about/about_mdbc/the_commission.html.

⁸Under the Australian system of government, ultimate responsibility for policy implementation rests with a minister. To be a minister, one must first be elected to parliament and then selected for a position in the cabinet. Departments are constrained and guided by legislation and are subject to the direction and control of a minister.

the Agriculture and Resource Management Council of Australian and New Zealand (ARMCANZ) and the Australian and New Zealand Environment and Conservation Council (ANZECC), have provided policy directions in relation to water needs for agriculture and the environment. These ministerial committees are supported by Standing Committees of senior officials.

In recent years, ARMCANZ and ANZECC have been fora for government ministers to coordinate efforts. The High Level Steering Group on Water, which consists of departmental heads, provided the ties between government agencies and the policy setting committees such as ARMCANZ and ANZECC. There are a number of other committees that involve lower-level government officials where the details concerning how to implement these policies are worked out. The committees have been key in implementing reforms concerning full cost pricing and the creation of the environment for the competitive provision of water. Recently, ARMCANZ, ANZECC, and a number of other committees have been restructured to separate pure agricultural issues from integrated natural resources management issues and environmental issues.

Coordination of Various Agencies

Coordination is achieved via a constellation of councils and bodies that often involve the same people. Agreements entered into by the states will necessarily reflect approval by the ministers who sit in the various government cabinets.

The MDBC is also an important point of coordination. Each year, each state develops a 3-year rolling plan that outlines the outcomes to be achieved against basin sustainability objectives in the management regions. The management regions correspond to the catchments in New South Wales, Victoria and South Australia. A consolidated 3-year rolling investment plan, based on state plans, then provides a summary of the investments being made across the basin. This allows for some evaluation of progress towards sustainability goals.

In Australia, it is recognized that states must work together on resources management issues. The process works because of the processes embodied within institutions to resolve issues. The constellation of myriad committees and groups of officials works reasonably well despite the complexity of the arrangements. The key is the continuities created by ministers and their deputies by sitting on various committees. Mutual trust and a culture of cooperation among individual administrators have grown up over the years. Further, in these settings, moral suasion is used as a mechanism to encourage states to act in a manner consistent with the common good.

Characteristically, new agenda issues are approached by setting a vision and then negotiating the detail once a consensus concerning a vision is achieved. A second feature is the complex web of people involved. It is common for many of the commissioners to chair subcommittees, sit on the High Level Steering Groups and be the head of a natural resources management department. These same people also interact through committee processes that involve ministers.

How to Share the Water

In the Murray-Darling river basin of Australia, water is used for passive, environmental and consumptive purposes. Historically, access to the Murray-Darling basin began with a framework that enabled virtually whoever wanted to use water for consumptive purposes to do so. Moreover, most of the infrastructure used to deliver water was paid for by governments and supplied at subsidized prices.

The combination of drought and water quality has become a significant issue for water users throughout the basin. Events such as droughts, algae blooms and increases in salinity provided an impetus for renegotiating how to share the water in the Murray-Darling river basin. Views on the situation are colored by location in the basin. Queensland, New South Wales and Victoria are “upstream states” and South Australia is a “downstream” state.

Priorities amongst Users

In general, across states, the consumption of water by people and animals takes top priority followed by agriculture. Most water licenses and legislation indicate that water needed for domestic purposes and livestock production is a prior right. That is, people may not interfere with the rights of others to consume water for stock or domestic purposes.

The importance of the environment has been underlined through a number of policy statements that have been issued. However, where in the list of priorities the environment is actually placed is not always well defined in practice. An example is the *Corporatization of the Snowy Mountains Hydroelectric Authority, Draft Environmental Impact Statement (EIS)* released by the Commonwealth (Department of Industry, Science, and Resources 2000). The EIS outlines how water levels in the Snowy river might be restored through water savings in the Murray-Darling but

[r]ather than recommending specific trade-offs between economic and environmental interests, or between competing environmental interests, the EIS has sought to compare and contrast the various advantages and disadvantages for each group of stakeholders of reducing water releases to the Murray-Darling Basin in order to provide increased flows in the Snowy River (Department of Industry, Science and Resources 2000, 2).

This reluctance indicates the difficulties that governments, communities and businesses face in placing the environment in a list of priorities. However, positive steps have been taken as 100 GL have been set aside for the Barwah-Millewa forest. The Barwah section of the forest is a Ramsar wetland indicating that this is a site of international importance (MDBC 1999).

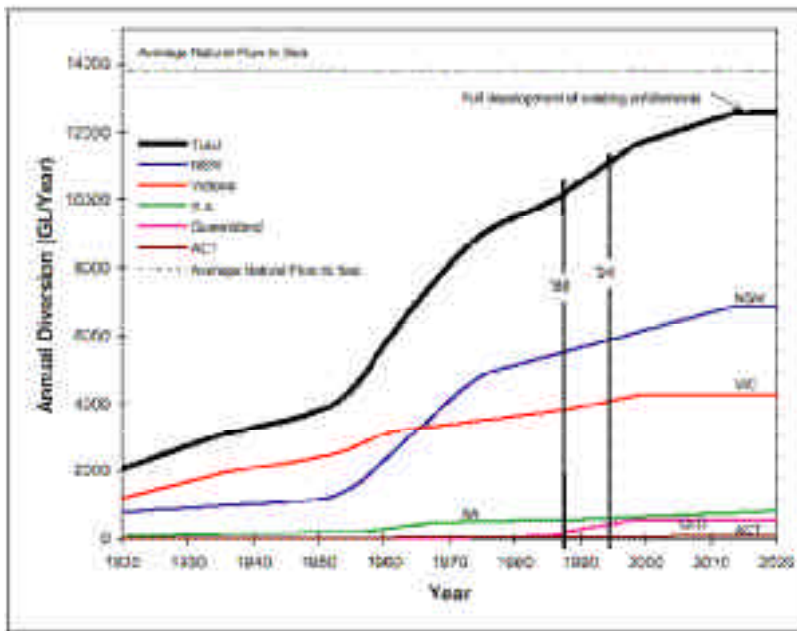
All levels of government have committed themselves to an Inter-Governmental Agreement on the Environment. This agreement commits them to a set of principles designed to ensure that all resources use and development in Australia are ecologically sustainable. Indicative of this change in emphasis, the New South Wales government recently reduced most irrigation allocations by 10 percent in the basin so that “allocations” to the environment could be increased. At this stage, however, no formal quantity of water has been allocated to the environment. Some irrigators, however, are of the view that this should occur and that any increase in allocations to the environment should be made only through processes that involve voluntary purchase of environmental flows at full market price.

Allocating Water among States

The basis for allocating water across states is largely the product of historical use. New South Wales and Victoria have engaged in intensive agriculture since the turn of the century and the pattern of increasing use can be seen in figure 4. Through the 1980s, the amount of water being used for consumptive purposes began to increase significantly. In 1993, a decision was made by the MDBMC to prepare a water audit that would:

- establish water use in the basin;
- describe current level of development;
- document recent trends; and
- assess the implications of those trends.

Figure 4. Historical use of the Murray-Darling basin by the states and projections as of 1995 without a cap.



Source: MDBMC 2000.

The MDBMC was concerned about the health of the basin. Salinity of water was increasing, algal blooms were occurring more frequently and biodiversity appeared to be declining. For the downstream State of South Australia, the situation was thought to be quite serious.

It was acknowledged by the MDBMC that water usage could not continue to increase within the basin. As a result, an overall cap on water diversions has been introduced, limiting the volume of water to what would have been diverted under the 1993–94 levels of

development. The cap is variable depending on climatic conditions; in dry years, less water is diverted based on the water that would have been available given the existing infrastructure.

Perhaps, the most dramatic impact of the cap has been an increase in water trading. The ability to move water to its highest and best use has resulted in significant increases in the price of water. Trade in water has been occurring in Victoria and New South Wales since the early 1980s. Trading became particularly important and widespread with droughts, diminished supplies, the cap on water and, in some areas, decreases in water allocations. The property right reforms that are underway in the states and territory will further facilitate trade.

Most of the states are putting in place legislation that separates title to land and water and allows licenses to be traded either permanently or temporarily.⁹ For example, in South Australia, it is now possible for a person who owns no land to hold a water license as an investment and sell water on an annual basis to any interested party. A system of well-defined property rights is not a requirement for water trading though it certainly facilitates more efficient trade.

Water Trading within and among States

The development of markets for water is well established in some states such as New South Wales and Victoria. In New South Wales, water trading was active and total sales amounted to 11 percent of total entitlements to consumptive users in 1997–98. Much of the trade involves temporary transfers of water. Until the new legislation is passed, land and water licenses are not separate. Permanent transfers would require cancellation of the license of the transferor and the issuing of a new license to the transferee. Temporary trades are essentially “leases” of a license. Moreover, the crops grown in New South Wales do not necessarily require high security water rights. In South Australia, the situation is considerably different, since the irrigation of grapes requires a very secure source of water. Most trades in South Australia are permanent.

In Victoria and the other states, there are significant issues to resolve with respect to third-party impacts. The states have been allowing trade to expand slowly in order to assess the impact on environmental health and water quality. There are also costs associated with allowing water to leave an area. Irrigation schemes and communities are struggling with this issue.

The next step in the water reform agenda is an interstate water trading pilot project. Under a pilot project, trade in water is permitted in the Mallee region of South Australia, Victoria and New South Wales. The geographic area covered is the Murray river between Nyah and the Barrages at the mouth of the Murray and the licenses from the Darling river, which are supplied from Lock 10, near the junction of the Murray and Darling rivers. The Mallee region was selected for two reasons. First, the same type of agricultural activity, such as irrigated production of fruits, vegetables and grapes for wine, is prevalent in the region. Second, the price per megaliter (ML) of water is relatively uniform throughout the region.

⁹At the time of writing, New South Wales had a new water bill ready that was soon expected to be enacted.

Only high-security entitlement¹⁰ holders engaging in the permanent transfer of water were allowed to participate in trading. In New South Wales, holders of private high-security licenses, in South Australia holders of water licenses granted under the Water Resources Act of 1997 and in Victoria holders of private diversion licenses are allowed to participate in trading. Even within this region, trading may have an impact on water supply as interstate trades can have an effect on other users. If water is coming from a different source, such as another reservoir or another river, then there will be transmission gains and losses along the system. As water moves down the rivers and channels there are more options for storage and, therefore, there is increased security. To reflect these security issues, a set of exchange rates has been developed.

Temporary trading between states, outside the interstate pilot project, was put on hold by the Minister for Natural Resource in Victoria. The difficulty appears to be in the way each state accounts for water use. New South Wales has a system of continuous accounting and Victoria has a “use it or lose it” system. Under this suite of arrangements, a Victorian water user could transfer water to New South Wales, carry it forward to the next season and bring it back without “losing” it. Victoria was worried about this because its allocations are based on the assumption that every year a proportion of the water would be lost. If this feature is abandoned, then all existing allocations may need to be reduced. Temporary interstate trades will not be allowed after February until the next irrigation season.

The pilot project was allowed to operate for 2 years and then the program was independently reviewed by Young et al. (2000). Under the pilot, 9.8 GL of water were traded at a price of approximately A\$1,000 per ML though there was considerable variability in the price over the time frame. The evaluation of the pilot project revealed that the ability to trade interstate tended to lead to “unused” water¹¹ being moved out of New South Wales and Victoria to South Australia to be used for horticulture and viticulture. The ability to trade water has highlighted the need to simplify and streamline the administrative checks and balances, and the need to put in place a system of binding salinity mitigation obligations.

Issues of Water Quality

One of the major failures of the institutional arrangements is in the area of water quality. With multiple jurisdictions and conflicting interest of resources users, it has been difficult to get jurisdictions to agree that there is a significant problem, let alone agree on solutions. The MDBC was formed initially to deal with the issues of water quality relating to algal blooms, waterlogging salinization, etc. Salinity is too large a problem to be solved by one government; it requires coordinated interstate action and community cooperation. The central planks of the Murray-Darling Salinity Strategy are:

¹⁰A high-security entitlement is a license for which the water will be provided except in severe drought conditions. A low- or general-security entitlement is a license for available water, which can vary from year to year.

¹¹Unused in the sense that it was not used by people who held allocations from where it was transferred. In practice, however, it needs to be recognized that before these transfers occurred the water was left in dams and then allocated to others.

- salt-interception schemes;
- changed operating rules for several lakes with a view to reducing evaporation and, hence, salt concentration; and
- a suite of land management policies and programs jointly funded by the states and the commonwealth.

One of the unique features of this strategy is the agreement between the Victorian and New South Wales governments to manage water resources within agreed limits. These states cannot construct or approve any proposal that would increase salinity by 0.1 EC¹² or more in the Murray river at Morgan unless they have access to salinity credits.

Under the salinity credit scheme, the New South Wales and Victorian governments received salinity credits of 15 EC each for their contributions to the costs of the interception schemes. States can earn more credits by financing schemes that reduce the expected salinity load at Morgan. The MDBIC maintains a register of works undertaken and the salinity credit and debit impacts. The salinity impact of any proposed irrigation scheme must be offset by acquiring credits in the register. South Australia requires that interstate water be subject to a Zero Impact Assessment. However, the difficulty with all these processes is the difficulty of making the agreements with irrigators binding, especially if the water can be traded again.

Despite the progress that has been made, some analysts such as Quiggin (2001) suggest that the present policies are still unsustainable. Even with the cap on diversions, if all entitlements existing in 1995 were fully developed by 2020, more than 90 percent of the average natural flow to the sea would be diverted. This pattern is unsustainable for the water-dependent ecosystems. This suggests that further steps must be taken to reduce the amount of water being diverted, if important ecological resources are to be preserved and the costs associated with salinity damage to downstream users in Adelaide are to be averted.

Water Pricing

In the 1990s, many of the states were reforming pricing of water for irrigation and water for household consumption (and stock watering in some cases). Basic principles of economics suggest that a resource will be used most efficiently where the competitive market would price the resource. This is usually taken to be the long-run marginal cost (or the incremental cost per unit of water). Water and many other utilities have large fixed or “start-up” costs, which leads to a decreasing cost industry where average and marginal costs decrease with the amount produced (at least over the relevant range). Thus, there is always a tendency for a few firms (often only one in a particular jurisdiction) to supply water. Moreover, pricing at marginal cost in a decreasing cost industry means that average costs are not covered in the long run. In the long run, firms must cover their costs. Further, marginal cost pricing will not allow for covering the costs of future expansion as is sometimes required in water systems.

¹²EC is a measure of electrical conductivity. 1 EC=1 micro-Siemen per centimeter measured at 25 °C.

These economic considerations are in part covered by the key elements of the water-pricing policy of Council of Australian Governments (COAG). In the case of pricing, the COAG reforms codified many of the policies that had been floating in policy circles at the time. The COAG pricing regime is to be based on the following:

- consumption-based pricing and full cost-recovery for urban water and rural water supplies,
- the elimination of cross subsidies as far as possible and their exposure where they exist,
- cost recovery that includes environmental costs (externalities) and the cost of asset consumption as well as taking the cost of capital into account,
- positive real rates of return on written-down replacement costs of assets, and
- future investment in new schemes or extensions to existing schemes to be undertaken only after appraisal indicates it is economically viable and ecologically sustainable.

On a state-by-state basis, full cost pricing is at various stages of implementation. Cost-recovery pricing is not a straightforward process to implement. Some states and territories are further along this process than others. According to the Progress Report to the COAG, water sold in urban areas is sold on a cost-recovery basis though there is some question whether proper account is being taken of the environmental externalities.

New South Wales established the Government Pricing Tribunal, which evolved into the Independent Pricing and Regulatory Tribunal (IPART). Both entities predate the COAG reforms. IPART reviews information on costs and revenues and determines bulk water prices. IPART considers, for instance, whether the department's costs represent an efficient level of service. Revising the price strategy of a resource is unlikely to be a painless process. The extractive users in New South Wales, particularly the irrigators, mounted a noisy opposition to the potential increases in price. However, the tribunal conducted its review in a very public forum and consulted with interested groups across society. In the end, IPART was able to develop a set of pricing rules accepted for adoption at the national level by the Standing Committee on Agriculture and Resource Management. The rules are currently being used to guide the process of price reform across jurisdictions.

