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Country Experiences with Water Resources Management

Economic, Institutional, Technological and Environmental Issues

Guy Le Moigne, Shawki Barghouti, Gershon Feder, Lisa Garbus and Mei Xie, editors

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FOREWORD

Water is a key determinant of economic growth and a major natural resource that must be carefully managed as part of environmentally sustainable development programs. In many countries, the real costs of supplying water of a given quality at a particular time and location are escalating. Without comprehensive management of water resources in countries where water-related issues have become critical, the growing and competing demands of water users in different economic sectors lead to inefficient allocation and lower economic growth; human suffering; and local, national, and international conflicts.

The Bank is preparing a comprehensive water resources management policy to guide its work in developing countries; the process involves learning from the experiences of others, confronting challenges, and formulating solutions. The Bank Group's broader agenda forms the context for its concern with water resources management. Our central institutional objective is to help reduce poverty in the developing world. We pursue poverty reduction primarily by helping member governments implement policies leading to rapid economic growth and productive use of the poor's most abundant asset—their labor. Development is a complex process, with a poverty reduction agenda of many dimensions: project (or investment), sectoral, national, and increasingly regional and global.

Within this context, improved water resources management is emerging as a priority for the Bank and its member countries. About 10 to 15 percent of total Bank lending, or about $2 billion per year, is for water projects. Our experience with the design and sustainability of water projects is growing, and we are therefore increasingly emphasizing issues such as dam safety, resettlement, environmental impacts, and international water rights.

We have previously dealt with water in a fragmented, sectoral context: as part of agricultural irrigation, urban water supply, or hydropower projects. We must change this. We must recognize linkages and tradeoffs more fully: an agricultural gain is sometimes an environmental loss. We have to consider longer-term issues more comprehensively, such as the silting of water reservoirs and the protection of watersheds through planting of seedlings. This means that we have to extend our time frame: water management is more than getting the water there now; we want to be sure an appropriate quality and quantity of flow can be sustained.

We expect to take the lead in forging international partnerships to address regional and global issues, one of which should be helping governments deal more broadly with water. We have done this in a limited way in a few countries—for instance, Mexico, Bangladesh, Egypt, and Pakistan—but we have to go further and deal with this issue regionally, for example, in the Middle East and in many of the major river basins. Societies must treat water as a valuable resource and improve their related planning, implementation, and operational procedures, as well as legal systems. With the growing competition for limited water resources, efficient water use patterns are crucial.

Barber B. Conable

Barber B. Conable
President of the World Bank, 1986-91

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Visvanathan Rajagopalan (OSPVP) and Michel Petit (AGRDR) designed the Bank's International Workshop on Comprehensive Water Resources Management, which was based on country case studies organized around five themes. (These studies have been adapted for this publication.) Mohamed T. El-Ashry (ENVDR), Shahid Javed Burki (EA2DR), Ram Kumar Chopra (MN2DR), Amnon Golan (EDIDR), and Harinder S. Kohli (EMTDR) chaired the workshop's thematic sessions. Discussion groups influenced the thematic sessions and provided dialogue that will help shape the Bank's work in this area; facilitators included Jerome Delli-Priscoli, Ted Kanamine, Charles Lancaster, Stuart Langton, and Bill Werick. Ulrich Küffner and Pat Bielaski also provided organizational support to the workshop.

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OVERVIEW

The Bank has initiated a reassessment of its water management policies and strategies, seeking to achieve a comprehensive approach in its operations. The conceptual framework of the process involves three levels at which water development should be examined: At the first level, the water sector is viewed as part of the whole economy. At the second level, the sector is treated as an entity composed of subsectors. At the third and most disaggregated level, each of the subsectors is examined. The main issues to be considered in the reassessment process arise from the conceptual framework, namely, optimization of economic performance, subject to institutional, technological, and environmental constraints.

The reassessment process comprises a series of activities, one of which was convoking an international workshop on comprehensive water resources management. It was held in June 1991 and was organized by Guy Le Moigne, Shawki Barghouti, and Gershon Feder of the Bank's Agriculture and Rural Development Department, and by the Bank's Training Division and Economic Development Institute. The papers presented at the workshop were adapted for this publication and provide country-based information organized around five broad themes: intersectoral water allocation and pricing, institution building, technological issues, environment and health, and international river basins. Each thematic section in this volume highlights the key issues involved and then focuses on how the issues are being dealt with in a particular country, region, or institution. Papers examining water management issues in various countries and in several international river basins follow the thematic sections. Maps featuring the water resources of selected countries and regions are included at the end of the publication.

Based on country experiences, intersectoral water pricing emerges as a contentious issue, with views expressed that pricing should either be based on the real economic value of water, or take much more into account. Allocation of water is generally viewed as requiring flexibility, adapting according to a country's development phase and climatic fluctuations. Health is not discussed widely, but is regarded as important, with some observing that concentration on human development and welfare should be reinforced and that all constituencies concerned with water, including users, should be considered. The need to link population issues to water projects is also noted. Planning is viewed as a tool for use at *all* levels to increase capabilities. The country studies stress that adaptable technologies and the need for research should not be underestimated. Overall, flexibility, cooperation, and a comprehensive approach are regarded as essential to water management, with the country studies in this volume representing part of a vital dialogue.

Improved water management requires that human interventions in the hydrological cycle not be viewed as isolated actions, but in terms of their system-wide consequences. The escalating costs of water development will confront decisionmakers with questions concerning, for example, allocation of resources, equity among populations, and better resource management. The Bank has an increasingly important role to play in assisting borrowing countries to prepare for the challenge of integrated water resources management, and it should thus be prepared to provide guidance and financial resources.

INVESTING IN THE CONDITIONS FOR PEACE

H.J. Hatch

The earth is often called the "blue planet" because its surface is mainly water. Yet over 1.5 billion people are seriously short of safe water, and each year more than 10 million deaths result from waterborne diseases (UNDP-World Bank Water and Sanitation Program 1990).

Without adequate water resources, human beings will not be able to sustain an expanding and peaceful existence on earth. Our sustainability is inextricably linked to regional stabilities and mutual security. These three components—security, stability, and sustainability—are the conditions for peace.

As commander/CEO of the largest public engineering organization and of the principle water resources developer and manager in the United States—and of a significant component of the U.S. defense establishment—I have a somewhat unique perspective. For over 30 years I have been on the front lines of the civil works battles of environment versus economics versus engineering and of the military efforts to guarantee the security of the United States. These two spheres have generally been considered separate; however, they not only intersect, but are interdependent.

In the context of civil works, engineering for economic development must embrace environmental values, while environmental sustainability depends on engineering. The old adversarial theme of development and engineering versus the environment is yielding to new partnerships, which can only flourish, however, in a secure, stable, and sustainable world. Thus, development is linked with the environment, and both are linked with security: investment for development must be considered within this broad, integrated context.

Security

Perceptions of security are evolving with the end of the Cold War, which has brought profound changes and a new era of challenges and opportunities: emerging democracies around the world, new coalitions and partnerships, and the advent of an intensely resource-interdependent global community.

In the United States, security has always been a powerful word; however, the means to attaining it are changing. Today, the emerging notion of security encompasses a broader array of conditions, opportunities, and potential threats, which in turn require new strategies. The threats are diverse and include environmental degradation and terrorism, unsustainable population growth, depletion of natural resources, economic mismanagement and decline, increasing social and economic stratification, health crises, and natural disasters such as earthquakes and volcanoes. The World Commission on Environment and Development set the stage regarding environmental quality as a security matter, stating:

> A number of factors affect the connection between environmental stress, poverty, and security, such as inadequate development policies, adverse trends in international economy, inequities in multiracial and multiethnic societies, and pressures of population growth. These linkages among environment, development, and conflict are complex and, in many cases, poorly understood. But a comprehensive approach to international and national security must transcend the traditional emphasis on military power and armed competition (1987).

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In this context, security defined as mutual safety and a community of beneficial relationships among and within nations is replacing traditional definitions. This pluralistic concept of mutual security can be attained only with economic, environmental, social, and political stability.

Stability

Stability is *not* preservation of the status quo, but rather the establishment of conditions that permit *orderly change* and that allow democratic institutions and market-driven economies to flourish. However, unless these conditions are established for the long run--perhaps 100 years--long-term stability will be impossible, and the sustainability of mutual security will be at substantial risk.

Sustainability

If peace and security are to endure, they must be based on sustainable economic, environmental, and social development. Sustainability is the continuing process of this three-way development that meets present needs without compromising the ability of future generations to meet their needs. I share the views of the Bergen Ministerial Declaration on Sustainable Development, which states:

> The attainment of sustainable development on the national, regional, and global levels requires fundamental changes in human values towards the *environment,* and in patterns of behavior and consumption, as well as the establishment of necessary *democratic institutions* and *processes* (Economic Commission for the European Region 1990).

Broadened Perspective

The Corps of Engineers and the World Bank share a desire to create and maintain security, stability, and sustainability. Our broadly based efforts can thus prevent or mitigate the circumstances that lead to insecurity and conflict in our rapidly changing world. The director of the Bank's Environment Department, Mohamed T. El-Ashry, recently stressed the importance of this challenge to the Bank.

Meeting this challenge will require a broader perspective in our mutual notions of security and recognition that security is inherently linked to stability and sustainability. It further demands an *integration* of security, stability, and sustainability into future development efforts.

As agencies concerned with security, we must do more than react to events. We need vision, strategic thinking, leadership, and sound long-range planning. Given this framework, how do we make it work?

In the past the Corps has used criteria that required projects to be based on good engineering and good economics. Today, these criteria are not sufficient: projects must also be environmentally sustainable. Additionally, our work is integrated into broader, more comprehensive strategies that extend beyond specific projects, ensuring that projects contribute to broader purposes than their immediate obvious outputs and that their impacts are broadly assessed.

For example, the anticipation and prevention of environmental damage require that the ecological dimensions of a project, policy, or action be weighed at the same time as the economic, social, and engineering considerations. Proposed development projects or actions should include environmental criteria in preliminary feasibility studies. We can thus plan to avoid or minimize adverse impacts and, if necessary, compensate for unavoidable effects over the life cycle of the project or action. The environmental aspects of all we do must have equal standing with other aspects: they are not simply a "consideration," along with economics and engineering. Thus, to extend, or broaden, its previous focus on engineering and economics to the environment, the Corps changed the guiding criteria and standards for its work.

Institution Building

We will fail to create and maintain security, stability, and sustainability unless we fully integrate the concept of institution building into our assistance efforts to developing and redeveloping nations.

All nations need effective public and private institutions. A primary objective of development efforts that promote sustainability, stability, and security should be to contribute to the growth and development of public and private institutional structures. We should transfer the capability to organize, manage, and sustain developmental programs and projects to the developing countries themselves, enhancing their capacity. We should encourage public-private partnerships and integrate free-market management philosophies into the fabric of such development efforts. However, we should be culturally sensitive and not inappropriately intrude upon the internal affairs of the nations we seek to assist.

The Corps has been involved in this type of assistance in Latin America, Eastern Europe, and the Middle East. For instance, in Honduras we are assisting in developing a solution to flood problems in the Sula Valley, a prime agricultural region. In this effort, we seek to help Honduras develop its own solution that recognizes the local conditions and environment, considers the long-term perspective, and utilizes technology appropriate to the size of the project and the capacity of public and private institutions to maintain and support it.

In Poland the Corps has entered a three-way partnership with the U.S. Environmental Protection Agency and the city of Krakow. The development effort is aimed at retrofitting modern water treatment equipment to help clean up the most polluted water system in Europe. The effort will provide the skills and resources to maintain the water treatment facility and enhance the quality of life. We will use these experiences, and those of others, to build upon successful approaches to sustainability.

(In this capacity, the Corps of Engineers works as a component of the U.S. Defense Department, in partnership with the State Department, in support of host nations. Specific activities normally result from coordination among ambassadors and local U.S. military commanders. The work is done on a reimbursable basis with U.S. or non-U.S. funds.)

In addition to these development efforts, we have recently drafted a report entitled "Water in the Sand." It was designed to add value, at minimal cost, to discussions of water issues in the Middle East. It recognizes the multidimensional aspects of water and provides historical background on collection of water, port and inland navigation data for each country and each major river basin in the region, trends leading to crisis, hydropolitical and social dimensions of the region, and alternative methods of coping with situations. It also provides lessons learned in building cooperation on water resources. This survey will enhance the user's ability to direct future resources to efforts that promise maximum benefit through achievement of cooperation on water resources in the region.

Summary

Examining comprehensive water resources management includes reflection about what succeeds in the sustainable development of water resources. The philosophy adopted for the Bank's water policy review, namely, to invite early participation of potentially impacted people, is the only practical way to develop water policies and programs in complex societies.

Those participating in the water policy review may wish to consider their opportunities for and roles and responsibilities in promoting the conditions for peace—security, stability, and sustainability—and the critical and broader role of institution building in development efforts. Projects alone are not enough: even projects that are economically and technically sound may fail to contribute to creating and maintaining the conditions for peace.

As global stewards we all must advance our knowledge of natural and human systems and manage the integration of these systems to ensure the prosperity and sustainability of humanity on this planet. We all must create solutions that combine economic growth with sound management of our water resources.

I do not presume to suggest what the World Bank should do (or how), but I have shared with you how one government institution is attempting to pursue its responsibilities while supporting the broad needs of those it serves within the context of national and departmental policies, programs, and authorities. Water resources are critical to security, stability, and sustainability. People will always require water, whether for domestic consumption or for agricultural or industrial use. We must join together globally in our stewardship of this most precious resource, the very foundation of our "blue planet."

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THEME I

INTERSECTORAL WATER ALLOCATION AND PRICING

INTERSECTORAL WATER ALLOCATION AND PRICING

K. William Easter

Public decisionmakers do not like to address water allocation, particularly among sectors, and water pricing because these issues involve imposing costs on certain farmers and landowners. These subjects are generally put at the back of country reports and are not dealt with unless water becomes extremely scarce. Country reports emphasize how the water supply must be augmented to meet the needs of an ever-expanding population with an increasing appetite for clean water. No one begins reports with a discussion of demand management, i.e., how these water appetites might be changed by water pricing or other conservation strategies. At best, conservation is discussed in terms of how much water might be saved if investments were made to improve irrigation efficiency and plug the numerous leaks in urban water distribution systems.