Conflict Resolution

One of the key lessons of the Murray-Darling basin is that institutions can serve as mechanisms to resolve conflicts. When institutions fail to resolve conflicts they must either evolve or be abandoned. As transaction costs among economic agents increase, in this case the various entities operating in the basin, there is an incentive to create institutions to internalize these costs. Challen (2000) points out that the voluntary agreements that the state and commonwealth governments have entered into allow for sharing and accounting for the resources. This results in mechanisms for managing the resources that avoid a situation of open access. As yet, however, the framework does not provide sufficient incentives for states to control resources use so that the activities of users in any particular state are viewed in

terms of the impact across the entire basin. When issues become serious, however, the framework does appear to enable governments to negotiate a solution. Illustrative examples of this include the commitment to cap water allocations and, more recently, to try and set valley-by-valley salinity targets.

MDBC

The Murray-Darling Agreement is a prime example of institutional rules designed to manage conflicts. Early conflicts arose between users of the Murray river for irrigation and navigation. However, an agreement between the states of New South Wales, Victoria and South Australia was not reached until after a series of severe droughts raised the cost of noncooperation past the threshold for the three states.

The existence of the River Murray Commission from 1917 to 1985 speaks of the commission's ability to work cooperatively with the states and to coordinate the construction and operation of some of the works on the river. Regulating the flows of the river clearly served the interest of the states (e.g., expansion of agriculture in the basin).

The commission expanded its role over time but was not able to evolve into an institution capable of dealing with basin-wide problems, such as salinity and the declining health of the riverine environment. As states realized they could not resolve these issues within their own jurisdictions and costs would continue to escalate with inaction, there was again the incentive to develop a new institution, the MDBC that, as discussed earlier, has a broad mandate to bring about basin-wide solutions.

Over the last decade or so, the MDBC has become increasingly aware of the need for the benefits of community consultation. To this end, in 1986 it established a Community Advisory Committee that reports directly to the MDBMC. Today, virtually all commission programs involve a large degree of consultation. Most policy reforms are, at least, discussed with the council and explored through transparent media and meeting-based processes. Draft policies and/or strategies are then released and finalized after a period of time.

Irrigation Schemes

Within the basin, most of the large irrigation schemes were created to deliver water and encourage the expansion of agriculture. The water-reform process, the expansion of water trading, and the cap on diversions have changed the operating environment of these entities. These entities have evolved over time from a means to put irrigation infrastructure in place to become major water managers. One irrigation scheme, Colleambly Irrigation, has been evolving into a natural resources manager at a time when there was a crisis in confidence about the land and water management planning process and the impact that irrigation in New South Wales was having on the environment. The New South Wales government was moving to impose costly monitoring and reporting requirements. Colleambly perceived that it did not have time to wait for natural resources outcomes to demonstrate that it was a responsible resources manager. Colleambly chose instead to apply for ISO 9002 and 14001 accreditation.¹³ The accreditation process provided a means of resolving conflict between Colleambly, NGOs and the media about the health of the river environment. The accreditation

process proved successful in demonstrating commitment to the environment and a means of differentiating itself in a competitive environment.

Catchment Boards

At the catchment level, people are most closely associated with the environment and the water resources. Throughout the basin, there are catchment boards with differing levels of experience, expertise and power. Most boards engage in public consultation and have varying degrees of community involvement. This is a means of engaging people in the issues and it is also a process of education for most of the interested parties. Through consultation, boards as well as the public learn about the state of the catchment and the positions of the various parties with respect to what should be done. South Australia is currently the only state that boards the power to raise levies.¹⁴

The planning process of water allocation and the consultation process with the community are often cited by catchment managers as a useful process for uniting divergent interests. The chairs of catchment boards, which are unable to navigate through the conflicts come under pressure to resign or not seek a renewal of their position. The process usually restarts with the appointment of a new chair.

The Courts

Ultimately, the court system in Australia serves as a place where remedies for conflict can be sought. Generally, this is an expensive process for water users, states or territories to engage in. These costs often serve as a means of motivating the different entities to work to solutions through other means.

Conclusions

The Murray-Darling river basin by its physical and geopolitical nature is difficult to manage and is likely always to be a source of conflict due to its economic significance. The lessons from the basin can be summarized largely in terms of how conflicts are managed. The sustainable management of resources has required innovative mechanisms to be put in place that will encourage reform in an environment of cooperative federalism. The system of tranche payments has proven to be a means of encouraging states to move in a consistent manner through water reforms.

¹³ISO 9002 is accreditation systems where a set of procedures to ensure a certain level of quality are in place. ISO 14001 is an environmental management system based on the same accreditation process.

¹⁴Until recently Victoria's boards also raised levies but a recent change in government resulted in the withdrawal of this power.

In Australia, there is an unspoken philosophy concerning how much room there is concerning adherence to rules. There is generally some tolerance about minor deviations from rules but there is a point of no return where payments are frozen, governments go to the courts seeking remedies and voters lose confidence in their elected officials.

The constellation of myriad committees and groups of officials works reasonably well despite the complexity of the arrangements. The key is the continuities created by ministers and their deputies sitting on various committees. Trust between individuals has grown up over the years. Moreover, in these settings, moral suasion works as a mechanism to encourage states to act in a manner consistent with the common good.

Institutions such as the MDBC and IPART in New South Wales have tended to use open transparent processes. The commission operates to create consensus concerning a common vision or broad principles and negotiates the details later. The commission will use a combination of moral suasion and public shaming to force states to honor commitments to the cap on diversions and salinity targets within the basin. IPART has used the open public setting to prevent interest groups from hijacking the agenda from the goal of full cost pricing.

Australia has done a number of things well in the basin. Capping water usage and establishing a salinity credit system represent major accomplishments. Adherence to these systems, where not all states bear the burden of salinity or benefit from enhanced environmental flows, is going to be the major challenge in the short term. Moving to full cost pricing and expanding water trading have proven to be sources of conflict that are gradually being resolved through the institutions, which appear robust enough to survive the demands of water users in the basin.

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CHAPTER 12

Water Resources Management in Omono Gawa Basin, Akita Prefecture, Japan

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Omono Gawa Basin

Physical Characteristics

The Omono Gawa basin is in the Akita Prefecture, about 500 kilometers north of Tokyo, lying between 39–40° North and 140–141° East with a surface area of approximately 4,952 square kilometers. It is the thirteenth largest basin in Japan. The two main branches of the Omono Gawa rise in the central ridge of Honsu with a watershed of up to 2,200 meters above sea level. The mountains and foothills are extensively forested and the dominant land use is forests and homesteads that cover about 85 percent of the catchment. On the valley floor and flood plains, paddy lands are d hemes have been undertaken in the basin. These include irrigation, drainage and flood control components, in addition to improvement of roads and other infrastructure. Existing irrigation and drainage systems have been incorporated into the new LID areas and farmers included in the LID organizations.

Omono Gawa is well endowed with water resources. Even in years of severe drought, such as 1994, a considerable volume of water is discharged by the river system. Until the development of flood protection schemes as a component of the Land Improvement projects, reduction of agricultural production occurred more frequently as a result of floods than of droughts, with flooding on six occasions between 1960 and 2000. The extent and severity

¹This study of the Omono Gawa basin in the Akita Prefecture, Japan has been funded by the Asian Development Bank (ADB) as a component of a Regional Technical Assistance Project, the Five-Country Regional Study on Development of Effective Water Management Institutions. The Omono Gawa basin was selected as one of three basins with existing institutional frameworks to provide examples of appropriate management institutions. During the field-study, during May 2000, the College of Agriculture, Akita Prefectural University provided extensive logistical support and assistance. Professor Dr. T. Mase was instrumental in identifying and recommending Omono Gawa to the study team, organizing the collation of an extensive dataset, and arranging for the study team to meet representatives of the main stakeholders in the basin. Dr. Mase's assistance in translation and interpretation is gratefully acknowledged, as are the contributions to the analysis of the basin and its institutions made by him and his colleagues (Dr T. Kondoh and Dr H. Jinguji).

of flood impacts have been reduced as the LID expanded with the construction of two large flood-control reservoirs in the upper catchments.

Social Characteristics

The population of the Omono Gawa basin is about 690,000, with the urban population representing about 70 percent of the total, and a population growth rate of approximately zero. Although agriculture is a more important industry in the north of the Honshu Island than in the more industrialized southern areas, expanding opportunities for other sources of income now mean that agriculture is a secondary activity. A common problem in agriculture is the difficulty in securing successors for the aging farming population. Agriculture is becoming a less attractive career for the younger generations due to limited income potential and the greater potential in industry and the public and commercial sectors.

Agricultural Characteristics

Agriculture involves about 51,150 families in the basin. Many farms now constitute a secondary source of income, with other urban and industrial sources being more significant. However agriculture, and particularly rice cultivation, has a strong tradition.

The northerly location of the basin restricts the growing season to the summer months (May to September) and allows only a single crop of rice. The restricted availability of land (typically 1.1 ha per holding), opportunities for off-farm income and the relative abundance of water resources (see section on Water Accounting) make maximizing land productivity important.

Average yields for paddy rice have reached 7 tons/ha with highly mechanized agriculture being the norm. Low temperatures and the short growing season have led to production of rice seedlings in “poly-tunnels.” Mechanized cultivation with mechanical transplanting and harvesting is widespread. Other field crops, notably vegetables and fruit orchards, are present in the basin but cover only about 10,000 hectares.

Water Accounting

Omono Gawa is well equipped with monitoring stations for both rainfall and river flows. Records for nine river gauging stations (table 1), with records available for the period 1967-1997, were analyzed. The record for the most downstream station, Omono Gawa at Tsubaki Gawa, Station Number 20329, was selected as the downstream boundary for water accounting. This station has a catchment area of 4034.9 km², about 81.5 percent of the total basin area. Eight rain gauge stations, with over 20 years of records available, were analyzed to obtain basin rainfall estimates, based on weighted averages of three zones within the basin, table 2.

Crop water requirements were estimated for each of the four major land surface covers (table 3) to determine maximum depletion rates by agriculture. Depletion rates for domestic and municipal use were taken as 40.8 million cubic meters (MCM) based on authorized abstraction licenses, population estimates and estimated wastewater return flows.

Table 1. Summary of gauging sites in the Omono Gawa basin.

Rain-Gauge Station	Latitude	Longitude	Stream Gauge	Catchment Area (km ²)
407 Iwami-Sannai	39° 42.3'	140° 17.5'	20329 Tsubaki Gawa	4,034.9
466 Kakunodata	39° 36.0'	140° 33.6'	20323 Jinguji	3,336.5
476 Tazawa lake	39° 41.8'	140° 44.1'	20317 Omagari Bashi	1,882.1
496 Daisyoji	39° 31.5'	140° 14.3'	20313 Omonogawa Bashi	1,240.0
551 Ohmagari	39° 29.3'	140° 30.0'	20303 Yanagida Bashi	475.6
596 Yokote	39° 19.1'	140° 33.5'	20301 Kawai	145.0
691 Yuzawa	39° 11.1'	140° 28.0'	20321 Nagano	1,088.0
771 Yunotai	38° 57.4'	140° 32.0'	20315 Yokote	216.2
			20306 Mato	255.0

Table 2. Rainfall and streamflow in the Omono Gawa basin.

Year	Annual Rainfall		Streamflow at Gauge Station Tsubaki Gawa
	(mm)	(MCM)	(MCM)
1977	1,716	8,495	7,534
1978	1,606	7,952	6,796
1979	2,260	11,192	9,272
1980	1,884	9,329	7,951
1981	2,209	10,939	8,968
1982	1,754	8,687	7,114
1983	1,679	8,314	7,228
1984	1,630	8,070	8,094
1985	1,741	8,624	7,033
1986	1,654	8,190	7,425
1987	1,909	9,456	8,094
1988	2,887	14,296	6,650
1989	1,610	7,970	5,901
1990	2,049	10,147	8,020
1991	2,069	10,245	8,656
1992	1,665	8,247	6,127
1993	2,010	9,953	8,061
1994	1,478	7,319	6,239
1995	2,250	11,144	9,104
1996	1,682	8,331	7,823
1997	2,008	9,944	7,580

Annual water accounts for the years 1990–1997 are summarized in table 4. Forests and irrigated agriculture are the largest consumers of water in the Omono Gawa river basin. Figures 1 and 2 illustrate the water accounting for this river basin for 1991 and 1994, respectively. The depleted fraction amounts to only about 21 percent of the gross rainfall volume falling on the basin, with a productive fraction of between 4 and 5 percent.

Table 3. Annual consumptive demand for major land covers in the Omono Gawa basin.

Month	Crop Evapotranspiration (mm)
Paddy	693
OFC	588
Pasture	364
Forest	474

Table 4. Summary of annual water accounts and indicators.

Year	Annual Rainfall (MCM)	Depleted Water (MCM)	Depleted Fraction (DF_{net})	Depleted Fraction ($PF_{depleted}$)	Depleted Fraction ($PF_{available}$)	Paddy Production (kg/m^3 ET)
1990	10,147	1,968	0.19	0.23	0.04	0.97
1991	10,245	1,968	0.19	0.23	0.05	0.91
1992	8,247	1,968	0.24	0.23	0.05	1.00
1993	9,953	1,967	0.20	0.23	0.05	0.83
1994	7,319	1,911	0.25	0.20	0.04	1.21
1995	11,144	1,967	0.17	0.23	0.04	0.91
1996	8,331	1,967	0.23	0.23	0.05	1.01
1997	9,944	1,968	0.20	0.23	0.04	1.00

A severe drought occurred in 1994. The rainfall analysis indicates this to be the driest year in the available record. This drought triggered the implementation of the Emergency Drought Management Committee. This drought was widespread across Japan. The impact of the drought management regulations is evident in the abstractions at the Naruse and Minase barrages. Abstractions for irrigation were severely curtailed after the 17 July 1994 instigation of the drought committee, with abstractions at Minase of only 74 percent of the authorized seasonal diversion. The estimated productivity of water in paddy cultivation during the 1994 drought reached 1.21 kg/m^3 , considerably higher than the already high average productivity achieved in the basin of 0.98 kg/m^3 of consumptive use. (The yield is given in milled rice rather than in paddy.)

The Nana Taki LID is typical of established locally managed irrigation systems in the Omono Gawa basin. The system is located on the alluvial fans at the points where the Omono Gawa tributary streams enter the valley plain. The LID serves about 1,608 hectares, operating four storage reservoirs (1,128 MCM, 0.75 MCM, .405 MCM and 0.196 MCM), an interbasin transfer tunnel (858 m long with a design discharge of 1 $m^3/sec.$) and one river headwork. In addition, about 24 groundwater pumps and natural springs are developed for irrigation purposes.

Figure 1. Water accounting diagram for the Omono Gawa river basin (MCM) Japan, 1991.