Demand management, including water allocation and pricing, should be the first issue addressed. Increases in supply should not be ignored, but with the escalating costs (including environmental ones) of new supplies, demand management is rapidly becoming the low-cost alternative. One only has to look at the energy sector in many developed countries to see how costs and environmental concerns have brought conservation and demand management to the forefront of planning efforts.

One of demand management's key problems is high transaction costs, which include those for research and information; bargaining and decisionmaking; and monitoring, enforcement, and collection. To establish an effective system of water charges, the last group of costs can be particularly expensive. These high transaction costs are one reason why expansion of supply is the first choice. Supply expansion generally involves low transaction costs for construction agencies and high production costs that are usually paid by someone else (the World Bank or a regional development bank). Many of the transaction costs involved in demand management alternatives are labeled political costs or lack of political will. What this really means is that bargaining and decisionmaking costs are very high when it comes to taking water away from one sector and giving it to another or when water users are asked to pay for a good they have been receiving for free.

If the costs of developing new supplies are rapidly increasing and the transaction cost of reallocation of water or demand management is high, what can be done to hold down the costs of providing water? The key is to develop institutional arrangements that lower the transaction costs of demand management strategies. For example, it is always argued that water fees for irrigation are an inadequate means of cost recovery because they are based on the amount of land irrigated rather than the volume of water used. The real question is whether new institutional arrangements can be developed so that water fees can reflect the quantity used. This will require new ways of thinking about irrigation and will depend on the scarcity value of water. Where water has a high scarcity value, it is critical that governments develop new institutional arrangements to improve the efficiency of water use. These arrangements are likely to involve:

- establishment of users' rights to water;
- improvement of delivery efficiency (quantity and timing);

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- effective water user participation;
- project rehabilitation, which may include land consolidation;
- improved monitoring and information systems concerning who receives water;
- consideration of the impacts of return flows and drainage water (negative and positive externalities);
- collected water fees being used to operate, maintain, and improve irrigation projects;
- the agency delivering the water also being responsible for collecting water fees (the agency must also have adequate resources and a willingness to collect the fees) (Easter 1987, 1990).

Once the institutional arrangements have been established for fee collection, the next issue involves the type and level of water fees:

- Should the fee be per unit of land irrigated, per irrigation by type of crop, or per volume of water delivered? Each type of fee has a different impact on water allocation efficiency, ease of fee collection, and cost of implementation;
- On what basis should the level of water fees be set: average cost of operation and maintenance, opportunity cost of water, ability of farmers to pay, or value of crops grown? Also, should there be a charge for negative externalities such as waterlogging, salinization, or pollution downstream?

These decisions will be based partly on established institutional arrangements and partly on government objectives. If the quantity of water delivered cannot be measured for each farm, then volumetric charges can only be used at some higher level, such as the irrigation district or village level (assuming village boundaries are the same as those of the water user organization). When investment in future development is a major objective, governments should want to capture much of the economic surplus generated by irrigation so that it can be reinvested. This would include reinvesting some of the surplus in project operation and maintenance so that the old irrigation investments remain viable. Capturing the economic surplus also involves income distribution objectives because irrigated farms usually have higher incomes than rainfed farms. Finally, the economic efficiency objective is served if water charges can be related to the quantity of water used (Easter 1987).

Charging for water is only one method of managing water demands. New water-saving technologies can be encouraged through education, technical assistance, subsidies, and low-interest loans. Better water control can also be promoted through education, new investments, and technical assistance. Demand can be managed by developing new market arrangements to facilitate the exchange of water, as California did in response to its five-year drought. (A water bank was established by the state's Department of Water Resources to facilitate water exchanges. Water was purchased from farmers at $125 an acre-foot and resold to urban users at about $175 an acre-foot.) Finally, water schedules and system-wide allocation procedures can be improved so that water deliveries better match demands. As part of improved scheduling, farmers need to be informed about probable seasonal water supplies. If supplies are going to be short and farmers know that before planting, they can adjust their cropping plans. The same is true if plentiful supplies are going to be available.

Cost Recovery

An issue that is closely tied to any discussion of water pricing is cost recovery. Without adequate water charges to cover operation and maintenance costs plus the cost of the original investment, the rest of the society is subsidizing those receiving the water. Thus, the decisions concerning what fees to charge and their collection partly involve the size of the subsidy, if any, that should be provided to a particular group of water users.

Generally, cost recovery is considered too late in the planning process, and expectations concerning fee collections are unrealistic. Setting the levels of water fees and collecting the fees require substantial resources and commitment. Thus, incentives need to be built into the system, such as bonuses for high collection levels or penalties for nonpayment of fees. Giving the irrigation agency responsibility for collecting fees can also provide incentives for high collection levels and improved service if the agency must rely on water fees for a substantial portion of its budget.

Collection levels will also be closely tied to the government's overall policy concerning cost recovery. For example, irrigation agencies may have difficulty maintaining high collection levels if agricultural inputs such as electricity, fertilizer, and pesticides are subsidized by the government. Farmers have expectations about what they "should" pay for government services, and these expectations may be zero for water.

Intersectoral Water Allocation

Intersectoral allocation of water is another highly political issue that usually involves high bargaining and decisionmaking costs. A number of issues are involved in such allocation decisions. For example, how are water services to be priced in various sectors? For hydropower, is electricity metered, and are charges or prices designed to encourage energy conservation or consumption? What are the collection levels, and how much electricity is used illegally (i.e., no payment made)? The same types of questions can be asked about water for domestic and industrial use. In some cases, fee schedules have been established during times of low energy costs and have not changed to reflect the new opportunity costs.

Generally, at the margin, water will have a relatively high value (willingness to pay) when used to supply domestic and industrial demands and a lower value (marginal value product) when used for irrigation. In contrast, the relative value of water used for navigation versus irrigation is not as clear and will vary depending on the alternative sources of transportation, the types of goods shipped, and the types of crops grown. Also, some uses are consumptive (e.g., domestic uses), whereas others, navigation and hydropower, are not. Nonconsumptive uses primarily compete with irrigation and domestic water uses in terms of the timing of releases that may not match irrigation and domestic water demands.

Because irrigation water uses generally have relatively low marginal value products and are by far the largest consumptive users of water (80 to 90 percent in many countries), it is the sector asked to adjust when water becomes scarce.[1] Flexibility, therefore, should be built into irrigation systems so that they can adjust to changing supplies. Systems need to be designed so that shifts can be made at relatively low costs to water-conserving crops and/or to rotation schedules for water allocation among farms and sections of an irrigation system (Easter 1986).

The value of water in various sectors is dependent on government pricing and taxation policies. For example, the government may keep agricultural prices low or impose export taxes on agricultural goods. Both measures will keep the marginal value product of irrigation water artificially low and alter farmers' ability to pay for water. In other countries, agricultural prices may be supported at levels above world prices, which encourages excessive use of water and other agricultural inputs. Thus, government pricing policy and development objectives need to be considered when decisions are made concerning intersectoral water allocation.

Other water allocation issues pose difficult economic and political questions with high bargaining and decisionmaking costs. First is the allocation of water among projects in a river basin that is in one state or province within a country. This problem is exacerbated when different agencies have responsibilities for different projects in the basin, i.e., hydropower versus irrigation. A second and more difficult allocation problem is when the water allocation involves two or more provinces or states within a country, such as in Pakistan. A final complication is added if the river basins cross several countries and water allocation decisions require extended negotiations among possibly unfriendly countries. In addition, once these agreements have been negotiated, they are difficult to change even where changing economic conditions make such potential adjustments beneficial to all provinces or countries involved.

Additional Pricing Issues

What water charges and/or regulations on pumping should be imposed when overpumping is damaging an aquifer? How are these charges or regulations determined and enforced? This problem is even more complicated when the aquifer involves more than one country. One important factor would be the future value of the water uses that will be lost because of damage to the aquifer. Another would be the transaction cost of alternative solutions to the problem. Finally, could variable water charges and/or regulations be used to alter groundwater pumping along rivers so that its interference with surface water irrigation is reduced?

One of the problems with water fees has been the inability of government agencies to collect them. This may be an area where the private sector could play an important role. Can private firms or water user organizations be given responsibility for collecting fees?

Fee collection might also be increased if farmers could earn more from the irrigation capital, i.e., increase their ability to pay. This might be done by intensifying crop production, increasing the number of cropping seasons, or using the capital equipment for other enterprises in the off-season. For example, pump engines could be used in other economic activities such as rice milling.

Additional Water Allocation Issues

Determining the value of water in alternative uses is necessary to improving water allocation decisions. For example, what is the value of water for in-stream water uses that maintain fish populations and/or dilute waste loads? This is not a simple task because these values will change over time in response to rainfall and changing discharge needs.

It is also important to devise new institutional and organizational arrangements that better coordinate water users and agencies managing and allocating water. Developing water user organizations to allocate the water is one good alternative. Ways need to be found to allow centralized planning with decentralized operation of the systems that involves close contact with the water users.

At what level should water allocation decisions be made? The interdependencies among water users argue for some basic planning and allocation decisions to be made at the river basin level. In contrast, information costs and bargaining and decisionmaking costs favor decentralized decisions where it is easier to obtain effective water user participation. Thus, sector and intersectoral investment and allocation decisions are probably best made at a higher level, whereas allocation decisions within one project should involve the water users and therefore are better handled at a decentralized level.

An important problem in allocating water within the water sector is the numerous agencies involved. How can better coordination be achieved among the different agencies involved in water allocation? It is not likely that one super water agency can be created, nor is it desirable. Thus, the best course of action is probably improved agency coordination.

A final issue involves incentives for private investment that would improve water allocation and water use. What private investments would have a positive impact on water allocation, and how could such investments be encouraged? For example, could cost sharing or technical assistance be used to encourage farmers to install structures that allow them to more efficiently allocate and use water?

Conclusion

With the growing pressure on water resources in many developing countries, it is time that demand management strategies be considered more seriously. We can no longer just look for the "easy" supply options because they are usually no longer available. Where water projects exist, therefore, conservation and water pricing options should be considered. Yet for demand management to be effective, new institutional and organizational arrangements are required: if these are not present, critics will be proved right because demand management strategies such as pricing will fail.

Water allocation within the sector often needs to be improved. As water has become increasingly scarce, irrigation is being asked to give up some of its water for other higher-value uses. If effective, this reallocation should have only minor impacts on irrigated agriculture and may even reduce drainage problems. To facilitate such reallocations, investments in water development must incorporate flexibility so that changes in water use can be made as demands change.

Note

1. These low marginal value products for water used in irrigation are appropriate measures of the value of water use in agriculture as long as these are marginal changes. However, if a significant amount of water is transferred from an area where entire communities have been built around irrigated agriculture, then secondary economic effects may need to be considered. This also raises several measurement and conceptual problems, as well as important political considerations.

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ALLOCATING CALIFORNIA'S WATER SUPPLIES DURING THE CURRENT DROUGHT

David N. Kennedy

This presentation discusses how California is coping with its five-year drought, particularly focusing on the establishment of a water bank to reallocate water from agricultural to principally urban uses. First, there is some background provided about water resources in California prior to the present drought.

Background

California's Department of Water Resources has two principle activities: First, it owns and operates the state water project, a system of dams and canals that provides about two-thirds of Californians with some portion of their supplemental water supply. The department built these facilities and has title to and operates them. Second, there are local assistance activities throughout the state where the department provides planning assistance and some grants and loans, and conducts studies for local water districts throughout California.

About 80 percent of the developed water in California is used for irrigated agriculture and about 20 percent for urban needs. The percent for irrigated agriculture is continually decreasing because agriculture, unlike urban use, is not growing in the state. Just a few years ago, irrigated agriculture required 85 percent of developed water, and that figure will continue to decrease. Most urban areas, and a majority of irrigation districts, depend on some combination of local and imported supplies to meet their needs; i.e., there are very few sections of California that depend entirely on the supply in their local area to meet their needs. In some urban areas, such as the San Francisco Bay Area and Southern California, about 90 percent of the water used comes from an imported supply. Consequently, over many years we have developed a statewide plumbing system with storage and conveyance facilities. It can move water in California from north to south and from east to west (the latter direction because the Sierra Nevada Range is in the east and most urban areas are along the coast). Thus we have developed—not by design but almost by happenstance—a huge plumbing system of reservoirs (over 1,000), pipelines, and canals that can move water within the state. Over time this system has gradually become increasingly interconnected, so that we can now serve either directly or by exchange much of the state.

Forty percent of total statewide demand in an average year is met by groundwater pumping. In a dry year, such as the present one, this percent increases up to 50. There is considerable potential to expand groundwater programs. There are several very large basins, some of which are operated beyond their safe yield, but if conjunctive use programs can be organized, there is the potential to more fully utilize the groundwater basins than is presently being done. Local, regional, state, and several federal agencies are involved in the development and distribution of water, yielding a tremendous mix of agencies involved in these spheres: this also leads to many problems.

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Water Rights Allocation

The established water rights in California are a form of property right. They cannot be taken from one use and given to another without compensation. (This is particularly relevant to the current drought, discussed below). There are several different kinds of rights, e.g., riparian rights, which much of the world exercises on land adjacent to watercourses. Generally, riparian rights, almost all of which were developed some years ago, constitute a small portion of the rights in California. Our system of appropriative water rights, obtained through a state permit system, is administered by a state agency, the State Water Resources Control Board, with its five members appointed by the governor.

There are also the "pre-1914 rights," those rights established before the permit system. These are unquantified rights, which occasionally cause problems in a particular situation, but essentially are not significant on a statewide basis. Contract rights give the public agencies with whom we have contracts the right to water service, and they can litigate against us if we do not deliver on that right. Our department has contracts with 30 public agencies in the state, most of which are wholesale agencies. At the retail level, there are several hundred agencies that receive water through these state contracts. A few of our federal contracts are with the Corps of Engineers, but most are with the United States Bureau of Reclamation (USBR), which has more than 200 water contracts in the Central Valley (the Central Valley Project).

Finally, there are "area of origin" rights, an unquantified statutory concept in which the areas, watersheds, and places of water origin cannot be deprived of the water needed to meet their reasonable needs. This concept is embodied in a statute legislated many years ago. It has not been quantified in the sense that there is no one who actually has an area of origin right: it is more of a vague political concept about which people argue; nevertheless, it is important to protecting the areas from which water originates.

Water Pricing

Most of California's local, regional, and state water prices are based on a cost of service concept. We get much advice about marginal pricing, but voters generally will not approve anything more than cost of service: if local politicians vote on raising water rates above cost of service, they are jeopardizing their jobs. The principle exception to cost of service is the USBR, with its long-standing "ability to pay" concept. This is how the USBR was organized many years ago to foster irrigation in the western United States. It entered into numerous contracts in which the amount paid for water depended on the ability to pay. There is great debate over the definition of that term. Over time, USBR prices generally have been increasing annually, but many think that there is inequity in that people getting water from the USBR pay one price and people getting water from our state project pay a much higher price, sometimes in situations where they are farming in adjacent areas.

The Current Drought

California, and most of the western United States, is in the fifth year of a drought. 1987 through 1990 were the four driest years much of California had ever had. Generally, reservoirs were drawn down to very low levels by the end of 1990. The crisis came at the beginning of 1991, when there was still little precipitation, and urban areas throughout the state were facing 50 percent water shortages. A 50 percent shortage in the Bay Area or in Southern California generally means a loss of all the landscaping and of all the lawns, shrubs, etc. Some farmers were indifferent, but those who make their living in the "green industry" said this was a multibillion-dollar problem (and, of course, most voters had a lot of landscaping). Thus, we had a serious problem. A 50 percent shortage in a major urban area in

California was front page news in every newspaper, every day. It was also receiving national television coverage. All of this coincided with a new governor taking over after eight years. Governor Wilson not only had a budget problem, but a serious drought problem as well. His view in January was that the drought was the highest priority. In early February, demonstrating the severity of the problem, our state water project reduced urban deliveries to 10 percent—a 90 percent reduction—and eliminated all agricultural deliveries: we told the irrigation districts that we serve that there would be no irrigation water during 1991. In the state project there are probably 100,000 acres of trees and vines that do not have any groundwater supply, so we were losing a tremendous amount of permanent planting. To put the 90 percent reduction for urban deliveries in perspective, most of the areas that we serve get some portion of their water from us, some portion from local supplies, and in some cases are also served by the Central Valley Project or regional supplies. But if anyone had told us last fall that we were going to have 90 percent urban shortages or a 100 percent cutoff for irrigated agriculture, of course we would not have believed it. At the beginning of February, when we assessed what was in storage, we were two-thirds through the rainfall season, and it was the driest year on record.

What were the effects? Some elected officials, some congressional representatives, and others were publicly calling on the governor to simply take over some of the irrigation rights in the Sacramento Valley, the biggest watershed in California and the one with a fair amount of water, and reallocate the water to other uses. There were editorial calls and much public debate that the time had come for the governor to simply declare a statewide emergency and reallocate everybody's water. There might have been good reasons to do this, but we believed there were better reasons not to do it: water rights are a form of property rights, and although the governor could legally take over these irrigation rights, he would have to compensate the owners for having done so. Under California's State Emergencies Act, the governor can take property, but has to compensate for it. As we debated this with the governor and others, we considered the multibillion-dollar litigation we would face if we simply took over those water rights. At the same time, we recognized that it did not make sense for rice farmers and people growing tomatoes and corn to have a 75 percent supply of water when the urban areas were going to suffer serious shortages and when some trees and vines were going to be without water. So we very quickly came up with a concept—the Drought Water Bank: the governor directed the Department of Water Resources to establish a water bank where we would purchase water from farmers and then resell it to those who had the most critical needs.

The operating principles of this bank would be as follows: All purchases would be on a voluntary basis; that is, the governor reserved the right to step in with emergency powers, but he wanted to let us try to do this on a voluntary basis so we would not have to spend the next 20 years in court. The price offered to the farmers was based on a "market test basis." First, some Department of Water Resources economists figured approximately how much it would take to compensate a rice or corn farmer sufficiently so that he or she would be interested in yielding a portion (or in some cases, all) of his or her water this year. We came up with about \$100 or \$110 an acre-foot, and at the same time we were talking to some farmers to see what it would take to have them not farm this year. We rather quickly came to a value of \$125 an acre-foot, and we signed the initial contract in early February. One problem was what if we could not get enough water at this price and would have to pay more later—what would happen to those who had signed up early? We therefore included a provision that all early contracts would be paid the amount that the later contracts were paid. We were able to purchase everything that we wanted at \$125 an acre-foot, but during the month and a half of negotiations, we received much advice from people who said we were not paying enough. Many rice farmers said that we were going to pay at least \$300, and they thought that we were being completely unreasonable and should pay more. As long as we were getting as much as we needed with \$125, we would not go above it, but were prepared to do so if needed. While we were meeting with farmers who were going to sell us water, we were also meeting with the districts who wanted to buy water from us to discuss the price they would pay. This became a complicated process.

California's water districts have a statute under which a district cannot permit water to be sold outside that district unless there is a surplus within the district. No one had a surplus, so we had to have some way to get the water out of a district although everyone in the district wanted to sell it. So we asked the governor to call an emergency session of the legislature. We put together a brief statute that is only in effect during 1991: it permits water district boards to approve the sale of water from one of their farmers to us although there is not a surplus within the district. This procedure has been successful.

Where do we stand as of June 1991? We have purchased about 750,000 acre-feet of water: 400,000 acre-feet from fallowing of farmland; 210,000 acre-feet of groundwater, which we had not originally expected to purchase; and 140,000 acre-feet from surface reservoirs. We have been storing the water in one of our state-owned reservoirs (Oroville) and in one of the federal reservoirs (Shasta). To obtain this amount, we have had 340 separate contracts with farmers or irrigation districts, an extremely complicated matter involving attorneys and hydrologists. Currently, of the 340 contracts, about 320 have been processed and approved. The remaining 20 are complex and involve difficult questions. For instance, we have to make sure we are getting real, not paper, water, and we have had to monitor and examine the details of every contract. Also, there have been a few instances of farmers selling us their production this year and then going ahead and irrigating.

Of the water purchased, about 400,000 acre-feet have so far been allocated: 320,000 acre-feet for urban needs in the San Francisco Bay Area and Southern California and 80,000 acre-feet for the trees and vines in the San Joaquin Valley.

Conclusion

Generally, the water bank is considered successful, and even the critics who advocated that the governor take over the water without compensation feel that the water bank has been a valuable way to deal with the drought. It has shown Californians that we can use water marketing to transfer water from agricultural to urban needs to meet the growing population. Some difficult issues, however, such as third-party impacts, have barely been addressed. There have been many angry letters from people with trucking, seed, and tractor companies who thought that they had been left out, and they had been as we dealt with this new situation.

Because of the complexity of California's water rights, it is difficult to mandate extensive changes in water policy. Most progress in California is made incrementally. Sweeping suggestions, although some of them sound like good ideas, run directly into the problem of existing water and/or property rights. If one proposes taking or reallocating these rights, then years of litigation will follow. We have found, therefore, that we can progress through negotiation. Because of the crisis hanging over our heads, we were able to make much more progress in much less time than is usual in California. I do not know whether this bodes well for the future or if it simply means that when we do not have a crisis we will return to the time-consuming approach to dealing with these problems.

THEME II

INSTITUTION BUILDING

INSTITUTIONAL ARRANGEMENTS FOR WATER RESOURCES DEVELOPMENT

Scott Guggenheim

The institutional arrangements for developing and managing water resources are the transmission gears between policy objectives and field-level performance. Whereas policies raise questions about *what* is to be done, institutional analysis asks *who* is expected to do it, and with what resources, and *how* are the institutional building blocks expected to interact. One general difficulty in discussions of institutions is that the term institutions can refer to phenomena as diverse as formally structured agencies, such as national irrigation authorities, to any recurrent system of relationships, such as institutional arrangements to improve water use efficiency.

Institutional frameworks are established by legislation that provides basic operative norms. Legislation is inherently incomplete, however, and the formal institutions established by law are always supplemented by informal institutions that can either complement the functions of institutions (such as water user associations) or compete with them. Basic questions about institutional integration include how well institutions function internally and how efficiently they interact with other institutions to carry out the functions set by policy. This paper highlights several key aspects of institutional structure and operation, including centralization/decentralization, the role of the private sector, local-level management, coordination, cost recovery, and environmental capability.

Centralization/Decentralization

Whether to promote centralized water development institutions as opposed to decentralized distribution among agencies is a common problem for governments. The main disadvantages of centralization are bureaucratic cumbersomeness and slow response. Its advantages are ease of coordination and the ability to provide for integrated development with internal human and material resources. Conversely, decentralized institutions can provide more flexibility and are usually more specialized. Their disadvantages can include poor coordination and redundancy among several different institutions working in a single area, and there is a tendency to delegate functions to institutions before they have the mandate, skills, or resources to manage them effectively. Other variables that affect the centralization/decentralization issue include:

- *complexity*. Small countries such as Jordan can effectively manage all aspects of water resources development with a single overarching agency (Abu-Taleb et al. 1992). Other countries limit the main agency to providing regulations and guidelines, with line agencies responsible for more specialized works;

- *timing*. For Turkey, Bilen and Uskay (1992) have argued that early development is best handled by a central agency, whereas later development needs to be distributed among more specialized institutions.

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One difficulty in addressing decentralization is that it cannot be resolved on the basis of *abstract* first principles. Optimizing institutional integration depends on distributing functions to the most appropriate level. Certain functions, such as development of national policy and regulatory frameworks, can only be carried out at the national or state level. This is usually true where there are multiple claimants on water resources, and thus high-level interagency coordination is needed. Other functions, such as watershed management planning, are more effectively conducted at the regional or local level. Decentralization strategies must proceed on the basis of not only devolving responsibilities to regional and local organizations, but also conducting analysis and planning to ensure that organizations are capable of managing their incremental functions.

The Private Sector's Role in Water Resources Development

Increasing privatization of water development places substantially different demands on public sector institutions. First, major decisions must be made about which planning, regulatory, and operational functions to retain during privatization. Second, institutional reforms are often needed to facilitate private sector management, such as establishing ownership rights to water resources that encourage their efficient development and exchange. Third, as the English experience shows, major institutional restructuring is often required before privatization can occur (Kinnersley 1992). Last, the private sector is generally less directly concerned with equity and environmental matters, and the public must depend on the sector to respect preexisting public policy frameworks.

Local-Level Management

The need to develop effective local water management organizations dovetails with the trend toward decentralization and privatization. A high priority should be increasing analytic discernment among different local-level management systems, which vary by function, structure, power, financing, inclusiveness, legal mandate and title to water rights, and means of integration with higher-level organizations. Preliminary field evidence indicates that relatively strong, single-function, local organizations have among the highest rates of farmer satisfaction, long-term sustainability, and cost recovery.

Given the current emphasis on water recycling, farm-level efficiency, and demand-driven irrigation needs, institutional linkages should extend to the farm level. Important related questions include: What factors produce local-level institutional success? How can farm-level institutions be integrated into the irrigation institutions operating at regional and national levels? What legal and administrative arrangements are needed to promote more effective farmer organizations? What functions are best carried out by local groups, and how can they be reinforced? What incentives are needed to promote active member participation in water user groups?

Coordination

Coordination problems generally fall into three categories: (1) international, (2) intersectoral, and (3) intrasectoral. At the international level, there is interest in institutions that can address concerns about riparian rights, yet concrete suggestions about the nature of the institutions that should manage them are usually absent. Even where nearly all participants seemingly benefit from international coordination, such as the Nile Basin development proposals described by Whittington and McClelland (1992), there are few signs of progress. Most experiences with river basin planning have not been encouraging. Even in developed countries, the logistical problems river basin planners face are institutionally daunting, and few of the preexisting local, regional, and national institutions will cede the requisite authority to make them effective coordinators. To develop a mechanism for addressing international issues, a central, short-term focus should be laying the groundwork for establishing an institutional framework within which required functions can be carried out with the necessary authority from the participating countries.

Within many countries, the general approach to intersectoral coordination is through ministerial-level coordinating committees, but these do not always provide optimal coordination. Increased privatization and the growth of environmental regulations are underscoring the need to avoid excessive and possibly contradictory efforts and regulations. Syria has formed what prima facie would appear to be the preferred approach (Bakour 1992). Since its Ministry of Irrigation is charged with identifying the functions and roles of the different institutions in the water sector, there are clear lines of command and mechanisms for evaluating competing claims on water resources. In practice, however, this has produced excessive duplication of effort, apparently because of overlaps with domestic and urban water authorities.

Functions are often distributed among many agencies: development of the Chao Phraya basin in Thailand, for example, involves 24 departmental-level agencies under 8 different ministries involved in planning, developing, and managing the river basin, with coordination provided by high-level interagency committees (Vadhanaphuti et al. 1992). An alternative scenario is described for Turkey, where the General Directorate of State Hydraulic Works virtually by itself manages all water functions, ranging from power generation to drinking water delivery (Bilen and Uskay 1992). Many new models of intersectoral coordination institutions are being explored, and evaluating the contrasting experiences of different models, isolating the designs that can be applied to other contexts, and assessing the relative weight of different variables in explaining their success or failure are research topics that will have a high payoff for developing countries.

Two common intrasectoral problems are how to match skills mix with system needs and how to attract and retain quality personnel. Also pertinent is that under general conditions of declining or no growth in government institutions, there is a need to reassess what duties can reasonably be performed with current staff and budgetary resources.