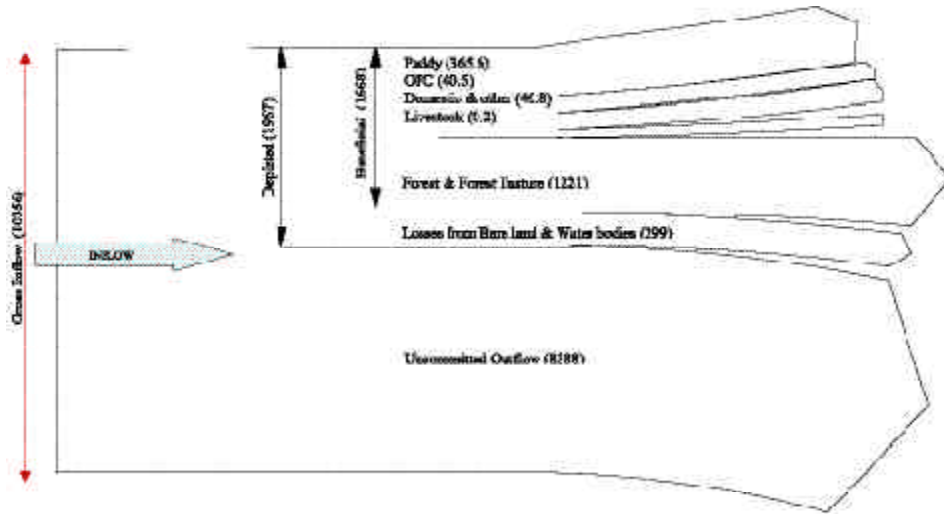
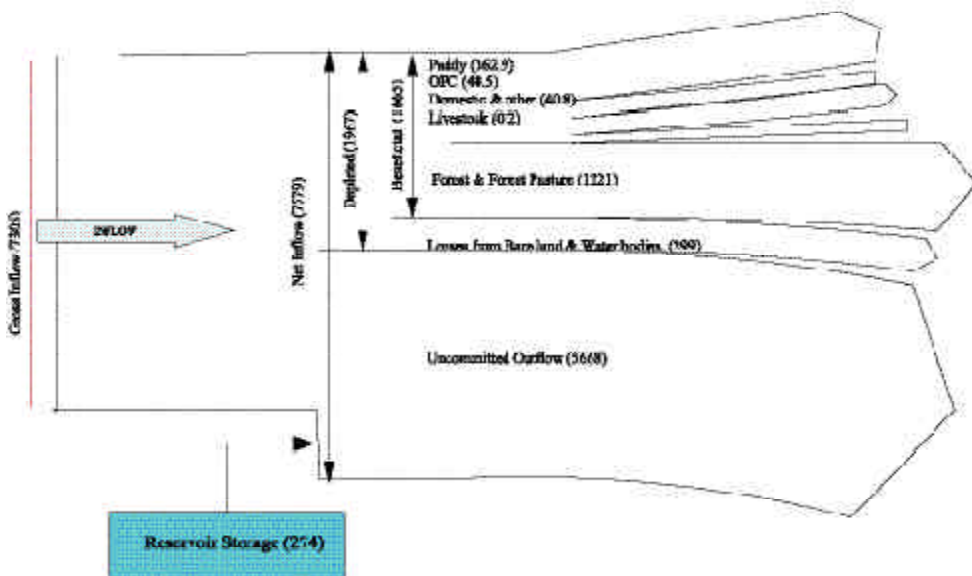


Figure 2. Water accounting diagram for the Omono Gawa river basin in (MCM) Japan, 1994.



Institutional Structure

Water is an important factor in Japanese society. The importance of rural communities and agriculture is embodied in the regulatory framework that controls water management in the country, the Rivers Act, first promulgated in 1897. This original act, and the Revised 1964 act specify firstly, the need for regulation of water to be vested in a single agency (Ministry of Construction), and secondly the principle of protecting traditional and existing uses.

The LID system has become recognized as one of the more successful innovations in the region to support user involvement in management of irrigation and water resources schemes. The experience in Japan has some enlightening and useful facts of more general relevance. Farmers in the LIDs are involved in effective water use and wish to increase their income in response to the price signals for agricultural produce. Farmers have a sense of both ownership over the water and belonging to irrigation facilities. The sense of ownership and shared responsibility are essential trends in farmers' self-governance of irrigation and the in attaining effective, equitable and sustainable use of water.

However, the LID system has grown out of a long experience in communal management of land and water resources and it should not be forgotten that this experience has included many years of bitter and painful conflicts among farmers concerning water allocation. The prevailing system of water management has been developed gradually by farmers themselves, subsequently being formalized by the Land Improvement Act, promulgated in 1949.

By the early 1960s environmental concerns became evident and Japan focused on the deterioration of the environment and communities. A new Environmental Pollution Control Act was promulgated in 1967, followed by the establishment of the Environmental Agency in 1971. Aggravation of pollution from excessive use of agricultural chemicals led to the issuance of the Agricultural Chemical Control Act in 1970.

In common with many countries, there are many institutions with interests in management of water resources. In Japan, the Ministry of Construction has the predominant role in river basin development and management, a position that has been maintained for over 100 years. However, although the role of the public sector is central to water resources management, farmer groups have a well-established role based on participatory development and management of natural resources for protection of agricultural water resources. In many cases, it is the farmer groups that take the initiative to identify requirements and to specify development objectives. The institutions with defined roles in the management of water resources are summarized in table 5.

The central office of the Ministry of Construction nominally allocates water resources. However, in most cases, allocation is delegated to the local prefecture office as approved by the 1964 Rivers Act (GoJ 1964). Licenses for abstraction of water from the main rivers are issued, without charge, for periods of 10 years. The delegated authority allows the local Prefecture Office of the Ministry of Construction to allocate water resources in tributary streams, subject to maintaining agreed minimum discharges at the confluence with the main river stem. Allocations from the main river stem are made under delegated authority from the Ministry of Construction to the Governor of the Prefecture. These allocations confer rights to extract water to approved maximum rates and for defined periods, as summarized in table 6.

Table 5. Summary of institutions with water-management responsibilities.

Organization	Level	Institution
Irrigation Department	National	Construction Department, Ministry of Agriculture, Forestry and Fisheries
	Provincial	Akita Prefecture Agricultural Policy Department
Water Resources Board		Water Resources Development Public Corporation
Environment	National	Nature Conservation Bureau of Environment Agency
	Provincial	Akita Prefecture Dept. of Life & Environment
Agriculture	Provincial	Akita Prefecture Agricultural Policy Department
Agrarian Services	Provincial	Akita Prefecture Agricultural Policy Department
Agricultural Development	Provincial	Akita Prefecture Agricultural Policy Department
Inland Fisheries	Provincial	Institute of Fisheries and Fisheries Management– Akita Prefecture Agricultural Policy Department
Water User Organizations	National	National Federation of Land Improvement Associations
	Provincial	Akita Prefecture Federation of Land Improvement Associations
	Omono Gawa	99 Land Improvement Districts serving about 73,000 ha of irrigation, drainage and flood control schemes.

Table 6. Summary of allocation of water rights in Omono Gawa (1999).

Sector	Allocation (m ³ /s)
Agriculture	143.0
Municipal and domestic	2.27
Industrial	3.40
Total	148.67

In addition to the decentralized authority over water exercised by the various ministries with water-related responsibilities, water users as represented by the Land Improvement Associations also play a significant part in the administration of water. At the Prefecture level, the Federation of LID associations adjudicates water-related disputes among the member associations. The federation and member organizations have played an important role in the development and management of the basin, originally in the development of the major infrastructure over a period of 50–60 years. This was followed by second-stage development of terminal irrigation facilities in the service areas, and included land consolidation to facilitate mechanization of agriculture and improvements to canals, drains and roads. In the third stage, development of sewage and water treatment facilities has been undertaken in collaboration with the municipal authorities.

Although water user rights are protected by licenses (issued by the National Government, Ministry of Construction) during periods of severe drought these rights may

have to be overridden in the public interest. Article 53 of the Rivers Act (GoJ 1964)) makes provision for the establishment of Emergency Coordination Committees with representatives from the water-related stakeholder ministries and line agencies. Representatives of the Ministry of Construction head each committee and they have the authority to adjudicate in the event of conflicting demands for limited water. Coordination Committees are established when drought conditions are declared.

For example, in 1994 the Cabinet of the Government of Japan declared a severe drought condition on 15 July, forming a National Coordination Committee drawn from 13 ministries, headed by the National Land Agency. Eight subregional coordination committees were also established with representatives from the relevant branch offices of the ministries. Of the 47 prefectures 29 were moderately or severely affected by water shortages and implemented emergency coordination committees, referred to as Special Commissions. These committees adopted seven measures to ameliorate the severity of the drought impacts on domestic, industrial and agricultural sectors:

1. Minimum level of power generation was guaranteed.
2. Dead storage water was extracted from reservoirs.
3. Pumping equipment was made available on lease, from municipal authorities, to farmers whose land was out of command due to the drought.
4. New groundwater wells were sunk and existing wells revived.
5. Treated sewage and industrial wastewater was used for agriculture.
6. Desalination plants were established for domestic supplies in the most severely affected coastal cities.
7. Water was imported from Vietnam and Korea for industrial use.

In 1994, the Shikoku Island received less than 40 percent of the mean annual rainfall. As a result, the Kagawa Irrigation Land Improvement District (KILID) in the Kagawa Prefecture worked with the local LIDs to maximize the benefit derived from the sharply reduced inflows (20% of normal flows) to the main distribution system. The LIDs reinstated traditional forms of water distribution, originally superceded following construction of the main intake channel. These earlier distribution systems were based on local irrigation tanks and ponds. Rotation of supply proceeded from upstream to downstream areas, with priority being given to longer-established paddy lands over newly reclaimed land. The *Bansui* and *Hashiri Mizu* forms of rotation were used by different LIDs in response to the preferences of their members. In the *Hashiri Mizu* form of rotation, literally “Running Water,” paddy fields are not inundated with ponded water but water is allowed to flow from lot to lot continuously. For *Bansui* rotation, water is rotated between terminal-area farmer groups, by time in proportion to relative areas served. Terminal areas remote from the source may be abandoned to minimize conveyance losses.

In the Omono Gawa basin, abstractions at the Minase and Naruse barrages for the Omono Gawa-Suji project were reduced and became more variable than in other years as

the impacts of the drought conditions became more evident. However, the drought was less severe in the basin than elsewhere, such as the Shikoku Island, and even in this year significant volumes of water were discharged from the basin.

Environmental Conservation

During the third quarter of the twentieth century the need for the economy to recover from the devastation of the Second World War resulted in the pursuit of shorter-term policies than in earlier times. These policies led to a strong focus on increased agricultural and industrial production and promotion of a strong economy. The pursuit of these goals, almost inevitably, resulted in an increase in the exploitative use of resources to achieve immediate gains.

The period of economic recovery contrasts with established Japanese cultural values that place great value on tradition and ancestral ties. The importance of rural communities and agriculture is embodied in the regulatory framework, the Rivers Act first promulgated in 1897, that controls water management in the country. This original act and the revised 1964 act specify, first, the need for regulation of water to be vested in a single agency (Ministry of Construction) and, second, the principle of protecting traditional and existing uses.

By the early 1960s, the economic renaissance of Japan became focused on the deterioration of the environment and communities. A new Environmental Pollution Control Act was promulgated in 1967, followed by the establishment of the Environmental Agency in 1971. Aggravation of pollution from excessive use of agricultural chemicals led to the issuance of the Agricultural Chemical Control Act in 1970.

A remarkable consequence of the recognition of existing water use by the 1897 Rivers Act, even after a period of a strong focus on production and consumerism, is the continuation of traditional water allocations to irrigated agriculture. During this study it was reported that in 2000, traditional irrigation water allocations, i.e., those that predate the 1897 Act, still account for about 60 percent of the total agricultural use (table 7).

The existence of a clearly enunciated policy and its implementation over an extended period, coupled with (now largely superceded) protectionist policies, has enabled the preservation of agricultural rural communities in northwest Japan. The protection of traditional values has preserved agricultural communities and extensive forest areas, and has provided the basis for the reinstatement of water quality.

Table 7. Summary of traditional water rights as a percentage of current agricultural water allocations (2000).

Basis	Current Use (%)
Area	50
Volume	60
Number of Intakes	80

Water Quality

Individual LID management organizations are responsible for the day-to-day operation, maintenance, and development of the irrigation and drainage systems in the area of operation. These organizations are responsible for the quantitative measurement of water abstractions and also for measurements of the water quality. Consolidated records of water quantity are submitted to the Ministry of Construction each season to demonstrate compliance with approved licenses. The LID and the municipal authorities monitor the water quality to regulate the quality of return flows from municipal areas to agriculture and vice versa.

The Ministry of Agriculture, Forestry, and Fisheries set the standards of water quality for agriculture. The LID can force municipalities or industrial users to construct and operate water-treatment plants if discharges are not within the approved standards. Standards of municipal water intake are higher than those set for agriculture. The LID has not had many difficulties in ensuring acceptable quality of return flows, although standards for pesticides in water are becoming more stringent and may impinge on agricultural practices in the near future.

The Tama Gawa and Naruse branches of Omono Gawa receive highly acidic flows that enter the watercourses from subsurface vents. These flows have resulted in the acidification of sections of the river. In the Tama Gawa subbasin, amelioration of the impacts has been implemented by addition of CaCO_3 through a treatment works near the Tama Gawa lake.

Conclusions

In considering the transfer of the Omono Gawa river basin institutions to other river basins, the socioeconomic conditions of Japan must be fully considered. There can be little dispute that, even after the recent turmoil in Japanese and other Asian economies, Japan is the most powerful economy in the region. This economic base, combined with a shared sense of traditional values and a moderate climate, creates a special environment that has nurtured the implementation of effective river basin management.

Specifically, since the early 1960s, a general and expanding popular demand to redress the detrimental practices of the previous 10 to 15 years, when the focus was increased production at almost any cost, led to a rapid development of water and environmental regulations. A long history of comprehensive river basin management under the Ministry of Construction, mandated by the 1897 Rivers Act, and the acceptance of rule of law by society in general, have provided the basis for effective management of water resources. The economic resources of Japan, due to its strong international trade, enabled deployment of advanced systems to support the implementation of the basin management philosophy. The widespread acceptance of the rule of law and a recognition of the intrinsic value of the natural environment, linked to the perception of cultural value of agriculture and rural societies have enabled the maintenance or restoration of the basin conditions. The economic base of the country has provided the capacity to implement the necessary infrastructure to address the needs to increase flood protection and to provide responsive irrigation systems.

The Omono Gawa basin is not short of water. Only about 20 percent of the mean annual discharge is consumed within the basin. Two large reservoirs perform both flood control and

water supply functions. These have ameliorated some of the worst water-related problems in the basin. The area of paddy rice has been reduced over the past 20 years as the impacts of reduced consumption took effect, as the nation became more wealthy and reduced subsidies.

Where the quality of the river water has been degraded due to natural inflows from acidic vents, the basin authorities have been able to implement water treatment works to ameliorate the impacts of these flows. Where domestic, industrial or agricultural return flows adversely affect water quality, the effective implementation of the existing regulations provides a mechanism to require the polluting party to treat the effluent. Both municipal and agriculture sectors, and the LID associations, have the necessary technical skills to confirm the compliance of the other sectors with the appropriate regulations.

The important lessons for other basins are the following:

Administration of a water-surplus basin does require positive management to ensure that drainage and flood-control structures are operated and maintained correctly. Also, even in water surplus basins, during times of drought there needs to be a well-documented and effective system available to manage revision of water allocations to ensure that basin-scale impacts are minimized.

Water-quality issues can be dealt with effectively when the sectors involved are able to monitor and evaluate compliance of the other sectors.

Water-management agencies focused on agricultural water management, such as the LIDs in the Omono Gawa basin, have a major role to play in the management of water resources. With appropriate delegated authority and support these agencies can be highly effective.

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CHAPTER 13

Integrated Water-Resources Management in a River-Basin Context: The Brantas River Basin, Indonesia

Tri M. Sunaryo¹

Introduction

Background

The motto of the 1999 World Water Day, “everybody lives downstream,” helps us to think of upstream-downstream relationships in water resources systems. It highlights the need to think beyond the traditional focus on isolated sites of water use entities, such as irrigation systems, hydropower plants or water purification plants. In a new paradigm shift related to integrated water resources management (IWRM) in the context of a river basin, attention is now being drawn to consider the upstream “off-site” influences on the various water use entities, as well as the downstream “off-site” impacts arising from them.