Cost Recovery

In an era of increasing privatization and declining public sector budgets, few water management agencies can sustain the high rates of low cost recovery that have characterized past projects. Cost recovery rates are highly responsive to institutional reforms. In the Philippine National Irrigation Administration, for example, basing agency budgets on the recovery of investment costs from farmers led to major reforms designed to provide better service and thus increase farmers' willingness to pay. In the western United States, rather than extending regional institutions to the local level, water is sold to locally elected, legally autonomous irrigation districts that must find their own mechanisms to raise the money for water charges.

Strengthening Environmental Capabilities within Water Institutions

Because of the declining quality of water resources resulting from pollution and environmental degradation, checking the loss of water resources through contamination is of greater concern to many countries than developing new sources. There are three main arenas where environmental policy reforms are urgently needed: First, international pollution problems—upstream discharge from one country contaminating the water resources of others—will become increasingly severe in the developing world as demand for usable water supplies rises and economic development continues to entail greater discharge of contaminants. Agreements on establishing acceptable regulatory frameworks and enforcement mechanisms for limiting water contamination face the same challenges and impediments as the riparian issues described above. Second, contamination of water supplies is usually the last link in the pollution chain: strategies for remedying water pollution will have to be based on improved technology and management rather than "end-of-pipe" damage control. Third, establishing a clear regulatory framework is necessary to successful privatization. England's experience with privatization suggests that the need for strong environmental assessment and regulatory capabilities will increase substantially as privatization proceeds (Kinnersley 1992).

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PRIVATIZATION AND THE WATER ENVIRONMENT IN ENGLAND

David Kinnersley

In the last four years, the organization and financing of water agencies in England and Wales (though not in Scotland) have changed considerably. These changes not only break new ground in various ways, but specifically reverse what were regarded as some key features of the major reorganization of 1973-74. This paper provides only a short overview of these developments, but four questions deserve consideration, however brief:

1. What is the new pattern of agencies?
2. Why and how was it adopted?
3. How is it working so far?
4. Are there lessons others can draw?

The New Pattern of Agencies

As a guide to the new pattern of agencies, two important demarcations are helpful. The first is between what are now called water utility services—the man-made activities of water supply, sewerage, and sewage disposal—and the river basin and environmental functions, i.e., flood defense, water resources, pollution control, fisheries, and navigation. Irrigation and hydropower do not play significant roles in British river basins: if they did, events would have been far different.

The second demarcation is between regulatory activities (issuing permits and licenses, allocating natural resources among different uses, etc.) and operational functions, with a direct physical impact (e.g., water supply and flood defense).

Water Utility Services

The utility services require most of the money and personnel. Water withdrawals for piped public water supply account for 60 percent of all volumes withdrawn. There are 10 recently privatized companies that provide (a) water supply to about 75 percent of the population in their respective territories, and (b) sewerage and sewage disposal services to all the users of these services. Additionally, some 25 older companies that have long provided water supply only on a special statutory private basis continue to do so for the other 25 percent of users, though the basis for their economic regulation has been changed to conform to that now applied to the 10 water and sewerage companies.

The 10 large companies serve populations between 1.5 million and 11.5 million. Areas served range from 9,400 to 27,000 km^2. The companies that supply only water are generally much smaller, serving populations between 100,000 and 1 million, though three that are adjacent are merging to form a much larger unit. The area of England and Wales is 150,000 km^2, and the population about 50 million. Average rainfall in 1989 was 801 mm, ranging from under 600 mm in the eastern region to nearly 1,200

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mm in the west. Average per capita household usage is 136 liters per day. Total volumes supplied in 1989-90 were 17,240 megaliters per day.

Because the 10 utility companies are now private monopolies of a service on which everyone depends, there is a newly created Office of Water Services (OFWAT), with considerable powers to monitor and regulate these companies' charges and level of service. OFWAT also administers a system of regional committees for consumer consultation. The director general of OFWAT reports to Parliament, not to ministers of environment, and has senior standing as a public official, similar to his or her counterparts in other privatized utilities.[1] The government has also set up a Drinking Water Inspectorate, whose tasks include enforcement of European Community Directives relevant to drinking water.

River Basin Functions

Since 1948, river basin agencies with multiple functions had covered all parts of England and Wales, and new tasks, such as pollution control, were later added. Then, in 1974, the number of agencies was reduced from 30 to 10, with their river basin roles and the provision of utility services combined into all-purpose authorities intended to deal with all aspects of the hydrological cycle.[2] This configuration has now been reversed: As indicated, the utility services (in 10 territories) have been separated and privatized into shareholder ownership, with shares traded on the Stock Exchange. The river basin functions have been kept together in the public sector, but transferred for the whole of England and Wales to a single body, the National Rivers Authority (NRA). The name is not adequate: the NRA has, in addition to its work on inland waters, major responsibilities for coastal flood defenses, pollution control, and some fisheries (in estuaries) and coastal waters up to the three-mile limit.

The NRA maintains a 10-region organization for its executive work, which includes both regulatory and operational functions. Broadly, pollution control is regulatory: flood defense, fisheries, and navigation are mainly operational.[3] But there are significant overlaps, and the NRA also can promote amenities and recreation related to water. It describes itself as "the guardian of the water environment."

Two points are relevant for completeness and accuracy. First, much setting of water standards now comes to Britain from European Community Directives. Enforcement of these standards is the responsibility of the central government's Department of the Environment, but the department asks the NRA to act on its behalf in much of this work. Otherwise, the NRA (headed by a board of 15 independent members appointed by the secretary of state) acts autonomously under legislation defining its duties and powers, though for some of its detailed decisions there can be appeals to the secretary of state.

Second, to deal with dangerous substances, Britain has just introduced Integrated Pollution Control (IPC), covering discharges to air, land, and water and the processes generating such discharges. IPC is administered by Her Majesty's Inspectorate of Pollution (HMIP), a division of the Environment Department, though it soon may become a separate agency. The NRA has a carefully defined relationship with this new agency regarding its work on discharges to the water environment.

Finally, Scotland provides a sharp contrast: no aspect of water management in Scotland has been privatized. The utility services are essentially provided by elected regional authorities dealing with many other public services, and there are separate river purification boards. The population is just over 5 million, in a land area about half that of England and Wales. Average rainfall is 1,431 mm. In short, in Scotland water is not under the severe strain generally imposed upon it in England and Wales. Also, the political balance is very different: a strong overall majority has only a small minority among members of Parliament representing Scotland.

Reasons for Change

The reasons for adopting the pattern just outlined may be expressed in two main ways. First and foremost, the Thatcher government developed a tremendous political commitment to reducing the public sector by transfers to private ownership. In this setting, water became a special challenge—the awkward candidate, which aroused not so much public opposition as, until the last moment, widespread incredulity. To anticipate a later point, let no one underestimate how much political willpower was required to privatize water utilities in the particular way England and Wales have.

Second, in financial terms, the regional authorities had been subject for several years to severe constraints on capital spending (for government macroeconomic objectives), although their dependence on borrowing had been greatly reduced by enlarging internal cash flows. As the backlog of necessary capital spending grew, ministers wanted to avoid meeting this obligation in the public sector.

Broadly, the all-purpose authorities created in 1974 were intended to be effective regulators of their own sewage works discharges and those of industry and agriculture. As they came to turn a blind eye more often to their own breaches of pollution controls (arising from capital restrictions), their general standing as stewards taking good care of the water environment was discredited. Underfunded, they could hardly hope to hold the respect of a public increasingly sensitive to environmental issues in general and water quality in particular.

How Is It Working So Far?

The answer to this question must be that, so far and on a superficial level, the new pattern is going well. The actual process of selling the 10 utility companies into private ownership went better than many of those involved had dared hope. But it was helped by the government writing off some £5 billion of past debts and contributing about another £1 billion. Because this so-called green dowry was roughly equal to the proceeds of the sale, it may not be too crude an assessment to say that the utility companies were virtually given away. However, the obligation that the new owners were taking on was to achieve a capital spending of some £24 billion in 10 years—more than double the rate of investment achieved in public ownership in the 1980s.

Not surprisingly, the utility companies do not welcome the combination of economic regulation by OFWAT and environmental regulation by the NRA to which they are now subject. Occasionally, it has been suggested that the two regulatory bodies may cause problems and conflicts for each other, but there is little or no sign of this being more than a "settling-down" process. A serious issue to be resolved in the next several years is how the private utilities will charge for water and sewerage services. Britain has almost no metering of household supplies, and managers repeatedly seem to stifle moves in that direction. Yet Mrs. Thatcher passed a law requiring them to abandon their traditional property tax method of charging by the year 2000. At least new properties now have to be built with provision for water metering. OFWAT has just conducted a consultation on metering and other methods of charging. For certain areas where water resources are under great strain, the NRA would welcome moves to metering as a way of linking the inclination of households to use more water to a recognizable unit price. In recent summers, many areas have had legal bans on garden watering or car washing by hosepipe.

The NRA's first two years have been successful. In the all-purpose regional authorities, river basin functions had been overshadowed. Specifically, the internalization of conflicts between, for example, sewage discharges and pollution control had led, largely behind closed doors, to the understandable policy of not adding to the problems that the utility managers already had with capital spending restrictions. Thus it was urged that what had been overshadowed need not receive much attention or resources in the future. But the exact opposite has occurred. Once the NRA was seen as an independent guardian of the environment, it was swamped with work.

Some of this workload is sorting out different inherited practices from 10 predecessor authorities. Much of it has been adapting polices and practice to new government policies, new public attitudes widely expressed through the media and Parliament, and the river basin problems that are worsening in some catchments in a very overcrowded island. In particular the quality of some rivers in farming areas is declining: diffuse pollution is at least as worrisome as point discharges. New policies on permit compliance have been published and widely discussed, and are ready to be implemented. Charges for direct discharges to rivers and coastal waters were introduced within two years, after 20 years of resistance and inertia. Overabstracted catchments have been identified. Flood defense requirements are being systematically reviewed.

The chairman of the NRA is a distinguished politician retired from the House of Commons after seven years of service in the Thatcher cabinets. This may not sound like the best training ground for environmental guardianship, but Lord Crickhowell has shown himself to be a good chairman, grasping especially one key point: the results that the NRA has to achieve must be achieved mainly through the efforts and expenditures of others, in factories, farms, sewage works, waterworks, and elsewhere. Thus, alongside the necessary work of detailed issuing of permits and monitoring, there are major tasks of political advocacy and public persuasion to be repeatedly addressed.

There are serious hazards still ahead. One effect of privatization—in water, one suspects, more than in other cases—was to strongly politicize the range of water policies that one hoped might become less politicized. The Labour Party states that if elected it will reverse water privatization. Another upheaval, another reversal, could be very damaging. Several times, Britain has reorganized water management as perhaps a substitute for better specific policies. This time, we are getting better policies as well.

Another hazard is whether the public will accept the price increases projected as necessary. In many cases, they may be five percentage points above the increases in the Retail Price Index. OFWAT is vigilant against excessive increases, but one objective of privatization was to get a much larger capital expenditure program financed by users through higher water bills, without ministers having to take responsibility for those higher bills.

Lessons for Others

Water policy problems occur in surprisingly similar forms in many different countries, despite differences of climate and natural resource endowment. Yet in practical terms, solutions to these similar problems need to be suited to very different institutional settings.

One contrast is between nations with federal governments (Germany and Malaysia, for example) and those with unitary governments. Another contrast—especially between Britain and France, for example, both currently with substantial private participation in water services—is the relative robustness (or weakness) of local government as a major actor in the water management scene. Across such differences, generalization is liable to be misleading. Someone as close to the British scene as I am may not be in a position to judge what others should learn from that scene, but my recent consultancy on these issues in several countries may provide some detachment: the following points provide a basis for discussion.

First, the latest British changes grew (political party doctrine aside) out of a failure of a system that had been adopted 15 years earlier with little controversy and strong arguments in its favor. It was undermined, according to this view, either by central government refusal to allow capital investment that could be afforded, or by economic decline that made that investment incapable of achievement. In both cases, these factors are external to water management. This suggests that water management may be specifically vulnerable to external factors, not necessarily because it is in the public sector, but perhaps because it is perceived as "capital greedy."

Second, only political rhetoric claimed that private ownership would achieve huge efficiency gains. The 10 authorities to be privatized achieved personnel reductions of about 20 percent in the first half of the 1980s, before privatization was even a prospect. More broadly, to achieve the sort of privatization by sale of companies and assets that Britain chose, it is necessary to make the companies efficient and potentially profitable before private investors can be expected to be sufficiently interested and a successful flotation to be within reach. Thus privatization is in no way a substitute for other difficult moves such as striving toward good operating standards and good financial results (worthwhile objectives in themselves). (An earlier proposal to privatize the all-purpose regional authorities as they were was widely opposed and soon abandoned.)

Third, recall the utility/environmental demarcation from paragraph 2 of this paper. The environmental functions have to remain in the public sector, on clear principle, because they depend on regulation and enforcement (in legal terms), and because they involve the allocation of common natural resources and the provision of indivisible public goods (in economic terms).

Further, the water utility functions can only be privatized if they can be reliably disciplined in environmental terms because of their huge impact on the water environment. Moreover, the management and the investors need to assess the framework of constraints (environmental and price controls) within which the private companies will have to work. Unless this is capable of being handled rigorously by government and private investment agencies, there are enormous hazards in English-style privatization, which involves selling infrastructure assets on which the entire community depends for health and hygiene, as well as for industry, commerce, and tourism.

Conclusion

English-style privatization is not the only type to be considered, but in Britain it is the one that we may be able to make successful. If this paper had to provide a single message, it would be that there are notable potential advantages to turning water agencies into well-run businesses, regardless of ownership. There are major hazards, however, in making them private monopolies unless there are also sustained and effective safeguards to prevent monopoly abuse in charges and to protect the water environment reliably.

Postscript

Since the World Bank workshop, the U.K. prime minister has proposed the creation of an Environmental Protection Agency, including HMIP and parts of the NRA.

Notes

1. This paper does not attempt to discuss the relatively heavy economic regulation built into British water privatization.

2. For changes in British water institutions from 1948 to 1988, see Kinnersley's *Troubled Waters: Rivers, Politics and Pollution*, published in London in 1988 by Hilary Shipman.

3. For land drainage and fisheries, the NRA has close links with the Ministry of Agriculture, Fisheries and Food (MAFF), which appoints some of the NRA's board members.

THEME III

TECHNOLOGICAL ISSUES

TECHNOLOGICAL ISSUES IN WATER MANAGEMENT

John D. Keenan

Water resources management refers to the conception, planning, design, construction, and operation of facilities to control and use water. The principal issues of water resources development are the control of water (flood control, land drainage, sewage conveyance); the use of water (hydropower, drinking water, irrigation, navigation); and the management of water quality (pollution control). Water use determines the amount needed, the timing of the need, and the requisite quality. It is often necessary to distinguish between *consumptive* and *nonconsumptive* uses of water. Nonconsumptive uses result in little or no diminution in the amount of water. For example, water used for navigation constitutes nonconsumptive use because almost all of it is still available for use in the local watershed. Consumptive use renders water unavailable for local use because of evaporation loss, inclusion with a product, etc. Spray irrigation is an example of a consumptive use because of the associated evaporation and transpiration losses.

The technologies used to address water resources problems include hydraulic structures and those aimed at controlling the quantity and quality of water. Particularly important hydraulic structures are dams; hydroelectric facilities; and the infrastructure required for flood control, drainage, and irrigation. In the regulation of water quantity, the objective is to match the supply of water with demand. Thus, these technologies may seek to control either demand (conservation, drip irrigation techniques, etc.) or supply (cloud seeding, storage, etc.). Regarding quality, the technologies of interest are designed either to alter the nature of the water (e.g., desalination) or to change the nature of its use (e.g., development of salt-resistant crops). Facilitating public/private development of technologies also merits attention. The following paragraphs briefly discuss the principal issues involved in the technology of water resources.

Major Issues

The following issues influence and shape the technological arena:

- *population growth*. Many nations are expanding at 2 to 4 percent annually. These rates roughly correspond to a doubling of population every four or two decades, respectively. This expansion, and the concomitant increases in agricultural and industrial production, sets the baseline for projections of water demand. The continued growth of societies places great pressure on water supply; already, some river systems are almost completely utilized;

- *value of water*. Often, water users do not pay an amount for water that reflects the true cost to deliver it. Consequently, there is no incentive for them to conserve water nor to invest in more efficient water use systems;

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- *geography and politics.* Hydrological boundaries and international boundaries do not coincide; that is, the important rivers flow across political boundaries. Consequently, there is a pressing need for international agreements concerning the allocation of water;

- *systems thinking.* Water resources problems are systems problems. One must approach them by thinking holistically: a piecemeal approach is destined to fail.

A pervasive issue is the perceived need to develop new sources of water. Some technological options include:

- *desalination.* The various desalting operations provide a means of using low-quality waters, and in some areas, desalination is vital to municipal supply;

- *development of groundwater supplies.* Related issues include the overexploitation, or mining, of groundwater; the relationship between surface and groundwater; the recharge of groundwater; pollution; and the monitoring of groundwater quality;

- *recycling of wastewater.* The pressures of escalating water demand necessitate examining the reuse of waste streams, including agricultural drainage, sewage, and industrial wastewater, determining how these techniques affect water quality and how they will be accepted locally;

- *storage facilities.* In many areas, annual flood waters are lost for lack of storage reservoirs.

Inefficient irrigation systems prevail in many areas. Methods need to be explored that will encourage improvements in the irrigation infrastructure and investments in more efficient application methods.

Environmental degradation often accompanies population and economic growth, with public health effects as well as a deterioration of water quality, rendering it unfit for various uses. Of specific concern are sewage, industrial waste, agricultural return flows (pesticide/fertilizer runoff), and abatement-safe handling of chemicals. Technologies related to water conservation, including those concerned with quality and standards, impact the long-term availability of and capacity to supply water. Soil conservation also influences the sustainability of water development projects and is intimately related to environmental protection.

Conjunctive use of surface and groundwater is being explored in some areas and may be viewed as the natural outcome of integrated management. The primary aim of conjunctive water use technologies should be to maximize efficiency.

Improving the hydrometeorological data base, using modern techniques such as sensor technology, telemetry, and satellite imagery, involves, among other things, forecasting, both for supply and drought, as well as long-range availability forecasts. Also important is the application of satellite data, remote-sensing, and geographical information systems (GISs) for water management, problem identification, supply runoff prediction, and other water resources activities.

Data collection management and the establishment of water-related data bases are significant components of effective water management. The management of technological transfer, including its adaptation and application, is another important area.

Future Perspectives

Water use efficiency must be a priority, specifically water use that is productive and retains quality. This entails not only new technology, but also the need for better techniques to evaluate efficiency. Those involved in water management must make policy choices, determining the extent of technology's role in the improved efficiency of water use and whether technology can mitigate or solve water problems. The technologies that are most appropriate need to be delineated for specific situations and areas, considering the level of technological and managerial skills required, and the technologies' impact, economic costs and returns, and limitations.

TECHNOLOGICAL ASPECTS OF WATER RESOURCES MANAGEMENT: EUPHRATES AND JORDAN

John D. Keenan

This paper discusses the technology available for resolving water problems in the Jordan and Euphrates drainage basins. In each of these watersheds, the discharge is strongly seasonally dependent. In addition, both the flow and the water quality decrease downstream as a result of evaporation losses, infiltration, and nonconsumptive uses. Because of these quality and quantity issues, long-term economic growth depends upon aggressive water resources management. Superimposed upon quantity and quality limits is an agricultural system that requires a significant and sustained hydrological and energy investment. Included in this paper are a review of the technologies used to improve water quality, a discussion of the use and limitations of technology in the context of the Jordan and Euphrates, and several examples of the application of technology in the study area.

Euphrates

The headwaters of the Euphrates River provide reputedly high-quality water. Data are not available to quantify this, although van Aart (1974) states that irrigation waters used in the lower part of the Euphrates average 300 to 500 ppm salinity and that the river water in the south may reach 600 ppm. Cressey (1958) reports that the salinity of the Euphrates averages about 250 to 445 ppm. Regardless, the use of the water for irrigation purposes upstream attests to its quality. In the estuary region located south of Basra, the salinity levels are naturally much higher. This is especially true at high tide in the autumn when the flow is lowest. During such periods, the salinity is typically over 5,000 ppm (van Aart 1974).

Talling (1980) presents groundwater data for the basin at stations located at Musaiyib on the Euphrates and at El-Zubeir on the Shatt al-Arab. These data indicate high concentrations of dissolved ions, especially sodium, magnesium, chloride, and sulfate. The salt content of the upper groundwater ranges from 7,000 ppm in the central part of the lower Mesopotamian Plain to 30,000 ppm in the south (van Aart 1974).

The lower part of the Euphrates is naturally prone to salinization. This results from a combination of poor drainage, centuries of irrigation, and natural soil factors. Edaphic factors in the lower basin contribute to a reduction in water quality as the river moves downstream. The flooding of the Abu Dibis depression by the Iraqis in the 1950s resulted in degraded water because of the rapid evaporation rate and the high salt content in the soils of the depression.

As noted in the section below, the three riparians—Turkey, Syria, and Iraq—have extensive plans for further development of the Euphrates. These plans are expected to mature and be implemented over the next 20 years, aiming at increased irrigation and an expanded industrial base as their populations grow. An unintended result will be the certain degradation of the quality of the water in the river's lower reaches, which will render the water progressively less fit for use by the Iraqis. The lower part of the

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Euphrates will probably experience a reduction in water quality proportional to that observed in the Jordan River in recent decades.

Current Water Use in the Euphrates Basin

Turkey uses the upper reaches of the Euphrates primarily for the generation of electricity via hydroelectric stations. This is currently changing as Turkish plans for making greater use of the stream, particularly for irrigation purposes, are being fulfilled. The Ataturk Dam has been completed, and the reservoir behind it has been filling since January 1991. It is presently about one-fifth full and is part of Turkey's GAP project, which will eventually supply 1 million ha with irrigation water.

The waters of the Euphrates and its major tributary, the Khabour, are used primarily for agricultural purposes in Syria. The Syrian economy has grown substantially during the past 40 years, and much of this growth has been attributed to increased agriculture. According to Beaumont (1978), water from the Euphrates for irrigation amounted to 3,000 million m^3 per year in the late 1960s. The implementation of the Tabqa irrigation projects over the next two decades will accentuate this trend. It is estimated that the Tabqa Dam will provide irrigation water for over 600,000 ha and that further development of the Khabour will bring another 400,000 ha under irrigation. Currently, approximately 250,000 ha are irrigated using Euphrates water.

Data are not readily available to document Iraq's use of the Euphrates. Bari states (1977) that little agriculture is supported in the al-Jazira region in Iraq, despite the potential fertility of the soil. The bulk of Iraqi agriculture is based in central and southern Iraq in the region around and south of Baghdad. Barley, rice, and dates are the staple foods. Beaumont (1978) indicates that the water withdrawn by Iraq rose from 27.3 percent of mean flow during 1940-49 to 45.1 percent during 1960-69. Most of this approximately 65 percent increase (in 20 years) is attributable to expanded agricultural irrigation. Gischler (1979) indicates that 48 percent of the cultivated land is under irrigation and that 80 percent of the irrigated land is affected by salinity. Presently, approximately 1 million ha are irrigated.

Water demands in the basin will continue to grow. Annual population growth in the three riparian states has averaged around 3 percent (Beaumont 1978; also see country papers in this volume). The increasing population will produce a proportional demand for electricity, agricultural production, and industrial production, all of which will in turn strain the region's water resources.

The use of the Euphrates system by the Syrians and Turks has serious international consequences. Of particular concern is the downstream riparian, Iraq. Continued use of the Euphrates for irrigation will lead to degraded water quality in the Euphrates, which will adversely affect the use of the water in Iraq. Also, increased use upstream by Turkey and Syria will reduce the flow in the river because the major use of the water is for irrigation, which is a consumptive use. Additionally, the irrigation water that is returned will be of degraded quality and will further aggravate the water quality problem. (The role of the Tigris-Euphrates link in Iraqi water supply is not yet fully developed.)

Large-Scale Constructed Facilities on the Euphrates

Over the years, the three riparians have formulated plans and implemented projects to achieve flood control on the Euphrates and to use its waters for the generation of hydroelectricity and large-scale irrigation. Little effort has been made to coordinate planning among the three riparians, and no formal agreement has been reached regarding the allocation of the water.

The Hindia Dam in Iraq, completed in 1913, represents the earliest modern development on the Euphrates. Its purpose was to divert water to reconstructed irrigation canals, including the Al Hillah irrigation channel. In the 1950s, a second dam was built at ar-Ramadi, which was designed for flood control and permitted flood waters to be impounded in Lake Habbaniah and the Abu Dibis depression.

The soils of the depression proved saline, resulting in a degradation of water quality and the scrapping of the irrigation plan. A third dam at al-Haditha, further upstream above ar-Ramadi and Hindia, was dedicated in 1985. It is intended to damp seasonal fluctuations in flow and to probably provide irrigation water in the future.

Syria has achieved considerable growth in irrigated land over the past three decades. According to Beaumont et al. (1976), reserves of cultivable rainfed lands have almost been depleted. Given the anticipated continuation of economic growth in Syria, an expansion of the amount of irrigated land is a necessity. Further expansion of irrigation requires more complete use of the Euphrates and the Khabour. Costly irrigation systems will be required for both rivers because each flows in a narrow deep channel.

Turkey plans to make extensive use of the waters of the Euphrates for hydroelectric generation and for irrigation. The first interest shown by Turkey in the Euphrates was as a hydroelectric source. The Keban Dam, completed in 1973, was designed to produce electricity and to attenuate the seasonal peaks in the flow regime of the river. This lower Euphrates project anticipates the irrigation of about 80,000 ha from the river basin's groundwater.

Turkey also has plans for three additional dams below the Keban. When completed, Turkey's GAP irrigation works are projected to require between 17.5 and 34 percent of the total flow of the Euphrates at Keban, resulting in a significant reduction in the river's flow, which will not be compensated by the seasonal flow regulation of the dams.

Given the proposed development schemes of each of the three users of the Euphrates, in the near future the waters of the river will be completely utilized. Successful completion of all the planned projects may lead to a very small surplus (or even a small deficit) of water in average flow years and severe shortages during droughts (Beaumont 1978). The anticipated completion dates of these projects are subject to conjecture; however, in the absence of improved efficiency and increased conservation, it is reasonable to assume water shortages in the basin by the end of the present century.

Jordan

The headwaters of the Jordan are generally of high quality. The three tributaries of the upper Jordan—the Dan, Hisbani, and Banias—have a salinity of about 20 ppm, clearly low enough to satisfy most uses. The salinity of the Yarmouk River is also reasonably low, reportedly 100 ppm. The salinity of the lower portion of the Jordan River system becomes progressively greater below the entry of the upper Jordan into Lake Tiberias.

Several natural sources render Lake Tiberias water saline up to about 350 ppm (Garbell 1985), too high for some sensitive crops, most notably the citrus fruits economically important in this region. Much of the salt results from the inflow of salty subterranean springs. (Considerable efforts have been devoted to reducing the salinity of Lake Tiberias. Current levels in the upper portion of the lake are about 240 ppm, still marginal for superior irrigation water.) As the Jordan proceeds down into the Rift Valley toward the Dead Sea, it becomes saltier, reaching several thousand parts per million by the Allenby Bridge near Jericho. Ultimately, the salinity of the Jordan River system reaches 25 percent (250,000 ppm) in the Dead Sea, a level approximately seven times that of the ocean. Naturally, this is too high to support plant or animal life, although certain minerals, especially bromine and potash, can be extracted by (solar) evaporative processes.

The development of the Jordan has accentuated the salinity of the lower Jordan. The salinity in the lower reaches of the river has increased recently (Nyrop 1980) as a result of the diversion of the low-salinity headwaters, both to Israel's National Water Carrier and to the East Ghor Canal.

Although the greatest water quality concern in this region is salinity and its impact on the agricultural fitness of the water, there is some recent concern about other water quality issues. First is domestic pollution of the upper Jordan, which may eventually threaten the National Water Carrier.