Along the path of water flowing in a river basin are the many water-related human interventions, including water storage, diversion, regulation, distribution, application, pollution, purification and other associated acts to modify the natural systems. All of these have one common effect, to impact those who live downstream of the water flow. This rather simple, but seemingly new, revelation drives home the concept that a river basin analysis of water would enhance the common understanding of the issues on overall productivity of water and related strategies. It also tends to highlight the importance of equity and sustainability issues related to IWRM.

The International Water Management Institute (IWMI) with financial support from the Asian Development Bank (ADB) is conducting a regional study on “Developing Effective Water Management Institutions.” The study is intended to help improve the management of scarce water supplies available for agriculture, within and responsive to a framework for IWRM in river basins. The Brantas river basin was selected as one of the case studies in this IWMI study, because the river basin management agency, Jasa Tirta I Public Corporation (PJT I), has been involved in preparing master plans, deciding on priorities and developing infrastructure for multiple uses. PJT I now acts as an autonomous water resources management organization for the Brantas basin, which seems typical for the requirements

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of many developing river basin situations in Asia. This case study is expected to illustrate how an effective institutional framework and a single basin organization have been developed and installed to cover multiple uses of water in a large river basin.

This paper begins with an explanation of the national water sector policy, focusing on the shifts of paradigms, basic policies, and principles of river-basin management and the corporatization of water resources in a nationwide context. The next section deals with laws governing water in Indonesia and also summarizes the role and competence of water resources stakeholders. Next, the paper introduces the Brantas river basin. In the following section, this basin is dealt with more deeply. The evolution of institutions is described: legal, financial and other aspects are explored. Finally, some achievements as well as some constraints of this institutional and legal arrangement are discussed.

National Water-Sector Policy

Paradigm Shift

Recent socioeconomic development has led to a shift in paradigms for water resources in Indonesia as in many other countries. Water that has always been regarded as a social good has transformed into an economic good with social functions. This paradigm change also affects the government role, which shifts from being a provider towards an enabler, from a centralized towards a more decentralized approach, from a single purpose towards a multi-sector approach, and towards broader participation.

In this perspective, water resources could be regarded as a national resource that must be managed wisely in order to gain the most benefit for the welfare of the people, both the present generation and future generations. Water could create conflict among the beneficiaries and among the users. Water is considered as strategic in order to sustain national development, so it requires a national commitment to conserve its sustainability. To gain a national commitment, utilization of water resources should involve public participation in every aspect, both managerial and investment, as well as financing of operation and maintenance (O&M). In this context, major points to be taken into account, especially in reviewing the available policies and legislation, include improving governance, institutional and individual capacity building, instituting demand and supply-management techniques and economic instruments, and promoting protection and conservation of water resources.

Basic Framework

Basic principles River basin management, as stated in Indonesian Government Regulation No. 35 of 1991 on Rivers, Article 2, consists of development, utilization, conservation and control of water resources. River-basin management could be defined as an effort to realize utilization of water resources to satisfy all demands, in an efficient and effective manner, with fair and even distribution, by taking into consideration conservation and control of water and its resources. River-basin management should be integrated (multi-sector), comprehensive

(upstream-downstream), sustainable (intergenerational equity) and based on an environmentally sound concept (ecosystem conservation) with the river basin (hydrological area unit) as one management unit.

These management principles are well summarized in the philosophy of “one river, one plan, and one integrated management.” One river (meaning river basin) is a hydrological unit that could cover several administrative areas defined as one management unit. In one river there should be only one integrated, comprehensive, sustainable and environmentally based concept of a development and management plan. One management system should guarantee an integration of policies, strategies, and program as well as implementation of the system for all of its reaches. The scope of river-basin management covers the management of the watershed, water quantity, water quality, flood control, river environment and water-resources infrastructure; and research and development (R&D).

Basic policy. To achieve its management objectives, the following basic policies are recommended for river basins:

- A river as a natural resource comprises social, economic and ecological aspects that should be utilized optimally for the welfare of the people.
- River-basin management should be based on environmental conservation, public service and economic viability.
- Those who obtain the utilization and amenity benefits from the water and water-resources infrastructure should gradually bear the cost of river-basin management.
- To obtain commitment, society should be involved in decisions on all management aspects (planning, implementing, supervising, controlling and funding) by means of a coordination body, referred to as a Water Resources Management Committee.
- River-basin management should be undertaken as a priority for strategic rivers by considering the local socioeconomic level, water demand and level of utilization and availability.
- Activities of river-basin management should, as much as possible, be corporatized by using the potential of both central and local government-owned corporations (BUMN and BUMD), public-private cooperation and private companies.
- Corporations are established in river basins where the beneficiaries can afford to pay contributions.

Role and Competence of the Stakeholders

Functions, tasks, rights and obligation of the stakeholders are shown in table 1. Stakeholders in water-resources management can be classified into three groups:

- The government, as the owner of the water resources and infrastructure, and to enhance the national welfare, plays the role of controlling, regulating and policing at the national and regional levels. It has also the right to have part of the revenue that the river-basin management institution gains while, on the other hand, it is obliged to contribute funding for activities towards public safety and welfare.
- The River Basin Management Agency, as the operator, has authority delegated by the government to manage water resources and infrastructure, perform river-basin management and develop the management system. The river-basin management institution has the right to collect fees from the beneficiaries as well as to receive contributions from the government for public-safety and welfare activities. It is obliged to give good services and promote public and private participation in the river-basin management, as well as give accountability for performing tasks for the government and society.
- Society, as users, has the right to receive good services and participate in decision-making processes, but it is expected to use water efficiently, take part in sustaining the environment, provide its financial responsibilities and, finally, provide constructive social control on river-basin management. Legal bodies and social bodies, such as water users associations, are included in this group.

Corporations

Purpose. Water is an economic good with a social function utilized by competing users (within and between sectors and across administrative boundaries). Therefore, a river basin should be managed by a neutral and professional institution that applies healthy corporate principles and general utilization norms on water resources based on public and private participation.

Objectives. Water-resources management should be conducted by a River Basin Management Agency (RBMA), a neutral and professional institution, that applies a balanced approach in its undertakings as well as protecting public interests in water- resources management and relying on public and private participation. Objectives of water-resources corporatization are as follows:

- Develop a river-management system that conserves the river as an integrated part of the ecosystem, while preserving its economic potentials and functions for the people's welfare.
- Improve the performance of river-basin management in a useful manner.
- Improve public and private participation in water resources management, including payment for services, in order to reduce demands on the national and regional government budgets.

- Develop a harmonious and well-motivated working environment to sustain prime-class service for public demands through competent management of water-resources infrastructure for stakeholders' satisfaction.

Scope of work. The basin corporation should develop master plans (including coordination with related agencies) in conservation, water-resources development, water-pollution control, flood control and land use of riverbanks. It should operate and maintain water-resources infrastructure, manage water and water resources and carry out watershed conservation in coordination with related agencies.

Financial sources. To achieve sustainable development, the budget for river basin management needs to be secured. This requires beneficiaries to gradually bear the cost for the river-basin management through the application of the following principles. The *beneficiaries-pay principle* consists of the *users-pay principle*, where the water users pay water use fees and taxes; and the *polluters-pay principle*, where the water polluters pay pollution fees and taxes. The *government-obligation principle* applies for funding semicommercial water use (irrigation) and social services (flood control, water-quality control, water-resources conservation).

Scope of Activities

Water-resources development. Water-resources development is an attempt to optimally use water potentials and prevent loss of capacity. Considering the uneven distribution of water availability during the year, it may be necessary to carry out water-resources development so that it will be useful for the welfare of the people. In the upper reaches, reservoirs are built to control floods, store water during the rainy season and to supply water in the dry season. In the middle and lower reaches, barrages and intakes are built for various purposes (irrigation, industry, drinking water, etc.). Finally, at the estuary, barrages are built to prevent saltwater intrusion into the river. Water resources development should use a holistic approach, well planned, with sustainable and environmentally sound management, performed in stages, reviewed and adjusted to the government's national policies. Basically, water resources-development goes through stages of SIDLACOM: *design* (covering SID: Survey, Investigation and Engineering Design), *construction* (LAC: Land Acquisition, Construction), *O&M*, as well as evaluation of the development results in order to adjust future development.

Water-resources management. Water-resources management activities enhance the development benefits and prolong the life of the water-resources infrastructure. In water-resources management, O&M are the main activities during the post- development phase of managing the water-resources infrastructure. Operation is an attempt to control and allocate water and its resources to achieve optimum utilization according to the purpose and minimize negative impacts, such as flood and drought. Maintenance is an attempt to securely sustain water resources, infrastructure and the environment. The scope of activities in O&M covers a range of issues discussed in the following paragraphs.

Watershed management. Watershed conservation consists of greening, reforestation, terracing, and other related activities in the frame of increasing sustainability of the watershed. To implement watershed conservation, it is necessary to establish coordination among related institutions. The RBMA plays an important role, especially preparing recommendations on the water-resources conservation program based on a Watershed Conservation Master Plan.

Water-quantity management. Water use licensing is a form of acknowledgment of water use rights as well as an instrument to control water use. The legal basis of water use licensing is the Government Regulation No. 22 of 1982 and other subordinate legislation at the provincial level. The RBMA issues technical recommendations on applications for water-use licenses. Water allocation is an attempt to manage a reservoir operation pattern (planning) based on demand proposals and water availability prediction. This allocation plan is prepared by the RBMA, then discussed and agreed in the coordination meeting of the Water Resources Management Committee (PTPA). Water distribution is an attempt to operate water resources infrastructure in order to distribute water to beneficiaries according to the agreement as stipulated in the PTPA meetings.

Water-quality management. Effluent discharge standards have set the allowable limit of concentration and amount of pollution load in wastewater discharged by a certain activity. This standard is used for effluent discharge licensing. Effluent discharge licenses provide a basis for controlling water pollution through law enforcement. The RBMA gives technical recommendations as one of the bases for approving the issuance of an effluent discharge license. Monitoring of water quality is carried out periodically, both for river water and for effluent discharge of dominant industries, tested in the laboratory. Monitoring results, evaluation and recommendations prepared by the RBMA are forwarded to the local government as a basis for law enforcement. Pollution control is carried out both in-stream (by means of flushing, increasing the capacity of river assimilation) and off-stream (at pollution sources) through implementing laws and economic instruments, as well as attempting to increase social control by society. The RBMA actively participates in the control of the pollution of water quality by preparing a Pollution Control Master Plan.

Flood-control management. Flood-control management attempts to control flood discharges by hydrological observation using telemetric equipment (Flood Forecasting and Warning System—FFWS), preparing a seasonal weather and flood prediction using a computer facility, which is connected to national and international databases, and by controlling water gates to distribute discharges. The RBMA prepares a Flood Control Management Plan and Manuals, and undertakes the control of the flood discharge by operating the infrastructure along the main river. The flood-control program is coordinated, discussed and decided upon at the PTPA forum before the onset of the rainy season. During flood disasters, the RBMA is involved in the Basin Flood Hazard Mitigation Unit, together with other concerned agencies that support the natural disaster countermeasures of the province.

River-environment management. River-corridor maintenance controls river corridor land use to protect the function of the river-safety area and to increase the benefit of the river for tourism and water sports. In any management practices, the river basin management agency

cooperates with related institutions and authorities. The government institutions act as a regulator that concentrates on guidance and regulation, while implementation of specific aspects in water-resources management is undertaken by the RBMA. In the Brantas river basin, the Provincial Water Resources Agency is the responsible institution for directing water-resources management; while PJT I acts as operator of tourism and sports activities at sites that are within its command. The RBMA implements river-environment land-use management by preparing land use patterns (planning) based on local and regional spatial planning through close coordination with related institutions in the basin, particularly the Provincial Development Planning Agency and the Provincial Water Resources Agency

Water-resources infrastructural management. The RBMA implements water resources infrastructural management mainly related to maintenance. Preventive maintenance takes the form of routine and periodic maintenance, and small repairs to prevent serious damage. Corrective maintenance covers large-scale repair, rehabilitation, and rectification to restore and increase the functions of the water resources infrastructure. Emergency maintenance involves temporary repairs that have to be done urgently due to an emergency condition, such as a flood.

R&D. To carry out water management activities it is necessary to follow knowledge development and proactively try to introduce innovations both in technology and management systems. To properly carry out water resources management, the RBMA carries out R&D, through cooperation with both national and international institutions.

Data networks and management information systems. Data sharing and information systems among government agencies should be developed and operationalized. The RBMA should develop a water resources data center for society and concerned agencies. To promote sustainability of hydrological operations and data, hydrology institutions and organizations should have appropriate administrative and budgeting arrangements along with a personnel program. Among the various data collected by the diverse institution, PJT I maintains and analyzes data on the surface water in the basin for reservoir operational purposes in maintaining water quantity, as well as quality to a certain extent, within the command area of 40 rivers in the basin. Other institutions, such as the Provincial Water Resources Agency, maintain and analyze the data on surface water for specific purposes of irrigation or flood control outside of the 40 designated rivers under PJT I in the Brantas river basin.

Water Policy

Considering the importance of water resources for the future of the nation and realizing the problems encountered in the past, the Government of Indonesia is reforming water resources policy to improve:

- the national institutional framework for water resources development and management
- the organizational and financial framework for river-basin management

- the regional water quality management regulatory institutions and implementation
- irrigation-management policy, institutions and regulations

Decentralization policy in Law No. 22 of 1999 on Local Governance states that the local governments shall have authority as much as possible in their own territories. Government Regulation No. 25 of 2000 on Central Government Authority and Autonomous Provincial Government Authority provides implementation guidance for this law. In applying these regulations in water resources management for any river basin which covers more than one district or municipality, the basic principle of “one river, one plan, one integrated management” should be kept as the basic principle for the implementation of integrated water resources development and management. This principle, of course, is intended to avoid inter-territorial conflicts.

Sectoral prioritization. It is stated in Indonesia’s 1945 Constitution that the earth, water, and all natural wealth contained in them are governed by the State and utilized as much as possible for the welfare of the people. This principle is the basis of all legislation for water resources management, such as Law No. 11 of 1974 on Water Resources, and Government Regulation No. 22 of 1982 on Water Resources Management. In particular, Government Regulation No. 22 of 1982 on Water Resources Management states the principle and fundamentals of water rights, and states that in water management the principle of public utility, harmony and conservation shall be applied.

Financing system. According to the basic legislation for water resources, Law No. 11 of 1974 on Water Resources, all the beneficiaries should be able to be involved in financing management. Society may contribute, but legal bodies, social bodies and individual water users should also contribute. It is elucidated in Government Regulation No. 22 of 1982 that any payment for water use is not a payment for the water, but is for the management service. Therefore, beneficiaries who either consume the water or only utilize the water potential should be treated equally in terms of their financial contributions.

Further legislation on financing water resources is found in Government Regulation No. 6 of 1981 on Contributions for Funding Water Resources Infrastructure Exploitation and Maintenance. This legislation states that the fee collected from the beneficiaries consists of the fee collected from those who benefit from water use and convenient water availability, and the fee collected from those who pollute the water. From these two types of fee, the water use fee has been applied, while the pollution fee is under preparation. However, according to this Government Regulation the fee may be paid to government-owned companies if they have been assigned by the government to manage the water resources. Law No.34 of 2000 revises the older Law No. 18 of 1997 on Taxes and Retribution, providing for a water tax, separate from any fees. The tax revenue goes to the province, which may redistribute it according to the development priorities and policies; and so may fund the managing agency, in this case, PJT I for the Brantas basin.

Table 1. Matrix of role and competence of the stakeholders.