Additionally, there has been heightened concern about eutrophication in Lake Tiberias, although evidence indicates that conditions there are not representative of lakes undergoing typical cultural eutrophication (Serruya 1980).

Patterns of Water Use in the Jordan Basin

The primary users of the waters of the Jordan are Israel and Jordan. Between them, the Jordan River system has been extensively exploited, and it accounts for about one-half of their water demand. The other riparian states are Lebanon and Syria. Present Lebanese use of the Jordan is minor compared with that of the others. The extent to which Syria uses the waters of the Jordan, i.e., the Yarmouk, is not presently known.

ISRAEL. The current estimate of Israel's total annual demand for water may be as high as 2,250 million m^3, approximately 80 percent of which is used for irrigation, 15 percent for domestic use, and 5 percent for industrial use. Approximately 64 percent of the arable land is irrigated, amounting to 278,000 ha. Present estimates indicate that Israel uses more than the total renewable water resources available to it, which are estimated at about 1,950 million m^3 per year—an extremely high degree of water resources utilization, despite a per capita consumption (537 m^3 per year; 86 m^3 per year for domestic purposes only) not out of line compared to other industrial nations (although it is high compared with its neighbors).

JORDAN. The history of irrigation in Jordan has been limited, and the estimates are that only 4.6 percent of the cultivated land was irrigated in 1972 (compared with 41.1 percent for Israel and 7.6 percent for Syria) (Percious 1977). Gischler (1979) puts these figures at 7.2 percent and 9.8 percent for Jordan and Syria, respectively. The total land area under irrigation is 55,000 ha, primarily in the Jordan Valley and the Southern Ghors. Eighty percent of the irrigation water of the Jordan Valley is provided by the East Ghor Canal, and the Yarmouk is the main source. The population of Jordan (and with it, water consumption) has been rising at a rapid rate. Total annual consumption was 730 million m^3 for 1990, of which 520 million m^3 were for agriculture. The total annual demand for water in Jordan for the year 2000 is estimated at 1,045 million m^3.

The Jordan River has been extensively developed by both Jordan and Israel, and the available quantity of high-quality water has been extracted, leaving only poor-quality, highly saline waters in the Jordan's main stem. The potential for conflict is great because the available water is being used and both societies are expanding with an increasing thirst. The pressure created by this complete exploitation of the Jordan could spill over into a nearby system (e.g., the Litani) as the principal riparian users of the Jordan seek other sources.

Large-Scale Constructed Facilities Associated with the Jordan Basin

JORDAN. The development plan undertaken by the Jordanians originally involved cooperative efforts with the Syrians. The Jordanian Great Yarmouk Project was undertaken at the same time as Israel's National Water Carrier (Garbell 1985). The first stage of the Great Yarmouk Project was a headwater irrigation program designed to provide controlled winter irrigation and expanded summer irrigation in the El-Muzeirib region of Syria. Initially, the plan called for two canals (the East Ghor and the West Ghor) to run parallel to the Jordan and carry low-salinity waters through the East and West Banks for irrigation and other uses. The West Ghor Canal was never started because of the 1967 war and the subsequent occupation of the West Bank. The upper East Ghor Canal phase was completed in 1962 (Rydewski and Rashid 1981); by 1979, it had reached a length of 100 km and is now 110 km.

A dam has been proposed at Maqarin on the Jordan-Syria border. It will be 140 m high and will store 195 million m^3 of water. The King Talal Dam, completed in 1977, lies across the Zarqa River. It has a storage volume of 52 million m^3 and a generating capacity of 5 million watts.

The Kafrein-Hisban Project, located in the southern part of the Jordan Valley, consists of a diversion dam on the Wadi Hisban, the Kafrein Dam, a pipeline between Wadis Hisban and Kafrein, and a sprinkler irrigation system. The purpose of the pipeline is to carry Hisban flows in excess of local needs to the Kafrein reservoir.

NATIONAL WATER CARRIER. For Israel, the implementation of waterworks following the nonratification of the Johnston Plan took the form of the construction of the National Water Carrier, an extensive conduit system designed to transport water from the water-rich (at least 1,000 mm precipitation/yr) north to the potentially fertile but arid (30 to 200 mm/yr) out-of-basin regions of the Negev Desert. The Carrier, completed in 1964, lies entirely within Israel's pre-1967 boundaries and diverts water from the Jordan from the northern edge of Lake Tiberias primarily to coastal areas and to the Negev.

The Yarqon-Negev section of the National Water Carrier, completed in 1955, is fed by wells east of Tel Aviv and provides 270 million m^3 for that city and for irrigating the Lachish area. Another portion of the system is used to collect water from northern Galilean creeks, which was formerly discharged to the Mediterranean, and to irrigate portions of the Esdraelon Valley. A third part of the system drained marshy areas (Huleh Valley) to improve the flow of the upper Jordan. These three parts of the overall system were completed early and are often not considered to be part of the Carrier proper.

The Carrier consists of a series of pumps, canals, and tunnels used to convey water taken from Eshed Kinrot on Lake Tiberias (210 m below sea level) to as far as 200 km to the south (Kally 1974). The average water flow is 320 million m^3 per year, and the maximum elevation difference is 360 m. As an adjunct to the Carrier, work has been undertaken to reduce the saline inputs to Lake Tiberias, which serves as a reservoir for the National Water Carrier (Garbell 1985): the salinity of Lake Tiberias is projected to eventually be reduced to about 130 ppm.

Regional Constraints to Technological Options

The design and operation of water resources systems in the Middle East are not easy. The quantity of available water is limited by the semi- to hyperarid climate of the region. The combined effects of evaporation, soil chemistry, and nonconsumptive use of water contribute to degraded water quality throughout most of the downstream reaches of the rivers under study.

Problems of water use in the Middle East are aggravated by the application of massive energy and water subsidies to agriculture. This is not unique to the Middle East, but in this region—particularly in Israel—the energy subsidy to the agricultural sector is excessively high, largely because of the great expense of bringing sufficient irrigation water to the most productive soils. Fully one-fifth of the energy resources currently consumed in Israel are used for pumping water, and 68 percent of the water is used for agriculture. The historical and ideological commitment to agricultural self-sufficiency is a major determinant of the pattern of water utilization in the Middle East. In economic terms, considerations of security, ideology, and politics are used to rationalize the provision of water at costs that exceed its marginal value (Naff and Matson 1984).

The pressures of expanding water demand are inevitably leading managers to consider using water of progressively poorer quality. Assuming that this water is to substitute for cleaner (sweeter or less polluted) water, then its quality must be improved to the level of those standards appropriate for a particular use. In the Middle East, the most readily available alternatives are saline and brackish waters, as well as various wastewaters. In the paragraphs below, technologies for desalination and wastewater renovation are reviewed.

Desalination Techniques

Desalination is one possible solution for some of the water needs of the Middle East because most countries there have coastal or other saline water supplies available. Israeli water planners have forecast an increase in water demand of at least 700 million m^3/yr by the end of the century (Ben Meir 1982). This additional demand will have to come from alternative supplies because virtually all fresh water has been used. Reductions in the cost of desalination make it less forbidding than it once was. Other countries face a similar situation. Approximately two-thirds of the global installed desalination capacity is found in the Middle East, much of it in the Arabian peninsula.

Desalination technologies reduce the concentration of total dissolved solids (TDS). Fresh water typically possesses less than approximately 1,000 mg TDS/l. Most published drinking water standards include a prescribed maximum of 500 mg TDS/l, and certain industrial applications, most notably boiler feed water, allow no more than about 5 mg TDS/l. Seawater typically has 33,000 mg TDS/l, with deviations depending on local rates of dilution and evaporation. Brackish water is usually defined in an intermediate position, at approximately 1,000 to 3,000 mg TDS/l, and brine refers to waters more saline than seawater. In the following discussion, the various desalination methods are organized according to their principal mode of operation. These include technologies based on distillation, membranes, and ion exchange. In theory, methods based on freezing are applicable to the desalination of water; however, there have been no commercial operations, and thus freezing is not included.

Distillation Methods

All distillation plants operate on the principle that vapors boiled off or evaporated from saline water are salt-free and that purified water can be produced by condensing these vapors. The distillation technologies are energy-intensive because of the need to drive the change of state.

MULTISTAGE FLASH DISTILLATION. Since its first commercial application in 1960, multistage flash distillation (MSF) has grown in use and today is both the most common evaporative process and the one with the greatest total worldwide operating capacity (6.76 million m^3/day [Liberti et al. 1985]). It is applicable to even the saltiest seawater and can yield a final product with as little as 25 to 50 ppm TDS. Generally, MSF achieves cost-effectiveness only when used to process more than approximately 1,000 m^3/day (Birkett 1983).

MULTIEFFECT DISTILLATION. Multieffect distillation (MED) is an evaporative process that was exploited commercially very early on (Birkett 1983; Fisher 1983; and Veenman 1978). It then became less popular, but, in recent years, has been developed into a highly efficient technology with further potential. MED is usually used for seawater and yields a high-purity product of about 20 ppm TDS. In MED, evaporation occurs on a heat exchange surface made either of horizontal or vertical tubes; therefore, the two process variants are termed horizontal tube evaporation (HTE) and vertical tube evaporation (VTE), respectively.

VAPOR COMPRESSION. A third evaporative process is vapor compression (VC), a new technology still undergoing development. VC differs greatly from the two processes discussed above because it is a single-stage compact system (Bulang 1981; Darwish et al. 1984; and Kamal et al. 1980). It is a highly efficient process, most likely the least energy-consumptive of all the evaporative processes. Vapor compression is used only in smaller operations because it is economically favored at nominal capacities of less than 3,800 m^3/day. Its operating temperatures are quite low, 55°C to 70°C, with efficiency increasing with temperature. Thus, the primary energy is not heat, but the electricity needed to operate the compressor. The low operating temperature also minimizes scaling and corrosion, and pretreatment for scale prevention usually consists solely of polyphosphate addition.

Membrane Processes

The distinguishing feature of the membrane processes is that saline water at ambient temperatures is forced through a barrier that allows the passage of water molecules but prevents the passage of dissolved materials. Thus, two fractions accumulate, one lower (the product water) and the other higher (the rejected brine) in TDS than the feed water.

It is often convenient to categorize the membrane processes in terms of the potential gradient that provides the driving force through the membrane. This may be pressure as in reverse osmosis (RO) or ultrafiltration (UF). (UF does not separate low-molecular-weight organics or salt from water; therefore, it is of limited value in the solution of the pressing water problems of the study area and will not be considered further in this paper.) The process may, however, be non-pressure-driven, as in electrodialysis (ED) or transport-depletion (to date, only used at the laboratory scale) (see Applegate [1984] and Belfort [1984] for relatively recent reviews of membrane technology).

REVERSE OSMOSIS. The first commercial application of RO was in the late 1960s, when it was used to desalt brackish water. The initial testing and development for seawater desalination began in the mid-1970s. Today, it is the second most widely used desalination process, behind only MSF in global installed capacity. (See Bakish [1985] on the theory and practice of reverse osmosis).

ELECTRODIALYSIS. ED technology was developed in the early 1950s and has been applied primarily to brackish waters (Katz 1982; Katz and Eliassen 1971). ED consists of alternating anion and cation exchange membranes with the feed water flowing between them. Direct current voltage is applied so that the anions and cations pass through the anion and cation exchange membranes, respectively. This demineralizes one stream and concentrates another. Membrane fouling is a recurrent problem that can only be solved by stopping the process and flushing the membranes with cleaning chemicals.

ELECTRODIALYSIS REVERSAL. Electrodialysis reversal (EDR) works on the same principles as ED except that the direction of the DC field is periodically reversed (Katz 1982; Katz and Eliassen 1971). When the reversal occurs, automatic valves interchange the concentrated and dilute streams. The process is thus self-cleaning because the films and scale are carried away with the waste when the flow is reversed. Virtually all electrodialysis equipment installed since the mid-1970s has used polarity reversal. The process has been used successfully to desalt brackish water up to 4,000 mg TDS/l with water recovery up to 93 percent. The energy consumption is quite low, typically 3 to 5 kilowatt hr/gal brackish water (2,850 to 4,750 kilojoule/l), including pumping. ED processes have also entered the market for seawater desalination. The worldwide installed capacity of EDR technology has reached approximately 330,000 m^3/day (Valcour 1985). Many of these installations are relatively small, and most are institutional or industrial.

Ion Exchange

Ion exchange occurs when ions in solution are exchanged for other ions on a solid surface. Water to be deionized or, as discussed here, desalinated, is passed through a bed of ion exchange material (these materials are almost always synthetic organic resins). There are both anionic resins with exchangeable anions and cationic resins with exchangeable cations. In desalination applications, both an anionic and a cationic resin would generally be used. Once the exchangeable ions on the resin have been exchanged, the resin must be regenerated. The reactions used in ion exchange are reversible; therefore, contacting the spent resin with a high concentration of the ion originally on it can shift the equilibrium point and regenerate the ion exchange resin.

Hybrid Systems

A variety of combinations of processes is possible to meet the particular constraints of an individual situation. Increasing attention is being paid to hybrids of RO and distillation. The various advantages of RO/MSF have been discussed by Awerbuch (1987). Very high recoveries have been shown to be possible using a hybrid system incorporating reverse osmosis and vapor compression distillation (de Moel et al. 1985). The actual process train included pellet softening for the removal of calcium and RO operating at 90 percent recovery, followed by distillation of the RO brine using VC. The RO/VC combination is promising for remote areas or for small communities (Aly 1986). Kamal et al. (1980) concluded that this process may be the way for distillation to compete with membrane processes in single-purpose (i.e., water-only) seawater desalination.

Systems have been developed that combine RO and ion exchange for a more efficient desalination process. One example is to first treat seawater by RO, producing a brackish permeate of 1,600 ppm. The water then passes through a thermally regenerated exchange system. The resin is regenerated with the heat of the seawater upstream of the RO unit (Barnes and Wilson 1983). The product is pH-adjusted and combined with brackish permeate to yield a final product of 500 mg TDS/l. A similar system was used for treating groundwater that had high concentrations of silica, sulfate, alkalinity, and hardness. The groundwater was processed by ion exchange followed by RO. After pH adjustment and appropriate blending, the product contained 400 to 500 mg TDS/l. Process efficiency was such that 91 percent recovery of groundwater was possible (Coillet and Cruver 1977).