Item	Government	RBMA	Society
Function	Policy and control ^a	Operator	Users
<i>Task</i>	Set up policy and regulations. Perform public authority (law enforcement, licensing, etc.). Carry out control and supervision on the task performance of the water management agency.	Carry out river utilization in the river basin, covering planning, development, utilization, control and conservation of water resources. Develop river management systems to secure the river basin function.	Use water efficiently in accordance with licenses and other authorized abstractions. Carry out treatment of respective effluent discharge according to the license received and the promulgated rules.
<i>Right</i>	Collect tax on surface water use from the beneficiaries. Share the profit of the water management agency according to the promulgated rules.	Collect contributions from the beneficiaries for the commercial services and to receive contributions from the government for social services (public safety and welfare).	Receive good services. Participate in decision making in all stages of activities.
<i>Obligation</i>	Guide the water management agency in carrying out its tasks. Contribute to funding of activities for public safety and welfare.	Render prime services to the beneficiaries. Attempt to increase public and private participation in river utilization. Accountable for task performance and fund utilization to government and the society.	Contribute to funding. Give positive social control. Conserve the environment by participating positively in water-resources conservation activities, such as greening, reforestation, terracing, etc.

^a 1. Central Government: Setting up macro policies and regulations for national level.

2. Local Government:

a. Provincial Government: Setting up policies and regulations as operational basis for the RBMA for inter-district/municipality river basin.

b. District/Municipal Government: Setting up policies and regulations as operational basis for the RBMA for river basins located in a single district/municipality.

Water Users' Participation

Water users' participation has been considered since the 1970s. Law No. 11 of 1974 states that water users can participate in the operation, maintenance and rehabilitation of water resources infrastructure. According to Government Regulation No. 22 of 1982 society is supposed to help the government in:

- controlling the destructive capacity of water on its source and environment,
- controlling and preventing water pollution, and
- protecting and securing the sustainability of infrastructural function of water resources

Particularly for the construction cost of water resources infrastructure, it is stated in the above regulation that the construction cost is borne by the government, but the members of society who obtain direct benefit from the infrastructure can participate in the financing according to their concern and ability. In the future, it is proposed in the reformed water resources policy that the society as the water users should be included in the decision-making process as well. Implementation of this stakeholder participation is described in the following paragraphs.

Water-sector apex body. A national water-sector apex body should be established to manage a coordination framework for national water resources. The apex body, comprising various ministers concerned with development and management of water resources, together with stakeholder representatives, will be responsible for guiding the development and management of water resources. The apex body will give guidance in policy formulation, resource allocation, program implementation and regulatory control in general, and inter-sectoral coordination and issue resolution in particular.

Stakeholder representatives. To promote stakeholder participation, a permanent group of stakeholders, NGOs, and public representatives will be part of the apex body. Currently, Water Resources Management Committees (PTPAs) have been set up at the provincial and basin levels in some provinces, and these will also include stakeholders. These committees, which are responsible for their respective governors, are supposed to be coordination bodies where decisions on management policies (planning, implementing, supervising, controlling, and funding) in their respective areas are made.

PTPA members currently come from the water-resources-related agencies and the water-using companies (State Electricity Company and Municipal Water Company). Other water users are represented by the related local government agencies, such as Irrigation Service, Industrial Service and Agricultural Service. However, it is planned to include all the stakeholders, such as farmer associations and industrial associations. In carrying out its tasks, the PTPA is supported by an implementing committee for each river basin area, which is called the Basin Water Resources Management Committee or PPTPA. This basin committee has a technical team for each activity area, which so far exists only for water allocation and flood control but it should be expanded to cover other areas as well, such as watershed management and water- quality control.

Private-Sector Participation

Infrastructural development is very important in supporting and realizing national development sustainability but government financial capability is very limited, so private companies should

participate in water resources development and infrastructural management in cooperation with the government. To be able to implement private sector participation, the government issued Presidential Decree No. 7 of 1998 on Cooperation between Government and Private Companies in Development and Management of Infrastructure. This decree regulates the preparation for cooperation, the selection of investors, contracting and implementation monitoring, in order to have transparency in the process, free competition for the private sector and an optimal service cost for society.

The basic concept of private sector participation is as follows:

- Private sector participation means a concession given by the government.
- The private sector has a right to have revenue.
- The government gives protection, assurance and regulation.
- Private-sector participation does not overburden the users.

Water and water resources may be developed by the private sector under the conditions that:

- The water user should have a license from the government.
- The water use is based on a principle of cooperation.
- The water user should keep conserving the ecosystem.

Water is an economic good that has a social function as well so that it should not be managed merely commercially or merely socially. Based on this concept, private sector participation in the development and management of water resources could be carried out through a partnership with the RBMA. The RBMA functions as the government's agent in managing water resources to keep the balance of the two, in order to achieve the business purpose as well as to keep the public service.

Water Laws

Water Sources

The Indonesian Constitution of 1945 gives the fundamental principle for water resources management. In Article 33 of the Constitution it is stated that the earth, water and any wealth in them are governed by the State and utilized as much as possible for the welfare of the people. At present, the basic law for water resources management is Law No. 11 of 1974 on Water Resources, which is supported by the Government Regulation No. 22 of 1982 on Water Resources Management. A new water law is under preparation, but the discussion in this section describes the situation under the existing law.

Water Uses

According to Law No. 11 of 1974 Article 5 Paragraph (1), inter-sectoral water uses are coordinated by the minister who has responsibility in water resources. Government Regulation No. 22 of 1982 gives detailed items and activities for coordination. The coordination items are: a) establishing water and water body use priority plans, b) setting priorities for water and water body use in conservation, development, and utilization plans, c) water and water body use regulation, d) regulation of the method for disposal of wastewater, as well as other waste material, e) regulation of the construction of water resources infrastructure, and f) regulation of other problems that may occur.

Coordination activities include a) collecting water quantity and quality data as well as inventories, b) collecting water demand data and recording the water balance, c) carrying out studies related to water resources conservation, development and utilization, d) preparing policy formulation in water resources development planning, e) preparing the water resources development plan based on the above policy, f) providing assistance and opinion in technology to related departments, local governments, agencies and other institutions in preparation of water resources use at national, regional and local levels, g) regulating the method and the condition as well as the registration of water resources use, h) regulating the method and the condition of wastewater disposal as well as other liquid and solid waste materials, and i) regulating the methods for supervision and control of the above policies. Water distribution is based on a water-allocation plan, which is agreed by the representatives of the water users and the water manager in the Water Resources Management Committee, Panitia Tata Pengaturan Air (PTPA).

Water Rights

The basic legislation for water rights is the Basic Constitution of 1945 Article 33 as mentioned above, which states that water resources are governed by the State and utilized as much as possible for the welfare of the people. Government Regulation No. 22 of 1982 gives the principle and the basis of water: (1) In water management regulations the principles of public utility, harmony and conservation shall be applied; and (2) A water right is a water use right. Moreover, this Government Regulation states that everybody has a right to use water for their main need in daily life and their livestock. This also conforms to the earlier Basic Agrarian Law No. 5 of 1960.

Water-Pollution Control

The legal basis for pollution control is Law No. 23 of 1997 on Environment Management, which replaced Law No. 4 of 1982 on Main Regulation of Environment Management. A Government Regulation following the new Law is under preparation, but, in the meantime, all legislation based on the previous law is still valid. According to Government Regulation No. 20 of 1990 on Water Pollution Control: (1) the responsibility for water pollution control lies with the Governor. East Java Province, which is the most advanced province dealing with water pollution control, has issued regional legislation, Provincial Regulation No. 5 of 2000

on Water Pollution Control. According to this Regulation, the Governor's responsibility can be delegated to the Head of BAPEDALDA. This means that BAPEDALDA is the agency, which coordinates all other agencies concerned with water pollution control. The RBMA, as articulated in the Ministry of Public Works Regulation on the management of the RBMA, is supposed to actively participate in supervision and control.

The legal basis for the water polluters to pay fees is stated in Government Regulation No. 6 of 1981 on Contribution for Funding Water Resources Infrastructure Exploitation and Maintenance. It says that the contribution for funding water- resources infrastructure O&M covers the funds collected as a payment from those who, due to their business activities, have caused water and water body pollution in the Corporation's river basins. Although this legislation meets the condition for river basins managed by a public corporation, the government is at present trying to set up all legislation needed for wastewater disposal licensing and fee collecting for all river basins.

Participation of Water Users

Ever since the basic legislation of water resources management was set up in Law No. 11 of 1974, participation of water users has been formulated. It is stated in this law that to secure the sustainability of infrastructural function of the water resources, the O&M of the structures should be carried out by involving the society, either legal bodies, social bodies or individuals that directly benefit from the structure. The government, central and local, operates and maintains the structures for public welfare and safety.

In regard to financing, the law states that those who directly benefit from the structure may be involved in bearing the cost of a replacement, while legal bodies, social bodies and individuals that benefit from the structure should participate in financing, in the form of a fee paid to the government.

Accountability of the Parties in Water Services

Legal instruments for ensuring the accountability of water service providers and users takes the form of a contract, which is made between the RBMA and the users who must have water use licenses. Government Regulation No. 6 of 1981, on Contributions for Funding Water Resources Infrastructure Exploitation and Maintenance, says that the obligation of the water users to pay the fee should be stated in a contract document between the RBMA and the users. However, the contract also states the obligations of the RBMA.

Conflict Resolution

In general, any conflict that may arise should be resolved in the coordination forum, such as PTPA. The PTPA can resolve water use conflicts (in quantity) effectively. However, in case it concerns the water quality and the water use fee, usually the conflict is discussed between the parties concerned based on the available legal documents. If this does not work, a mediator will be needed, since taking the case to courts is the last resort. The mediator is usually

somebody who has more power than the conflicting parties; it may be the Governor, the Regional Assembly or the Minister of Finance.

One problem with RBMA is that they have very limited public authority. They cannot stop delivering water to any water user who does not want to pay, nor can they stop wastewater disposal that pollutes rivers. Public authority is held by the Governor. As a government-owned company, PJT I is designated to act only as an operator of water-resources infrastructure, that deals with water, enhances conservation, performs O&M and does other specific tasks in water resources as ordered by the government. PJT I does have the right to stop water delivery to users who do not comply with the water service contract or refuse to pay their fee. But in terms of river water quality PJT I cannot stop the wastewater produced by the polluters. Unless a polluter-pays principle is adopted, PJT I will solely act as a water-quality monitoring institution, even though there are arguments that in its present state PJT I is supporting the government in enforcing the water-quality regulation on the Brantas river. How the government can force polluters to pay their fees is still being discussed and is part of the reform agenda.

Physical Characteristics of the Brantas River Basin

The Brantas river has a watershed of 11,800 km² and stretches 258 km from the spring at Mt. Arjuno to the point where it branches into two rivers, the Surabaya river and Porong river, both of which flow into the Madura Strait. The river flows clockwise with Mt. Arjuno and Mt. Kelud as its center. Along the main flow there are many tributaries, among which are the Lahor, Konto, and Widas rivers (as shown in figure 1). The average population density is 978 persons/km².

Historical Perspective

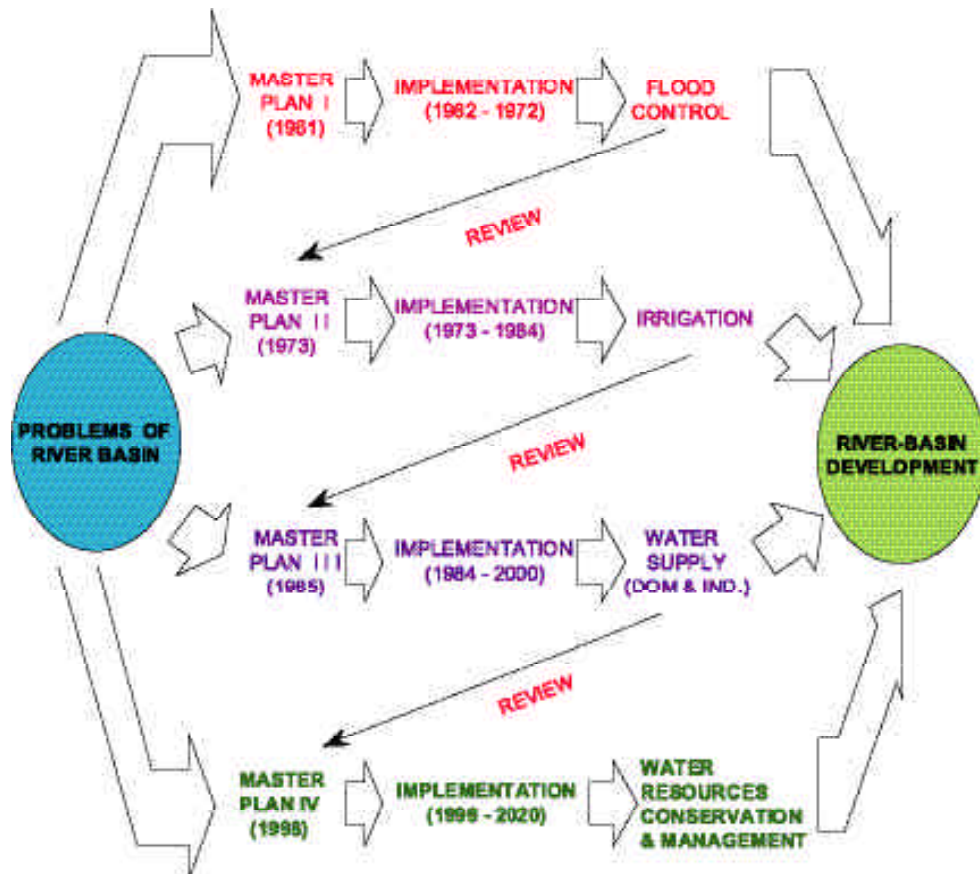
The river valley is very fertile; it has been developed since the nineteenth century, when the Dutch colonialists built irrigation and flood diversions. However, integrated water-resources development was started in 1960 through a series of master plans. In 1961, the first master plan (Master Plan I) with the main purpose of flood control was prepared using Japanese reparation funds. Large reservoirs, constructed in the upper reaches for reducing floods, also supplied water for irrigation as well as for hydropower generation.

In line with the government policy in the decade after, which was “self-sufficiency in rice production,” the first master plan was reviewed in 1973, becoming the second master plan (Master Plan II) with the main purpose of supplying water for irrigation. In this period more reservoirs and barrages were built. A flood-control project in the Ngrowo basin was continued in this period, changing a swampy area into a farmland.

Having success with self-sufficiency in rice production, the government then started to strengthen the industrial sectors in 1980s, so that the river-basin development plan was reviewed again in 1985 to form the third master plan (Master Plan III) with the main purpose of supplying water for industry and municipalities. In this period, as the industries boomed, many land use changes occurred, from irrigated land into industrial areas as well as new

settlement areas. In 1997, this process was halted by the national economic crisis. However, the Brantas river water is now used for hydropower generation, domestic use, irrigation, fishery and industrial water supply as well as for recreation. A need to review Master Plan III was then felt, with the main purpose of arranging better conservation and management of water resources. Master Plan IV was ready in 1998. Figure 2 shows the development of the Brantas basin through the master plans.

Figure 2. Master plan of the Brantas river-basin development aspects.



Water Resources in the Basin

The average precipitation in the basin is about 2,000 mm/year, of which about 80 percent falls in the rainy season. The potential surface flow is approximately 12 billion m³/year, while the total annual utilization is about 3 billion m³/year. The physical aspects of the Brantas basin are shown in table 2.

Table 2. Physical aspects of the Brantas basin.