Comparison of Desalination Technologies

The type of desalination technique appropriate for a given situation depends largely on the raw water TDS level and the desired product TDS level. Generally, the distillation-based processes can be used to achieve very high-purity water (less than about 50 mg TDS/l), whereas the membrane-based processes can achieve TDS levels in the range of several hundred mg/l. Other comparison factors include environmental impacts, energy requirements, and costs, which are discussed below.

ENVIRONMENTAL EFFECTS OF DESALINATION. The major impacts of desalination relate to water intake and discharge. These must both be carefully managed to minimize or eliminate harmful environmental effects.

Discharge involves both physical and chemical effects. Physical effects include temperature and flow changes from the discharge. The temperature may rise appreciably downstream from thermal process plants. A change in the temperature may produce a wide range of biological, chemical, and physical changes. The chemical effects include increased concentrations of brine, chlorine or other biocide residuals, and various descaling chemicals (Winters et al. 1979). The total dissolved solids can also increase to 1.3 to 2.0 times the original level. Heavy metals—especially copper, well known for its toxicity—are also potential hazards. The quantities of heavy metals actually discharged vary as a function of corrosion and the materials of construction. Heavy metals and other toxicants may accumulate by transfer through the food web. (Sludge disposal is also a possible problem with large-scale desalination plants.)

ENERGY CONSIDERATIONS. Energy requirements for distillation processes are substantial because of the change of state of water. The energy may be supplied by the combustion of fossil fuels: this is especially attractive in areas where the cost of such fuels is relatively low, as in much of the Middle East. Alternatively, desalination may be combined with the generation of electricity in such a way that lower-temperature, i.e., partly expanded, steam is used to drive the distillation process. Other possibilities include nuclear, solar, and geothermal sources.

COMPARATIVE ENERGY REQUIREMENTS. Regardless of the particular desalination process selected, there are a number of crucial operating cost factors, including the energy required, either for changing the state of water or for overcoming the osmotic pressure gradient. The energy requirements reported by a variety of authors have been summarized recently by Keenan (1991). These data support the contention that one of the principal advantages of RO relative to the distillation processes, especially MSF, is the reduced energy requirement.

POSTTREATMENT REQUIREMENTS. Desalted water, whether derived from membrane or from distillation technologies, tends to be aggressive, i.e., corrosive. Consequently, both distillates and permeates require a certain amount of posttreatment, especially to control corrosion and to improve the potability of the product water. A variety of different treatment methods is available, but typically, small amounts of alkali, such as lime, are added to the product to stabilize it, i.e., to render the product less corrosive.

COMPARATIVE COSTS. During the 1980s there was a shift in the prevailing wisdom regarding the economics of desalination. In the early 1980s, the economic situation was such that membrane processes were favored over distillation for the treatment of brackish waters and for seawater desalination for small-scale operations and for sites where energy costs were high. The data available since that time indicate that today, even for large-scale seawater applications, the membrane-based technologies have become competitive. The major reason for the increased competitiveness of RO is a reduction in the costs associated with it resulting from operation at higher pressures, increased energy recovery, and decreased chemical and membrane replacement costs. The relative price of energy remains a critical criterion of the difference between the two competing processes.

The cost data suggest that RO is generally the most cost-effective process for the desalination of brackish waters. EDR also tends to be most economical where the feed water is relatively low in dissolved salts because the energy requirements are roughly proportional to the TDS concentration. For the other processes, energy, and thus total operating costs, is more independent of the salt concentration.

Among the distillation processes, there is increasing support for the contention that MSF is not the least expensive. Grieg and Wearmouth (1987) concluded that mechanical vapor compression is the cheapest, followed by thermal vapor compression. Leitner (1987) states that MED, either in the vertical or horizontal configuration, produces the lowest-cost water among the distillation technologies.

In sum, the technological state of the art and the current economic situation clearly favor reverse osmosis for most situations in which the desalination of either seawater or brackish water is needed. Furthermore, RO is competitive in all situations, principally because of a significant reduction in the operating costs of RO installations, most notably energy, membrane replacement, and chemicals.

Reclamation and Conservation Technologies

In this final section, the potential for increasing water availability via the reclamation of storm water and wastewater is explored. The terms reclamation and renovation refer to technologies used to render spent waters fit for some other purpose.

Storm Water Renovation

The use of storm water for a variety of purposes has had a long and obvious history, ranging from rain barrels to runoff agriculture. Unfortunately, the quality of rainfall is rapidly degraded during runoff processes. The most important mechanism by which storm water becomes contaminated is entrainment of suspended particles. (In urban areas, storm water may become mixed with domestic wastewater: this mixture is termed combined sewage.) Typical contaminants are suspended solids and associated materials, including metals, pesticides, fertilizers, and pathogens. Thus, depending upon its history, storm water may have a quality level almost as degraded as that of wastewater.

Storm water treatment technologies are almost always directed to the removal of suspended solids. Thus, sedimentation and (to a lesser extent) filtration processes are most commonly encountered. Holding basins are widely used in storm water treatment systems.

Wastewater Reclamation

Wastewater reclamation can be an important method of supplementing available water supplies. Its potential role increases dramatically in a water-scarce region such as the study area. The two principal purposes served by wastewater reclamation are water supply augmentation and water pollution control. If the wastewater is applied to the land, then the application of nutrients and groundwater recharge are additional objectives. Historically, the most important and earliest method of wastewater reclamation has been land treatment and disposal directly to agricultural land.

Generally, the wastewater constituents of concern in reuse applications are suspended solids, organic matter (i.e., biochemical oxygen demand [BOD]), and pathogenic microorganisms. Sometimes, especially with industrial wastewaters, the presence of toxic organics, heavy metals, etc., may be an issue. Suspended solids removal is typically achieved in sedimentation processes, although filtration may be cost-effective in certain situations. Organics removal may be accomplished by biological treatment and occasionally by chemical coagulation. In the Middle East, stabilization ponds are the most frequent biological treatment units. Disinfection involves suspended solids removal and chlorination (or ozonation).

There are several filtration procedures by which particulate materials may be removed from water and wastewater. Filtration through a bed of sand is probably the earliest, and still most popular, method of water filtration. For water and wastewater treatment purposes, slow and rapid sand filters are available. Dual- and multiple-media filters have some applicability in wastewater treatment.

Use of Reclaimed Wastewater

The reuse of wastewater effluent is not readily accepted by everyone. For a variety of reasons, some people may reject the use of effluent for different purposes. In Muslim countries, the use of effluent is still limited. In Israel, however, the reuse of wastewater is part of the national water policy (Shuval 1980).

Reclaimed wastewater can theoretically be used for any purpose to which water can be applied. The major constraint is that the water must be treated to the degree appropriate for that use. Sometimes, economics will prevent the use of reclaimed water for certain purposes. For other purposes, however—notably irrigation and some industrial applications—wastewater effluent is a technically acceptable alternative.

The principal use of reclaimed wastewater in the study area is associated with Israeli efforts, notably in the agriculture and industry sectors. Industrial reuse of water is legally enforced in Israel. Other options for reuse include aquaculture, recreational impoundments, some restricted municipal use, and groundwater recharge (Shuval 1977). Restricted municipal use refers to street cleaning, watering of golf courses, and other noncontact purposes. There are too many lingering public health questions regarding the survivability of viruses and the presence of trace contaminants to recommend the use of reclaimed wastewater for unrestricted municipal uses.

HEALTH EFFECTS. There are many potential problems that need to be confronted to reuse wastewater safely. Problems may arise from food crop contamination, surface or groundwater pollution, or pathogen-laden aerosols. Pathogens of concern include various bacteria, viruses, protozoa, and helminth worms. The technology used for wastewater reclamation must be appropriate to the purpose to which the water will be put, and generally this should include the capability to remove and/or destroy pathogenic organisms. In the study area, the principal use of reclaimed wastewater is for irrigation.

The Israelis have developed guidelines for wastewater reuse in agricultural applications. These regulations establish buffer zones of 300 m between spray-irrigated fields and residential areas when low-quality effluent is used (Shuval 1980). Under current regulations, effluent may be used for unrestricted irrigation of all edible crops if the effluent has been well-treated with coliform levels approaching those of drinking water. Oxidation pond treatment is required for all cases of wastewater irrigation. The minimum adequate treatment is considered to be one to two days' detention in an anaerobic pond, followed by three to seven days' detention in aerobic-facultative ponds.

WASTEWATER IRRIGATION. The reuse of wastewater effluents as irrigation water enables augmentation of an area's water supply. As noted, there is often a variety of reasons why a given people will not reuse wastewater effluents. This approach, however, allows water planners to align water use with water quality constraints; that is, high-quality water is saved for high-quality uses, and progressively lower-quality uses receive lower-quality water.

There are several disadvantages associated with the use of reclaimed wastewater for irrigation purposes (Noy and Feinmesser 1977). The production of wastewater is essentially constant over the course of a year, but the demand for irrigation water is seasonal. This necessitates the use of storage mechanisms or the disposal of effluent during the nongrowing season. Treated effluent may contain small particles sufficient to plug spray nozzles and clog the pores of soil. Certain effluents may contain substances harmful to the crops (chloride, sodium, boron, organic acids, phenols) or to the animals and people consuming the crops (heavy metals, pathogens). Under some conditions, the use of wastewater may produce nuisances (odors, insects).

Summary

The design and operation of water resources systems in the Middle East are complicated. As noted, the quantity of available water is limited by the semi- to hyperarid climate of the region. The combined effects of evaporation, soil chemistry, and use of water contribute to degraded water quality throughout most of the downstream reaches of the rivers. Problems of water use in the Middle East are aggravated by the application of massive energy and water subsidies to agriculture.

Technologically, two important alternatives are the desalination of saline waters and the reclamation of storm water and wastewater. With respect to desalination, the economic situation has changed over the last decade such that the membrane processes are now sufficiently competitive to be considered as alternatives in all projects.

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THEME IV

ENVIRONMENT AND HEALTH

WATER POLICIES RELATING TO ENVIRONMENTAL AND HEALTH ISSUES

Jonathan P. Deason

In recent years, those involved in the development and use of water resources around the world have become increasingly concerned about the unintended effects of large development initiatives on human health and on land, water, air, and other natural and cultural resources. In response to such concerns, many nations have established legislative, regulatory, and institutional frameworks to protect and improve these interests. Despite the increasing attention focused on these areas, however, environmental and health problems are escalating, largely because of the intense pressure on water resources from population growth and economic development.

The tough realities of competition for scarce resources and disagreements over the degree to which goals can or should be reached raise many inextricably interrelated issues. To facilitate discussion of these issues, the multidimensional spectrum of environmental and health issues has been divided into five categories in this paper, with each category briefly discussed.

Water Pollution and Health

Pollutants in water span a wide range of organic and inorganic constituents. Technically, any substance in surface or groundwater becomes a pollutant when its concentration reaches a level at which it interferes with intended uses of the water. In many areas of the world, uses directly related to public health are of special concern. In all countries and river basins, adequate planning for water use, preservation, and enhancement must consider the complex interrelationships among water quality, supply, use, and disposal. Quality and quantity are inseparable, and therefore quality must be evaluated along with the purposes for which water supplies are developed.

Sources of water pollution generally are grouped into two broad categories: *point* and *non-point sources*. Point sources are those from which pollutants are discharged into water at identifiable and discrete points. Non-point sources are those involving numerous sites throughout a given area from which pollutants are transported to surface and groundwater through many discrete routes. Common non-point pollutants include sediments, pesticides, chemical fertilizers, animal wastes, oils, and naturally occurring salts. Although much work remains to be done to control point sources of water pollution in many areas of the world, the situation with non-point sources of pollution is even worse. In both cases, major efforts are needed to identify sources of pollution, determine the nature and extent of pollutants from such sources, develop and implement appropriate preventive and control techniques, develop effective regulatory mechanisms, and assess and evaluate results.

The Orontes River basin in Syria is one example of a river basin experiencing increasing water pollution hazards; it receives large amounts of fertilizer, municipal sewage discharges, and agricultural drainage flows (Bakour 1992). In Pakistan, where practically all sewage is untreated, waterborne diseases cause 60 percent of all infant deaths and 40 percent of all urban deaths (Mulk and Mohtadullah 1992). Fish kills and adverse impacts on livestock and human health in the Awash and Bilate river basins in Ethiopia have been described by Abate (1992), and the impacts of elevated pesticide levels and

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inadequately treated point source effluents in the Chao Phraya River basin in Thailand have been reported by Vadhanaphuti et al. (1992).

Erosion, Deforestation, and Sedimentation

Erosion and deforestation are significant problems in many areas. Erosion processes are greatly accelerated where deforestation and other vegetative cover modifications have occurred. Erosion is a major contributor to salt loadings in numerous water bodies worldwide. Salts are highly soluble; are concentrated by physical, chemical, and biological processes; and can lead to accretion of unacceptable levels of trace concentrations via bioaccumulation and bioconcentration. Abate (1992), for example, has cited the uncontrolled deforestation in Ethiopia that has led to soil erosion and ecological imbalances.

Sediment, a product of erosion, causes tremendous damage wherever it is deposited in streams, rivers, lakes, and reservoirs. Major environmental problems include swamping and increased flooding, clogging of irrigation and drainage works, interference with fishery resources, and increased water treatment costs.

Salination

In addition to erosion and sedimentation, other processes lead to increasing salinity in many water bodies. These include intensive water uses—such as municipal, industrial, and irrigation uses—resulting in salt-laden effluents and return flows. The salt-concentrating phenomenon occurs when consumptive uses remove water from systems without a corresponding reduction in the total salt load, resulting in increased concentrations of salts in return flows. Many rivers, especially in arid regions, reflect a progressive increase in salinity levels from their headwaters to their mouths. A related problem is saltwater intrusion resulting from overextraction of groundwater resources. Bakour (1992) has examined salinity buildup in agricultural operations in the Euphrates basin in Syria, and Schwarz (1992) has discussed saline buildup in Israel, providing recommendations from the Israeli experience for addressing these problems. Vadhanaphuti et al. (1992) have also cited saltwater intrusion in the Chao Phraya basin in Thailand.