Main River: Kali Brantas	Length	320 km
Geophysical coordinates	110° 30' and 112° 55'	East longitude
	7°31' and 8°15'	South latitude
<i>A. Catchment Area</i>		
Kali Lesti		625 km ²
Kali Konto		687 km ²
Kali Widas		1,539 km ²
Kali Brantas		6,718 km ²
Kali Ngrowo		1,600 km ²
Kali Surabaya		631 km ²
Total		11,800 km ²
<i>B. Reservoir Capacity^a</i>		
(Sengguruh, Sutami, Lahor, Wlingi, Lodoyo, Selorejo and Bening)		
Gross storage (initial/present)		525/297 million m ³
Effective storage (initial/present)		378/247 million m ³
<i>C. Water Availability</i>		
Average precipitation		2,000 mm/year
Runoff coefficient		0.50
Potential flow		11.8 billion m ³
Natural flow in the Brantas mainstream ^b (1977–1999)		7.51 billion m ³
<i>D. Water Utilization^c</i>		
Irrigation		2,400 million m ³
Domestic		209 million m ³
Industry bulk supply		139 million m ³
Maintenance flow		204 million m ³
Fisheries (irrigation return flow)		41 million m ³
Total		2,993 million m ³
<i>E. Socioeconomic Condition^d</i>		
East Java population (1999)		35.2 million
Brantas river basin population (1999)		15.2 million
East Java rice production (1999)		9 million ton
Brantas river basin rice production (1999)		2.3 million ton
Gross Domestic Product (East Java, 1999)		152.9 billion Rp
Gross Domestic Product (Brantas river basin, 1999)		89 billion Rp
Brantas basin contribution to east Java		58%

Sources: JICA (1998) and Jasa Tirta I (1998 Annual Report).

^a As computed by Jasa Tirta I Public Corporation (2001 Annual Report) from previous survey results.

^b As computed by Optimal Solutions Ltd. (2000) for the Lengkong Baru.

^c As computed by Jasa Tirta I Public Corporation (2000 Annual Report) from statistical data.

^d Quoted from "Brantas History" Final Report, Volume II–Data Book, Koei Research Institute and Jasa Tirta I Public Corporation.

Water-Resources Infrastructure

At present, there are seven earth dams, six barrages, and three rubber dams in the main river and tributaries with various purposes, as shown in table 3. The location of each can be seen in figure 2. Of the seven reservoirs of the large dams five are operated yearly, the other two, Wlingi and Sengguruh, are operated daily. For reservoirs operated yearly, the operating rule-curve of the reservoir comprises a time frame of a single calendar year. During that period, the reservoir stores water that increases the water level from a certain level to a maximum level and releases the water after this peak level is achieved until it reaches another certain level. Reservoirs operated daily have a shorter time frame, i.e., the whole process takes place in a single day. For example, Karangates is a yearly-operated reservoir with a gross storage

Table 3. Water resources infrastructures in the Brantas river basin.

Structure	River	Purpose
<i>Large dams</i>		
1. Sengguruh dam	Lesti	1. Sediment control to the Sutami reservoir
2. Sutami dam	Brantas	2. Hydropower generation 3. Water supply for domestic, irrigation and industrial uses
3. Lahor dam	Lahor	4. Hydropower generation 5. Flood control 6. Recreation 7. Water supply for domestic, irrigation and industrial uses
4. Wlingi dam	Brantas	8. Flood control 9. Afterbay of the Sutami hydropower plant 10. Water diversion for irrigation 11. Hydropower generation 12. Flood control 13. Recreation
5. Selorejo dam	Konto	14. Water supply for irrigation, and additional supply for hydropower plants downstream 15. Hydropower generation 16. Flood control 17. Recreation
6. Bening dam	Widas	18. Water supply for irrigation 19. Flood control 20. Recreation
7. Wonorejo dam	Song	21. Water supply for domestic uses 22. Hydropower generation 23. Flood control
<i>Barrages</i>		
8. Lodoyo	Brantas	24. Afterbay of the Wlingi hydropower plant 25. Hydropower generation
9. Mrican	Brantas	26. Water diversion for irrigation
10. New Lengkong	Porong	27. Water diversion for irrigation, domestic and industrial uses
11. Gunungsari	Surabaya	28. Water diversion for irrigation
12. Jagir	Wonokromo	29. Water diversion for domestic
13. Tulungagung Gate	Ngrowo/Parit Agung Canal	30. Water regulation for domestic and hydropower uses and for flood control
<i>Rubber dams</i>		
14. Jatimlerek	Brantas	31. Water diversion for irrigation
15. Menturus	Brantas	32. Water diversion for irrigation
16. Gubeng	Mas	33. Water diversion for domestic uses

of 343 million m³; downstream of this reservoir is another reservoir called Wlingi that is operated daily. This reservoir acts as an afterbay of Karangates, regulating the fluctuating water level that exits daily from the Karangates waterway.

Besides the above key infrastructure, there are also two diversion tunnels to release excessive water to the Indian Ocean, a hydropower plant on the coast of the Indian Ocean, and many more irrigation structures along the Brantas river and its tributaries.

Exploitation and Protection of Groundwater

Groundwater in the basin is used mostly for domestic, irrigation and industrial use. The users are supposed to obtain licenses from the Mining Service of the regional governments. Some groundwater, particularly for irrigation use is managed by the Groundwater Irrigation Projects under the Provincial Irrigation Service.

Barriers to Seawater Intrusion

Intrusion of seawater into the Brantas basin does not have any significant effect. The three structures furthest downstream in the basin are Lengkong Baru and Jagir barrages in the Porong river and Wonokromo river, respectively, and the Gubeng rubber dam in the Mas river. Their distances from the sea are about 50 km, 13 km, and 12 km, respectively. These structures are intended to regulate water supply, but the last two also function as barriers to the intrusion of seawater into the Surabaya city. The Brantas Delta Irrigation area downstream of the Lengkong Baru barrage never suffers from salinity.

Water Management Problems

The available water is low due to the high rate of uncontrolled losses, while water demand is always growing with regional development. Uncontrolled losses include water losses along the water distribution system that are caused by unpredicted reasons, such as cracks in the dike, losses due to absorption of water by the soil along the unlined canals, etc. However, the Brantas river basin has also been facing other problems, such as flooding due to sedimentation caused by erosion, especially from volcanoes, and pollution due to domestic, industrial and agricultural effluent discharges.

Development has been carried out in a holistic approach, a planned, sustainable and environmentally sound management system based on “one river, one plan, one integrated management” through a series of master plans. Based on these master plans, many water resources infrastructures have been built. However, so far several problems have been encountered:

Watershed management. Sedimentation in the reservoirs decreases the reservoir capacities significantly, particularly in the Sengguruh, Sutami, Wlingi and Lodoyo reservoirs. According to a 1997 survey, the effective storage of these reservoirs had been reduced to 48 percent, 58 percent, 27 percent, and 46 percent of the original volume, respectively. The sedimentation

in the Sengguruh and Sutami reservoirs resulted from soil erosion in the watershed due to deforestation and improper land cultivation management, while that in the Wlingi and Lodoyo reservoirs is mainly due to the eruption of material from Mt. Kelud, which erupted last in 1990.

Water-quantity management. The water allocation plan is a general plan of water release from reservoirs and barrages along the water distribution system that includes both intake and gate operation curves as well as water use/abstraction plans, for a certain period of time, usually one season. This water allocation plan is set from compromise among beneficiaries and is stipulated under a Governor's decree that settles matters between the users and the operator of the system for the season. If there are changes, such as increasing demand of a certain sector, then the allocation plan could be revised. In terms of water quantity, insofar as it can be supplied as required, it is based on the agreement in the provincial water resources committee (PTPA) meetings. When the available water is less than the requirement, it can be managed by controlling the demand. However, when the treatment plant capacity for domestic water supply increases in the future, the existing water allocation plan should be adjusted.

Water-quality management. Water quality still faces a big problem with the effluent discharges from industries and domestic use. The available water quantity is not sufficient to dilute the pollutants.

River-environment management. River-environment management is confronted with socioeconomic problems, which affect the awareness of the people using the river water and the river itself.

Infrastructure management. The infrastructure management in the Brantas basin is carried out as much as the budget allows; however, the biggest group of beneficiaries, the farmers, have not contributed to this management effort, so far.

Evolution of Institutions for Basin Management in Brantas

Initial Arrangements

Beginning in 1961, the development of the Brantas river basin was carried out by the Brantas River Basin Development Project (BRBDP). This project was under the Directorate General of Water Resources Development, Ministry of Public Works, and it handled the planning, design and construction of water-resources development. However, after finishing the construction, the Project continued to deal with the O&M as well. Master Plans I (1961), II (1973) and III (1985) were prepared by Japanese consultants with Japanese reparation funds and grants. The construction was also carried out with Japanese aid. A significant transfer of knowledge occurred during this period.

Limitations and constraints of institutional arrangements. Up to 1990, six reservoirs and three barrages had been built. The total investment was about Rp1,700 billion (based on a 1992 price level). The benefits of the development consists of flood control for a 50-year return period, water supply for 83,000 hectares of irrigated areas directly supplied from the main river, energy production of about 875 million kWh/year, bulk water supply for industries and municipal drinking water of about 300 million m³/year. After construction, it was necessary to maintain the function of the water resources infrastructures to ensure optimum benefit over their planned lifetime. O&M activities were performed but these activities encountered some problems.

Until 1990, the Brantas river basin had no permanent institution that could perform O&M activities in a sustainable manner. The Brantas River Basin Development Project (BRBDP) was a temporary institution whose duty was only to carry out the construction and not the O&M. The Project encountered problems in obtaining funds for these activities due to the limited National Government Budget. Lack of the O&M budget resulted in degradation of the water resources infrastructure. Weak coordination among related agencies complicated water resources management. This posed risks of water resources degradation, which in the long run would harm economic development of the basin.

Need for change. The need for applying integrated water resources management in the Brantas basin has been recognized since the 1970s when some of the infrastructure had come into operation. However, BRBDP was only a Project organization, which was temporary and did not have any power for coordination, while integrated river basin management requires a high level of coordination among many agencies. The institution that had the coordinating power was the Public Works Regional Office of east Java, but this organization was not specialized in river basin management. It was realized that river basin management has many aspects that need to be carried out seriously, and this could be done by a permanent river basin management agency.

Brantas River-Basin Management Organizations

Purpose, objective and scope of the organization. As an effort to solve the aforementioned problems, by developing a pilot corporation system in managing the river basin, in 1990, the government established a public corporation, namely Jasa Tirta Public Corporation, as a government owned company (BUMN) to manage the Brantas river basin. Table 4 gives the details of the legal basis of the corporation. Government Regulation No. 5 of 1990 established Perum Jasa Tirta for organizing general utilization of water resources in a good quality and properly for fulfilling people's needs, The corporation also carries out certain governmental tasks in managing the river basin, covering conservation, development, and utilization of the river and water sources, including giving information, recommendation, education and guidance. In 1999, the name, Perum Jasa Tirta, was changed into Perum Jasa Tirta I.

The objective is to take part in developing the national economy by carrying out the national development program in the field of water resources management with a plan according to the government policy in managing the basin. This covers comprehensive and integrated development and utilization of water resources, considering regional development,

Table 4. Legal basis for the corporation.

1.	<p>Institutional Aspect</p> <p>a) Law No. 11 of 1974 on Water Resources. <u>Article 3</u>: Water and its resources, including the natural riches contained therein, shall be controlled by the State. <u>Article 4</u>: The power of the Government may be delegated to its agencies at the central or regional level or to specific corporate bodies in accordance with conditions and procedures as specified by Government Regulation.</p> <p>b) Government Regulation No. 5 of 1990 on Jasa Tirta Public Corporation. <u>Article 2</u>: In order to carry out the O&M of water and water resources infrastructure, a Public Corporation has been established under the name of Jasa Tirta Public Corporation.</p> <p>c) Government regulation No. 93 of 1999 on Jasa Tirta I Public Corporation. <u>Article 2 Paragraph (1)</u>: Jasa Tirta Public Corporation, which was established by Government Regulation No. 5 of 1990, is to be continued based on stipulations in this Government Regulation. <u>Article 2 Paragraph (2)</u>: The name, Jasa Tirta Public Corporation, stated in paragraph (1) above is further changed into Jasa Tirta I Public Corporation.</p>
2.	<p>Operational Aspect</p> <p>a) Minister of Public Works' Regulation No. 56/PRT/1991 on general policy for Jasa Tirta Public Corporation Management. <u>Article 6</u>: The Corporation shall carry out main tasks that cover:</p> <ul style="list-style-type: none"> a) CO&M of water resources infrastructures. b) Dealings in water and water resources. c) River basin management, i.e., conservation, development and utilization of water and water resources. d) Rehabilitation of water resources infrastructures.
3.	<p>Financial Aspect</p> <p>a) Law No. 11 of 1974 on Water Resources Development. <u>Article 14 Paragraph (2)</u>: Communities directly benefiting from existing waterworks and structures either for their subsequent or immediate use may be required to share the related management costs. <u>Article 14 Paragraph (3)</u>: Corporations, associations and individuals directly benefiting from existing waterworks and structures either for subsequent or immediate use shall share the related costs in the form of a contribution payable to the government.</p> <p>b) Government Regulation No. 6 of 1981 on contribution for funding water resources infrastructure exploitation and maintenance. <u>Article 2</u>: Contribution to exploitation and maintenance cost of water resources infrastructure covers:</p> <ul style="list-style-type: none"> 1. Funds collected as a payment from the parties specified in Article 3 Paragraph (1) who have obtained the benefit from the use and the comfort through the availability of water, from water bodies and through the availability of water resources infrastructures as the achievements of the Corporation's management either for immediate use or subsequent use for third parties. 2. Funds collected as a payment from those who, from the activities, have caused water and water body pollution in the working area of the Corporation. <p>c) Government Regulation No. 93 of 1999 on Jasa Tirta I Public Corporation. <u>Article 45</u>: The amount of contribution for water resources infrastructure exploitation and maintenance should be stipulated in a Decree of the Minister of Public Works based on a proposal from the Board of Directors.</p>

and following the principles of environmental development and corporation management. According to the above legislation, Perum Jasa Tirta should organize the following businesses:

- Raw water supply for domestic water supply, electricity generation, plantations, fisheries, industry, harbors and flushing.
- Tourism, consultancy and other services, which can support the achievement of the objective.

The above businesses should be organized by taking into account economic principles and assurance of the safety of state property.

The scope of its main task covers the following:

- exploitation and maintenance of water resources infrastructure
- water resources dealings (any activities in water allocation and distribution for business purposes, to gain revenue from the service fee applied)
- river basin management, including conservation, development and utilization of water resources
- rehabilitation of water resources infrastructure

The vision of Perum Jasa Tirta I is to maintain, conserve and develop water resources through professional and innovative management, which is environmentally sound, in order to contribute to regional and national development. The mission of Perum Jasa Tirta I is to provide services for the public utilization of water resources and to gain profit based on sound business-management principles.

Achievements

After operating for several years, Perum Jasa Tirta I has piloted management systems and technology for advanced water-resources management. The performance of Perum Jasa Tirta I shows that the purpose of the corporation can be gradually achieved in technical, financial, management and other aspects.

Technical aspects. The Brantas river basin management is carried out based on “one river, one plan, one integrated management.” In performing planning and management activities, Perum Jasa Tirta I carries out coordination with all agencies concerned. Master Plan IV (Development and Management) was set up in 1998 in coordination with the Public Works Regional Office. This master plan was set up for nearly all management aspects related to water resources management. Setting up of the master plan in coordination with all water resources agencies concerned is one way to get agreement on inter-sectoral water allocation. The Brantas River Flood Control Master Plan was established during the preparation of the

Brantas River Master Plan, while flood control management is carried out through coordination with local government agencies and in cooperation with other concerned agencies. The Flood Forecasting and Warning System, operated with telemetry installed in 1990, is well maintained and can control floods better than the manual system. Water allocation is carried out through coordination with the PTPA members. The operation of the reservoir is prepared by Jasa Tirta I Public Corporation using computer simulation. Carrying out water allocation through PTPA is expected to reconcile inter-sectoral water allocation and obtain a fair and transparent result.

The Brantas River Pollution Control Master Plan (2020) and Action Plan (2005) were set up in coordination with the Directorate General of Human Settlements, Ministry of Public Works, while the water quality is managed with the coordination of BAPEDALDA. The NOPOLU Model is used to develop the scenario for pollution control and to calculate the river-carrying capacity through a simulation. The water quality shows improvement although the standard values have not been achieved. Pollution control is carried out by the Environment Pollution Control Committee or KPPLH, consisting of all concerned agencies, and established by a Governor's decree. In KPPLH there are 4 working teams, for the Clean River Program, Clean Town, Domestic Waste Pollution Control, and Industrial Waste Pollution Control. Perum Jasa Tirta I is Vice Coordinator I of the team for the Clean River Program. In daily operation, Perum Jasa Tirta I actively participates in the supervision and control of water quality, as it is supposed to, according to the Minister of Public Works Regulation No. 56/PRT/1991 on General Policy on Jasa Tirta I Public Corporation Management. Effluent discharge standards are currently stated in Gubernatorial Decree No. 136 of 1994; however, this is being updated, a process involving all related agencies with the coordination of BAPEDALDA.

Conservation of water resources is carried out in coordination and cooperation with related agencies in the Department of Forestry, BAPEDALDA, universities, NGOs and traditional Moslem boarding schools (*pondok pesantren*). A technical team for synchronizing the program and activities for greening in the upper Brantas basin has been established by the Assistant Governor for the Malang area, consisting of the agencies concerned, in which Jasa Tirta I Public Corporation sits as Secretary I. This team is responsible to the Assistant Governor. Public education is carried out in coordination with the Department of Home Affairs, universities, NGOs, and *pondok pesantren*. Obvious physical achievements of Jasa Tirta I Public Corporation in maintenance can be seen in the well-maintained water-resources infrastructure. The management of the river environment of certain rivers has been cleaner and nicer so they can be used for sports and tourism. The Brantas water-resources management received international acknowledgement by receiving the ISO-9001 Certificate from SGS International Certification Services in May 1997 (Certificate Number Q9755).

Financial aspects. Ever since its establishment, Perum Jasa Tirta I has been carrying out O&M of water-resources infrastructure, funded by the beneficiaries. Although it has not been fully funded by the beneficiaries, step-by-step it is attempting to apply the principle of "full cost recovery." The beneficiaries who have contributed so far are the State Electric Company (PLN), Domestic Water Supply Company (PDAM) and industries. Their tariffs are so far based on an agreement between Perum Jasa Tirta I and their representatives. They are then approved by the Minister of Public Works and legitimized by a Ministerial Decree. In the

future, the Basin Water Resources Management Committee is expected to be the forum for agreeing on the tariff for each water user using the full cost-recovery principle.

Beneficiaries' participation in funding the river management has increased, although it does not yet satisfy all the requirements. The funding rose from Rp 2.6 billion in 1991 to Rp 26.1 billion in 1998. The desire of the private sectors to participate in investment for water-resources development by establishing joint ventures had increased. However, due to the economic crisis, many joint-venture programs were postponed or canceled. Other than O&M fees, Perum Jasa Tirta I also raises funds from non-water services, such as consulting, construction, equipment rental, land rental and tourism, and from joint ventures in resource utilization.

Accountability. In general, PTPA should be the forum to which all parties have to be responsible, since agreements in water-resources management should be made in the PTPA. However, so far the PTPA handles only allocation of water quantity and flood control. For other matters, such as watershed management, water quality and river environment, each agency is responsible for their respective supervising department. As the existing coordinator in managing water quality, Perum Jasa Tirta I submits monthly reports to BAPEDALDA, particularly for water quality. An Annual Report covering operational and financial matters, and Quarterly Financial Reports are forwarded by Perum Jasa Tirta I to the Minister of Settlements and Regional Infrastructure and the Minister of Finance as the representatives of the owner.

Mechanisms for coordination and conflict resolution. A mechanism should be able to resolve any conflict that may arise in its own coordination forum. If it concerns only two parties, those parties should attempt to resolve the issue between themselves. However, if this does not work, the Governor, the Minister of Public Works or the Minister of Finance, or the House of Representatives is usually asked to be the mediator. Interagency coordination is carried out in a forum according to the problem. Inter-sectoral competition for water is addressed in two stages. In the planning stage, a Master Plan is set up. The Public Works Regional Office was the coordinator for setting up Master Plan IV in 1998. In the operational stage, issues are discussed and agreed in the PTPA. So far the PTPA is an effective forum for reconciliation of inter-sectoral competition for water.

Stakeholder participation. Coordination fora are the means for stakeholder participation, mainly involving so far the government agencies and Perum Jasa Tirta I. For public participation, Perum Jasa Tirta I together with the local governments and all agencies concerned carry out special activities, such as cleaning the river and river corridor (PROKASIH). In some cases, positive social control has been given by the public through newspapers. However, it is planned that public participation in decision making will be applied through PTPA, in which NGOs will be included as members. Financial participation has been given by the water users as mentioned in the previous section. Irrigation Water User Associations participate financially in their own irrigation schemes.

Private-sector participation. The private sector had begun to participate in water resources utilization when the economic crisis happened, and afterwards their participation was held

back. But recently, it has resumed its participation in domestic water supply. However, financial participation has been given in public education activities.

Resource mobilization and performance assessment. As consulting and construction services are part of its tasks, Perum Jasa Tirta I mobilizes its staff for these businesses. During the assignment, the performance of the staff assigned is assumed to be good as long as there is no complaint from the customer.

Data management. Data managed by Perum Jasa Tirta I covers a) hydro-meteorological data, b) water-use data, c) water-quality data, and d) financial data. So far, Perum Jasa Tirta I is not managing all intakes. Intakes for hydropower plants, domestic water supply, and some irrigation areas are managed by the water users. Some industrial intakes use flow meters, some do not. Data on water use by PLN and PDAM are obtained from the water users; as also with some irrigation areas in the downstream part of the basin. Water use by industries is measured by flow meters for those who use the meter, but for those without flow meters the water use is estimated as a constant.

Hydro-meteorological data are collected manually and through the available telemetric system of the Flood Forecasting and Warning System. Some are stored in hard copies, but most in computer files, which are then processed. Data on daily water use are collected in each concerned Division, while data on water quality are collected through the Water Quality Laboratory. Both of them are processed monthly in the Head Office. Financial data are stored in ASGL (Accounting System General Ledger) and processed monthly too. At present, Perum Jasa Tirta I, in cooperation with the Indonesian Institute of Sciences, supported with aid from the Government of Austria, is setting up a water-quality telemetric monitoring system and a Decision Support System, in which all technical data will be stored in a database system connected with water-management models.

Regulatory functions. Through its Research and Development Bureau, Perum Jasa Tirta I studies regulations in water management aspects, such as in licensing, standard of wastewater quality, tax and fee collection, etc., and forwards proposals for improvement to the agencies concerned.

Constraints

Under the decentralization policy, all natural resources are under the authority of the respective local governments. Applying this principle for the water resources in the Brantas river basin and considering that the river basin covers 14 district and municipal areas, it would be difficult for each local government to separately manage the water resources in its area of the basin. To overcome this problem, the district and municipal governments could make agreements for managing the water resources of the Brantas river basin by giving concessions to Perum Jasa Tirta I. That could help assure the sustainability of the water resources and good public service, private and public participation and help resolve potential conflicts among the local governments, and among sectors and users. A change of the ownership

authority of natural resources under decentralization should not affect the O&M or give negative impact to the user.

Financial support for the sustainability of the management of water resources has not been given by all beneficiaries, especially farmers even though they are the biggest water user group. According to Government Regulation No. 6 of 1981 on Contribution for Funding Water Resources Infrastructure Exploitation and Maintenance, the fee from the farmers should be collected as a the deduction from the land tax collected by the local government. This mechanism has not been applied. Supported by Law No. 34 of 2000, this Government Regulation will be improved in the reformed national water-policy program, adjusted to the decentralization policy as well as the water-resources financial-system arrangement.

A general financing system for water resources corporations, which can support the water management, has been formulated but not written in any legislation as yet. This system, which includes water-use fee tariffs and effluent-discharge fee tariffs as well as their collection mechanisms, is included in the reformed water resources policy program to be established. Apart from the above constraints, as a pilot agency, Perum Jasa Tirta I is at present getting ready for dealing with various aspects of water-resources management in the basin.

Technical aspects. To improve water-resources management by means of enhancing R&D activities, individual capacity-building and demand- and supply-management techniques, the following points are under consideration:

- Decision support systems in all engineering aspects of water-resources management, covering database management systems. This project is carried out in cooperation with the Indonesian Institute for Sciences (LIPI).
- Telemetric water-quality monitoring system with an up-to-date model reference laboratory for water quality and environmental analysis for the twenty-first century. This project is also carried out in cooperation with LIPI.

Financial aspects. To improve governance in water-resources policy, a cost-allocation concept of beneficiaries' contribution to the water-resources management cost is prepared by applying economic instruments, e.g., the full cost-recovery principle. Up to 1999, only O&M cost recovery was applied to certain beneficiaries (PDAM, PLN and industries), while farmers still received water free of charge. Effluent-discharge fees have been formulated but have not yet been applied.

Management aspects. To promote protection and conservation of resources, the following activities are being considered:

- Public and private participation in water-resources development and management will be more widely opened.
- Application of the Brantas river basin management system in four river basins: Bengawan Solo, Jratunseluna and Serayu-Bogowonto in Central Java as well as Jeneberang in South Celebes.

Legal aspects. Due to the reforms in the national water resources policy and the decentralization policy, the following legislation concerning Perum Jasa Tirta I will be modified:

- Government Regulation No. 6 of 1981 on Water Resources Infrastructure Exploitation and Maintenance Fee
- O&M fees from farmers should be adjusted to the new financial system.
- Government Regulation No. 93 of 1999 on Jasa Tirta I Public Corporation.
- Due to the decentralization policy, the local governments are supposed to receive part of the revenue from the natural resources in their respective areas.

Conclusions

Water-resources management should be undertaken in an integrated (multi-sector), comprehensive (upstream-downstream), sustainable (intergeneration) and environmentally sound concept, for fair and just results. In line with this ideal, the river basin as a hydrological unit is considered as one management unit, under implementation of the decentralization concept in an autonomous spirit that embraces river-basin management trans-boundary aspects. River basins should be managed by a neutral and professional institution that applies healthy corporate principles and general utilization norms in water resources, based on public and private participation.

Participation of the public and private sectors, and of the community is an important aspect in performing better water-resources management in the context of the paradigm shifts. Both public and private sectors are involved at each decision-making level through coordination fora, and water-resources beneficiaries should bear development and management costs. Role sharing among the beneficiaries could be divided into three parts:

- Government as the owner of the water resources and their infrastructure, plays the role of controlling and regulating at the national and regional levels exercising its public authority.
- The River Basin Management Agency has a concession to manage water resources and its infrastructure, including receiving contributions and rendering water-resources services.
- Society acts as users that have the right to receive services and participate in decision making, but are expected to use water efficiently and take part in sustaining the environment.

The concept of a River Basin Corporation developed and implemented in the Brantas river basin shows good achievement and is expected to be applied gradually in other river basins in Indonesia.

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CHAPTER 14

Summary of the Proceedings of the Regional Workshop on Integrated Water Resources Management in a River Basin Context: Institutional Strategies for Improving the Productivity of Agricultural Water Management

Opening

Participants from eleven different countries arrived in Malang, East Java, Indonesia on Sunday, January 14 2001 to attend the Regional Workshop on “Integrated Water Resources Management in a River Basin Context: Institutional Strategies for Improving Agricultural Water Management.” The workshop jointly organized by IWMI, IFPRI and Jasa Tirta I Public Corporation was sponsored by the Asian Development Bank (ADB). The introductory session of the workshop included brief statements from representatives of the four collaborating agencies, and covered the objectives of the workshop and those of its underlying studies.

The purpose of the workshop was to discuss two studies, a five-country study by IWMI, and the other by IFPRI, both focusing on how to improve the productivity of water management. IWMI’s regional study conducted in selected river basins in China, Indonesia, Philippines, Nepal and Sri Lanka had proceeded for the past 2 years, while in Vietnam and Indonesia, IFPRI was in the early stages of investigating the interaction of basin management and agriculture. The role of Jasa Tirta I was as the local collaborating partner for the workshop arrangements. Malang, where the headquarters of Jasa Tirta I are located, was seen as a very appropriate setting for the workshop on the basis of its long experience in effectively managing the Brantas river basin. Rusfandi Usman, the President Director of Jasa Tirta I, introduced his organization’s activities in the management of the Brantas river basin and expressed his hope that the workshop recommendations would help improve strategies for river basin management.

Coinciding with the holding of this workshop, ADB’s Board of Directors was about to approve the Bank’s new Water Policy, developed after a long process of consultation. As shown in its sponsorship of this workshop, ADB plans to support networking and sharing of experience in the region. ADB shares with its stakeholders a common vision of rivers that provide life to the people and ecosystems of the basins and that support economic development. Wouter Arriens, speaking on behalf of the ADB, said, “[t]he water crisis in Asia is at heart a crisis of governance. We cannot influence how much water is available, but we can influence how to manage that water. The best practices need to be translated into policies and procedures that can be replicated. Both IWMI and IFPRI are focusing on these issues. The most challenging part of IWRM is how people can collaborate for better water resources planning, development, management, and conservation.”

The Director General of Water Resources, Dr. Soenarno, of the Indonesian Ministry of Settlements and Regional Infrastructure formally opened the conference. His opening remarks stressed the relevance of the workshop for Indonesia's current reforms in governance and water-resources management within which decentralization, stakeholder participation and public-private partnerships pose new challenges for the management of river basins.

Prof. Frank Rijsberman, Director General of IWMI delivered the opening keynote address. He described the formulation of the World Water Vision, which analyzed the challenges of coping with increasing demands for water in the context of different scenarios for technology and values. IWMI is involved in continuing the dialogue on water, food and the environment. He outlined IWMI's concepts concerning three stages in the river-basin development, as an increasing portion of the renewable supply is brought into use. He highlighted recent innovations in water management, such as the spread of treadle pumps in Bangladesh, well recharge in western India, increasing attention to the role of the private sector in many countries and work in China on growing "more crop with less water," and then echoed the call that "water should be made everybody's business."

Methodological Issues

Tissa Bandaragoda of IWMI introduced the framework for river-basin studies, combining water accounting, socioeconomic studies and institutional analyses. This framework is being applied to subbasins in five countries: Nepal, Philippines, Sri Lanka, Indonesia and China. The study is intended to field-test new paradigms for integrated water resources management, assess the hypothesis that "water scarcity induces institutional change," and identify the conditions for effective institutions for IWRM. Studies are being conducted by local research teams in cooperation with IWMI.

R. Sakthivadivel of IWMI discussed the institutional implications of IWMI's approach to "water accounting" in river basins. Water accounting takes rainfall as an input, and analyzes flows through the basin, usually including irrigation return flows and groundwater. Basins are assessed in terms of a three-stage model of river-basin development:

- In the construction-oriented stage, the renewable supply is abundant relative to demand, in "open" basins.
- During the transitional stage, as more of the available supply is used, management becomes more important, and institutional changes, such as the transfer of irrigation management may be needed.
- When most water is used, the basin is "closed" in the sense that little water flows to the sea beyond that necessary for preventing saltwater intrusion and preserving habitats. Institutions for water allocation become crucial for good management to prevent pollution, resolve conflicts over the quantity and quality of water, and deal with other problems such as groundwater overdraft.

No single set of institutions can cater to all basins. Instead, institutions must be dynamic, changing with the changing basis of development in the basins. In the following presentation, Madar Samad outlined the socioeconomic information gathered for evaluation of the five river basins.

Lessons from Some Best Practices

On Monday afternoon, three studies highlighted lessons from basin management in Australia, Japan and Indonesia. Tissa Bandaragoda presented a paper on institutional arrangements in the Murray-Darling basin of Australia, written by Darla Hatton MacDonald and Mike Young. Australian states initiated the formation of the Murray-Darling Commission to address water scarcity and salinization. Stakeholders participate in multiple layers of governance in a pattern of cooperative federalism. Australia has now embarked on major reforms including expansion of water trading and moving toward full cost recovery. Water diversions have been capped and a system of salinity credits established.

Toru Mase described lessons from the Omono-Gawa basin in the Akita Prefecture, complementing R. Sakthivadivel's presentation of the paper written by Ian Makin, T. Mase and T. Bandaragoda. Japan's irrigation water management draws on a long history of local management during which farmers established rules among themselves in a process of self-governance. Any government assistance must be based on requests from the Land Improvement Districts to which farmers belong. Japanese experience indicates that participatory irrigation management (PIM) is more effective if due attention is paid to the size of farmer groupings and to clear rules for dividing water, thereby facilitating hydrological decentralization.

Trie M. Sunaryo of Jasa Tirta I presented a case study of how the Brantas basin is now managed. After the construction of major infrastructure in the basin, the Jasa Tirta Public Corporation was established in 1990. Jasa Tirta I manages the major reservoirs, helps control floods, monitors water quality and engages in other activities, such as education, to improve the river environment. The case study concluded that water resources should be managed in an integrated (multi-sector), comprehensive (upstream and downstream), sustainable and environmentally sound manner. Participation of the public and private sectors and of the community is essential. The government acts as the owner of the water resources and infrastructure, Jasa Tirta operates major hydraulic infrastructure while society acts as the water user.

On Monday evening, workshop participants attended a dinner and a cultural performance.

National Water-Resources Policy of Indonesia

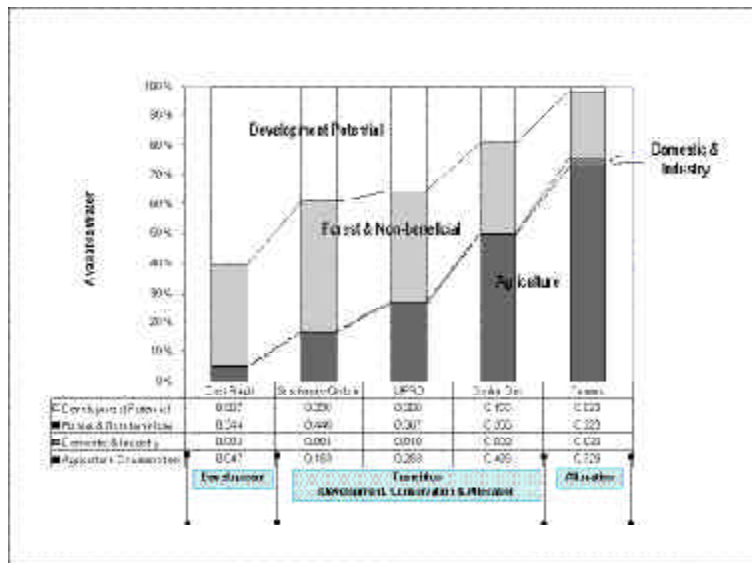
On Tuesday morning, Her Excellency Erna Witoelar, Minister of Regional Settlements and Infrastructure for Indonesia, explained Indonesia's reforms in water-resources policy. This is part of national reforms in governance, promoting decentralization and participation. The reforms are intended to set up a national-level framework on policy coordination through an apex body, and to revise water law, regulations and national water policy. Management of

river basins will be improved through basin committees with stakeholder participation, basin-level management units in less-developed basins, self-financing corporations in strategic developed basins, secure water allocation through a water rights system and enforceable control of water pollution. Public irrigation networks are to be made sustainable through redefining roles of irrigation institutions, management transfer and joint management, autonomous water user associations, revised financing through user-controlled irrigation fees and government-supported funds for improvement in irrigation.

Five-Country Regional Study

Interim findings from IWMI’s research in the five basins were presented on Tuesday. The five basins, as it turned out, can be neatly ranked in terms of increasing water scarcity, as shown in figure 1, although this was not part of the original criteria for selecting research sites. Each basin has its own specific issues but there are many shared concerns.

Figure 1. Ranking of the five basins in terms of increasing of water scarcity.



The Fuyang basin in China experiences severe water shortage. Groundwater aquifers are being overdrawn. The paper presented by Jinxia Wang discussed the basin’s water management challenges, analyzed the evolution of management institutions, particularly for groundwater, and offered the researchers’ recommendations to establish water-administration bureaus to improve management of water distribution, and to make greater use of economic instruments in water management.

Irrigation in the Ombilin basin of West Sumatra, Indonesia has been affected by construction of a hydropower dam upstream that diverts water into another basin. The presentation by Helmi explained that waterwheels had been used to provide continuous irrigation to rice grown on highly porous soils. Even though the amount of water available

could still be adequate for the crop, river levels are now too low for many waterwheels to operate properly. Coal-washing also generates large amounts of sediment. Basin-management institutions have not yet been established but they could be set up under new government policies.

The east Rapti basin in Nepal is still an open basin in terms of overall water supply and demand. The presenter, K. R. Adhikari explained that since almost all rain falls during 4 months, the basin still experiences seasonal shortages in many locations. Increased diversion for irrigation creates conflicts with dry-season flows for the Chitwan National Park downstream. Farmers are making increasing use of groundwater even though they have not responded to government programs for subsidized tube wells.

For the Philippines' Upper Pampanga river basin, the presentation by Honorato Angeles stated although laws, regulations and policies exist to regulate water management they have not been fully implemented as yet. The researchers identified a need for better coordinating mechanisms in the basin, as well as better data for water management.

The Deduru Oya basin in Sri Lanka also experiences seasonal water scarcity in parts of the basin, as discussed in the presentation by K. Jinapala. Much of the middle and tail parts of the basin lack water in the dry season though some farmers pump directly from the river. Drinking water is a major problem since groundwater in two-thirds of the basin is not suitable for drinking. As yet, there are no institutions capable of coordinating water use in the basin in an integrated manner.

The brief synthesis of the five basin studies presented by Randolph Barker, emphasized the three major stages in basin development. Greater attention is needed to the historical development of institutions. All sites reported a need for reliable data, inadequate planning, absence of well-defined water rights and absence of mechanisms for integrating the use of surface water and groundwater. There were various site-specific problems, but all basins suffered from seasonal water shortages. The researchers have made recommendations for solving problems in basin management, and this workshop would formulate action plans concerning how institutional changes could respond to these problems.

Field Trip

On Tuesday evening, workshop participants visited the Jasa Tirta headquarters, listened to a briefing on the organization, observed the control room used for monitoring water levels, flood management and other activities, and then had dinner.

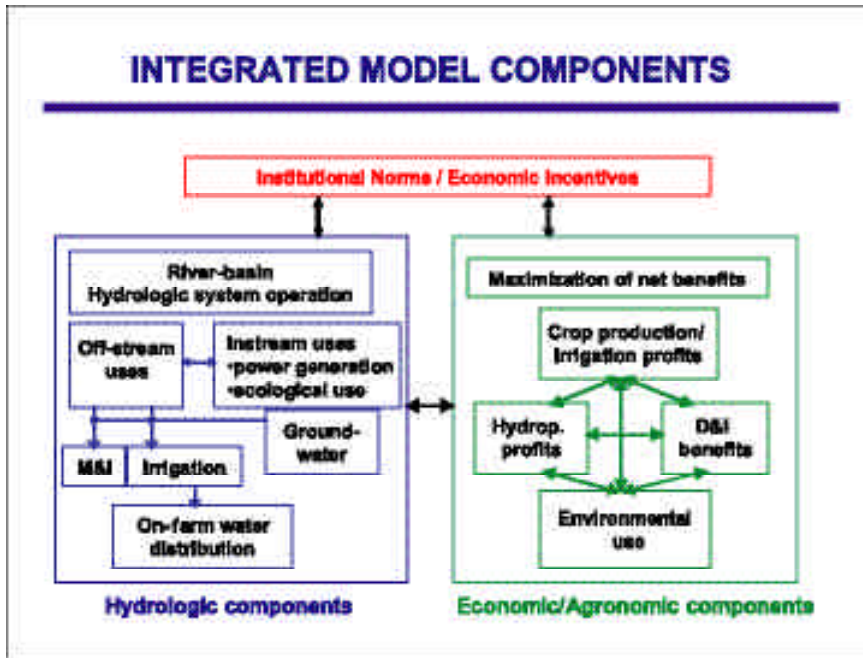
On Wednesday morning, participants began the day by traveling to the headwaters of the Brantas river and planting a tree in the Jasa Tirta Arboretum. They then visited several reservoirs on the upper Brantas river, learning how the reservoirs were built and how PJT has responded to problems, such as high levels of volcanic sediment entering the watershed.

Integrated Hydrological-Economic Modeling for River-Basin Management

On Thursday morning, IFPRI researchers presented papers on their current research. The modeling approach being applied by IFRPI offers a tool for assessing possible changes in

water-management institutions through integrated analysis of hydrological and economic systems, as depicted in figure 2.

Figure 2. Integrated analysis of hydrological and economic systems.



The paper presented by Charles Rodgers described the basin, earlier studies and the approach used in the current study. Integrated modeling provides a mathematical representation of how water flows through the network, and how water is used in response to economic costs and benefits, as influenced by various management arrangements. The Brantas model is initially being developed in a simplified form, to check its consistency with current hydrological models, and then it will be extended to allow analysis of possible changes in management.

The paper on the Dong Nai basin in Vietnam, presented by Nguyen Chi Cong, described Vietnam's water laws and other recent changes in national water policies, development of the Dong Nai basin, the challenges of increasing industrial and urban demand and plans for formation of river-basin management institutions. Integrated modeling could assist policymakers to develop efficient, equitable, and sustainable strategies for water allocation.

Situation in Other Asian Countries

On Thursday morning, participants from Thailand, Laos, Vietnam and Cambodia described water-resources management in their countries. On Friday morning, papers were presented

on water policy development in Sri Lanka and integrated water resources management in Malaysia.

In Thailand, the National Water Resources Committee and the Office of the National Water Resources Committee were established in 1996 to provide an apex body for the sector. River-basin committees are being established in subbasins, such as the upper and lower Ping, as flexible pilot efforts on a participatory bottom-up basis to support the eventual establishment of a Chao Phraya basin organization. A new water law is under preparation, which should take account of current government policies for decentralization.

In 1996, the Lao Peoples Democratic Republic enacted a Water and Water Resources Law. A national Water Resources Coordination Committee and its Secretariat were then established. They have prepared a Water Sector Strategy and Action Plan. Following its support to these efforts, the ADB is now assisting in the preparation of an integrated approach for the management and development of the Num Ngum river basin.

Vietnam's recent Law on Water Resources assigns overall responsibility to the Ministry of Agriculture and Rural Development, but bylaws, regulations and enforcement need further action. A national water-resources council is to be established. Preparations have been made to establish a basin organization for the Red river.

Recently, Cambodia established a Ministry of Water Resources and Meteorology. A law on water resources has been drafted. The draft would allow free use for drinking, washing and other domestic purposes but would make other uses subject to licensing. In irrigated agriculture, the government policy is to devolve responsibility for all aspects of irrigation scheme operation to Farmer Water User Committees.

In Sri Lanka, a comprehensive program for integrated management of water resources was initiated in 1990. A temporary Water Resources Council and Secretariat were established in 1996. The Council includes representatives from academia, the private sector, nongovernment organizations, farmer organizations and a gender representative. The policy development process has featured extensive stakeholder consultation but further dissemination and communication are needed with those who have not taken part in consultation meetings. In late 2000, a separate ministry was established for Water Resources Management and Irrigation. A Water Resources Act has been drafted which would result in the formation of a National Water Resources Authority.

Salmah Zakaria outlined current initiatives for integrated water-resources management and integrated river-basin management (IRBM) in Malaysia. Land and water are state matters in Malaysia's federal system but, at the national level, there is a National Flood Commission and a National Water Resources Council. Water management faces challenges from rapid economic growth, urbanization, industrialization and increasing sensitivity about environmental issues. Irrigation operators are corporatized entities. Three states have river-basin committees and one has a basin authority. National consultation on IWRM/IBRM has involved public agencies, environmental and consumer NGOs and others. Immediate needs concern improving public awareness, building institutional capacity and networking among stakeholders. In the longer term there are needs for review of legislation, better enforcement, more river-basin organizations, infrastructural improvements, preventive measures, planning, public participation and appropriate financing arrangements.

Action Plans

On Thursday afternoon, participants were divided into six groups. Initial action plans were formulated for the five countries involved in IWMI's study. Those involved in the IFPRI studies in Vietnam and Indonesia spent time learning about each other's activities, analyzed the differences between the basins and discussed opportunities for further collaboration between IFPRI and IWMI.

The action plan for Indonesia made short-term recommendations that management in the Ombilin basin be discussed in the province, that persons from Jasa Tirta give briefings on management in the Brantas basin, that key decision makers visit Brantas and that provincial policy and regulations be drafted with public consultation, and then submitted to the provincial parliament. In the medium term over the next 5 years, a provincial water-resources committee should be established, information systems developed and a basin-level committee prepared for the Ombilin basin.

The action plan for Sri Lanka stressed the need for an integrated approach to the basin, additional studies of river management and water quality, educational efforts and institutional changes.

The action plan for the Philippines recommended dealing with water shortage with more storage, efficient and equitable management and watershed conservation. Deterioration of irrigation facilities should be addressed by more subsidies, increased irrigation service fees, adjustments to fee collection incentives, strengthening of Irrigators' Associations and reorganization of the National Irrigation Administration. Better enforcement and more measurement were needed to improve the water quality. Integrated water-resources management should be developed through better coordination, but since allocation problems are not urgent, basin planning was not felt to be a pressing issue.

The action plan for Nepal covered the need for better institutions at the national level, and basin-level efforts for water allocation, appropriate groundwater development and watershed conservation.

Panel

On Friday morning, panelists briefly proposed their main recommendations on the topics covered by the workshop:

- Integrate diagnosis of institutional reforms in the short and long term with economic and hydrological analysis, and with best practices.
- Clarify and assess water-resource problems and issues thoroughly before formulating IWRM strategies and actions.
- Consider institutional sustainability, from the viewpoints of owners, operators and users of water facilities, with coordination and guidance from a national apex body.

- Strengthen the capacity through human-resources development programs that address technical, economic, social and political issues.
- Cooperate among water users to develop arrangements to share scarce water resources.
- Establish an appropriate balance between centralized arrangement for integrated river-basin management and decentralized arrangements for water allocation based on water rights and economic incentives.
- Generate local and private-sector investments, involving the nonagriculture sector and applying pricing mechanisms that encourage water conservation.
- Recognize the effectiveness of a strategy that, like Jasa Tirta's, promotes a single objective, expands tasks incrementally, invests heavily in staff, manages existing water infrastructure, establishes financial sustainability through cost recovery, maintains long-term technical assistance partnerships and pursue the highest standards.

The active discussion following the panelists' presentations noted the importance of water rights, participation, need for additional information on institutional strategies in agricultural water use, poverty and water conservation. The action plans identified during the workshop need to be developed further in consultation with stakeholders.

Closing

M. Samad summarized the conference activities, describing the relationship between the IWMI five-country study, IFPRI's integrated modeling, case studies of best practices, emerging issues, action plans and future areas for collaboration. Speaking on behalf of the participants, Maria Orden provided feedback on various aspects of the workshop. Mark Rosegrant of IFPRI commented on the high level of interaction, the complementarities revealed between IFPRI and IWMI work, and IFPRI's willingness to collaborate in future efforts. Speaking for the ADB, Kenichi Yokoyama noted that ADB's Board has now approved the Bank's Water Policy. He expressed thanks to all who contributed to the workshop and stressed ADB's intent to continue supporting sharing of experience in water management, at the final IWMI workshop for this study at the end of the year and on other occasions. On behalf of IWMI, Tissa Bandaragoda thanked all those who had contributed to the workshop and encouraged participants to continue taking on the challenges of improving water-resources management. The representative of Jasa Tirta I formally closed the workshop.

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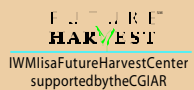
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