Water Reuse and Conservation

In arid regions, the reuse of existing water supplies should be a significant part of plans to meet future demands. In addition, where water use efficiencies are low, conservation may have significant potential to reduce adverse environmental impacts. For example, improved efficiencies and recycling can lead to reductions in total salt loads of return flows in irrigation operations. In the municipal and industrial sectors, changes in urban land use plans—from irrigated lawns and parks to the greater use of grasses and shrubs that thrive in semiarid or arid conditions—can reduce demands for water supply and reduce total loads of return flow constituents.

The use of new technologies is also important in this area, including the replacement of water-cooling processes in industrial operations with air cooling and the application of new research results on the suppression of surface evaporation from reservoirs in arid areas. Israel has been particularly aggressive in the reuse of wastewater, with about 65 percent of total municipal and industrial effluents in Israel reused, primarily for irrigation of limited industrial crops (Schwarz 1992).

Adequacy of Institutional Arrangements

The effectiveness and efficiency of institutional arrangements in responding to environmental and health concerns about water resources development warrant special attention. Institutions governing water resources planning, development, and management need to be designed to reflect current societal values to prevent environmental degradation, protect public health, and provide effective enforcement. In most countries, the diversity of governmental entities with water resources, environmental, and health-related responsibilities makes effective coordination imperative.

The significance of this issue is illustrated by Bilen and Uskay (1992), who have described major institutional changes recently implemented in Turkey to address environmental concerns: the framework used is a comprehensive, hierarchical governmental structure under Turkey's General Directorate of Environment. Vadhanaphuti et al. (1992) have recounted the lack of enforcement of environmental laws in the Chao Phraya River basin: despite the establishment of a National Environmental Board in Thailand in 1978, there is little or no enforcement of environmental acts, including requirements to conduct environmental impact assessments for proposed projects. Similarly, Abu-Zeid and Rady (1992) have indicated limited implementation of 1982 provisions for the protection of Egyptian watercourses from pollution.

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INCORPORATING ENVIRONMENTAL POLICIES INTO WATER RESOURCES MANAGEMENT IN FRANCE

Jean-Louis Oliver

Water plays a role in almost all human activities: economic, social, cultural, and even religious. Water management is not a new problem for decisionmakers. At any period of time, both national as well as local governments have dealt with specific uses of water, usually domestic supply, irrigation, navigation, and fishing. Today, however, the challenge has become more demanding for various reasons:

1. Economic and social activities are more complex and interrelated;

2. Urbanization and industrialization have grown on a large scale, even in France, which used to have a sound and diversified agricultural tradition;

3. Both old and new technologies can generate pollution, but they can also be improved to mitigate adverse effects on the environment.

The Situation in France

Even if geography and climate blessed France with enough surface and groundwater, there could still, in some regions, be problems, relating to quantity (flooding or shortage of water) or quality (pollution). As in other countries, water management in France involves:

- many activities and operators, from the public or private sectors;

- several levels of public structures, acting for national, regional, and local governments.

The situation may be even more complicated in France because the French are quite individualistic: for example, there are more than 36,000 local governments, most of them very small, which are in charge of water supply and sewerage facilities. (Governments thus far have always failed to reduce this exorbitant number.)

Water resources management cannot be the responsibility of just the national government, even with the help of local governments. It is the responsibility of governments, however, to evaluate and implement the best organization for their specific context, balanced to meet two objectives: simplicity—to be understood by everyone and effectively implemented; and stability—to be reliable and to last long enough to be efficient. The organization must also be flexible to be adapted to space and time because water problems may vary considerably by area (even areas near one another), especially in France with its diverse geography and climate. Water problems may also change dramatically and swiftly according to the current, rapid evolution of economic and social uses.

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It is the responsibility of the national government to provide the legal and regulatory framework and to induce the environmental policies necessary in three main areas:

1. *legislation and institutions* to organize dialogue and cooperation that engender coherent operations;

2. *definition of economic mechanisms,* not only to provide financial modes of operation, but also to regulate environmental policies, introducing into the system the external costs so that the money cycle is linked to the water cycle, to achieve social and environmental objectives incrementally and pragmatically;

3. *technology and research development* in the broad field of environment, relating to clean processes, new technologies, and human skills improvement.

In France, the national government provides guidelines and keeps the system and procedures under control, similar to a referee rather than a player. In addition, it represents the country in bilateral, European, or multilateral negotiations and agreements, which are increasingly important to all environmental concerns.

Legislation is essential to environmental and water management, which involves behavior and rights because water use regulations are closely related to private property rights, specifically those concerning land ownership, free enterprise, and liberal economic and social activities. Good laws as well as good studies are just pieces of paper whose effectiveness depends on the ways they can be implemented in the field: we must be modest enough to sometimes accept imperfect but realistic solutions that work and that may be more useful than a too-perfect theory.

In France environmental policies are implemented through four main pieces of closely linked legislation, from conception at the national level to application at the departmental level, mainly by the state administrations. These include laws on:

1. *industrial activities* and their relation to the environment, covering any type of pollution—air, water, solid waste, noise, etc.—through multipurpose licenses or declarations;

2. *nature conservation*, concerning land, landscape, forestry, mountains, and impact assessment studies;

3. *solid waste*, covering prevention and recycling, collection, transportation, and treatment and regeneration of household urban wastes as well as industrial solid wastes;

4. *water*—the 1964 water law (see below) is the most significant vis-à-vis environmental issues. A new water law (on which I worked) was passed by the French Parliament in December 1991: it confirms and reinforces the basic framework of the 1964 water law.

All this legislation has several common key principles, including:

- Prevention is better than punishment or fines;

- Polluters must pay;

- Pollution must be taken into account as early as possible;

- Efficiency must be sought comprehensively, using regulation and standards, as well as financial penalties and incentives to use the best technologies available;

- In case of mistake or failure, sanctions are unavoidable.

The Basic Framework of the 1964 Water Law

The challenge for lawmakers in water resources management legislation is to build a core composed of a few simple though key principles that can be referred to at each stage and that are applicable to each specific regulation on water uses: domestic supply, irrigation, and hydroelectric power. The 1964 water law introduced in France the modern concept of water resources management. According to improved knowledge of the water and energy cycle worldwide, water resources were considered an interrelated whole system within the limits of hydrological river basins and included rainfall water; all continental surface waters; all waterways, rivers, canals, springs, lakes, ponds, and marshes; groundwater, renewable or nonrenewable; and seawater along the country's coasts.

Since 1964, all water resources in France have been governed by the same law (this was considered revolutionary in France!) that covers both quantity and quality aspects, which are impossible to separate inside the hydrological basin. According to the 1964 law, France has been divided into six large hydrographical basins according to the main rivers. For each basin, two new specialized institutions were created: the basin committee and the basin agency.

The *basin committee* is a "local water parliament." It is the dialogue body and the decisionmaker in the basin's water management problems. Each basin committee studies and approves a master plan for water resources management in the long term, with intermediate phases, goals, and priorities. Every five years, the basin committee votes on a program of coordinated actions, aimed at improving both quantity and quality of water resources. Its key function is to vote every year on two types of fees, or charges, collected from any water user of the basin. One is based on the quantity of water intake during the year; the other, according to the amount of pollution ejected during the year. The rates of these two fees are calculated not only to provide the funds to achieve the five-year program, but also to put modulated pressure on economic operators. The money collected is redistributed among the water users themselves, according to the specific actions they will undertake to improve water resources management in the basin, through incentives (e.g., subsidies or soft loans) for investments or for operation and maintenance.

The *basin agency* is the financial and technical executing body of the basin committee. It is a public structure where the private sector as well as the state administration and local governments work closely together.

After 25 years, these two river basin institutions have yielded good results (although all problems have not of course been solved). All water users, regardless of activity, agree to pay—sometimes a large amount—because they have been consulted beforehand, they can see how the money is being allocated, and they receive a return on their investment, a little later, inside the river basin itself.

Conclusion

Because the French basin institutions are efficiently involved in the economic as well as the technical fields, all regulation, monitoring, and enforcement are the responsibility of the state administration through its representatives at the departmental level (the prefects) who deliver, control, and enforce the licenses or declarations required for water uses, with the assistance of technical public services. The French river basin agencies do not realize, operate, or maintain any equipment related to

water uses. The basin committees and agencies do not assume any activity previously assumed in either the public or private sector: their specific missions are completely new and useful. For France, these river basin arrangements provide a fair deal and a balanced solution: different skilled bodies assume different jobs that require close coordination at every level.

THEME V

INTERNATIONAL RIVER BASINS

ECONOMIC AND INSTITUTIONAL ISSUES: INTERNATIONAL RIVER BASINS

Peter Rogers

More than 200 river basins, accounting for over 50 percent of the earth's land area, are shared by two or more countries. The more than 280 treaties between countries on water issues illustrate the tensions that divided basins engender. Two-thirds of these treaties have been in Europe and North America, where the problems first became acute. Elsewhere, large-scale development of water resources has only become widespread during the past decades. Current water development is driven by population growth and technological advances, such as hydroelectric generation and modernized year-round agriculture. A worldwide perception of virtually global water scarcity, relative to emerging uses of and needs for water, is historically new, and the accompanying conflicts have only begun to manifest themselves. Rapid population growth and economic development in many parts of the world are severely straining natural resources, such that water is beginning to have a scarcity value and an emotional intensity resembling that of petroleum.

The concern with international river basins and the need to move quickly with mechanisms to defuse conflicts before they become deeply entrenched are also part of the current interest in global environmental issues. Most of these issues are transnational, but the stakes in transboundary water conflicts, because they are more tangible and "closer to home," are perceived more sharply by the individual participants than the stakes in the protection of the global ozone layer or a reduction in emission of greenhouse gases. In addition, unlike ozone depletion or carbon dioxide buildup, water problems usually involve portraying a neighboring nation or people as an antagonist, which tends to intensify popular emotions, cluster water issues with other historical grievances, and favor the combative set of attitudes associated with zero-sum situations.

Some of the major international water conflicts are located in the Middle East, a region chronically short of water where many of the rivers are not large. For example, managing the waters of the Jordan is a perennial and growing problem among Lebanon, Jordan, Syria, and Israel. The Turkish and Syrian developments on the Euphrates cause friction between Turkey and Syria and with downstream Iraq. The sharing of the Nile waters between Egypt and Sudan had proceeded in a relatively cooperative atmosphere that is now being disturbed by Ethiopia and six other upstream riparians (whose territory generates the bulk of the flow) demanding access to use of the water for their own needs.

The issue is no less serious in other parts of the world. For example, with World Bank assistance, India and Pakistan settled a serious conflict over the use of the Indus that was precipitated by partition in 1947, although it took until 1960 to arrive at a satisfactory treaty between the countries. India and Bangladesh have had an unresolved water dispute since 1975 concerning diversions by the Farakka Barrage in India on the Ganges and cooperative augmentation of dry-season water supplies in that monsoon zone. The Bangladesh floods of 1987 and 1988 reopened the question of basinwide management of high flows between these two countries. Problems have already arisen, or are expected shortly, on the Amazon, Niger, Senegal, and Zambezi rivers.

Furthermore, water often crosses international boundaries underground, and problems are now arising concerning the use of the northeastern African aquifer shared by Libya, Egypt, Chad, and Sudan;

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the northern Sahara basin shared by Algeria, Tunisia, and Libya; the Chad aquifers shared by Chad, Niger, Sudan, Nigeria, and Cameroon; the lower reaches of the Rhine recharge aquifers shared by Denmark, the Netherlands, and Germany; and aquifers along the southern border of the United States, shared with Mexico. Much of the discussion about international river basins pays insufficient attention to these important groundwater resources.

Major Issues in International River Basins

Technical, Scientific, and Environmental Foundations

An international river is a common property resource shared by the basin states. For water used in river basins, both positive and negative externalities usually exert an effect in only one direction, that is, downstream (table 1). An upstream country affects the volume or quality of a downstream country's water by diverting or polluting it, but the downstream country cannot do the same, because it has no access to the water until it has left the upstream country. Since, given enough time, water is the universal solvent and the major geomorphological transport mechanism, externalities are caused not only by intentional water uses but also by other natural and human activities in the upstream reaches, such as intensification of agriculture or forestry. This unidirectional feature of water use generally rules out resolution of basin conflicts through mutual control of bidirectional external effects. The downstream partners must often balance the asymmetrical water relationships with the use or exchange of resources from outside the water domain, for example, economic or military power. Shared groundwater resources, however, might violate the unidirectional nature of shared surface waters: downstream exploitation of a surface stream could deplete the groundwater reservoir in the upstream reaches of the basin.

Upstream activities can produce externalities with a positive as well as a negative impact on downstream users. Traditional water uses are hydropower for peak and base load power production; irrigation diversions; municipal and industrial diversions; maintenance of flow for navigation, adequate dilution of wastewater, or general ecological objectives; storage for flood control and recreation; and groundwater development. Some nonwater uses also have externalities, which typically involve land use changes associated with agriculture, forestry, animal husbandry, filling of wetlands, and urban and suburban development. There are also, however, natural (i.e., not human-caused) processes that produce downstream effects that are often mistaken for externalities. Large and small landslides, sometimes provoked by earthquakes, in fragile high mountain environments such as the Himalayas generate huge sediment loads in rivers, inducing drainage congestion and flooding, as well as improved soil fertility, downstream. Natural deposits of salts and heavy metals contaminate surface and groundwater leaching through them. The selenium damage caused by the irrigation drainage waters reaching the Kesterson wildlife sanctuary in California and the increasing salinity of the Colorado River are examples of external effects jointly caused by humans and nature. The sediment-drainage congestion-flooding sequence is often used to call for basinwide management of land use practices, but recent literature is equivocal about cause-and-effect relationships in this regard.

Legal Underpinnings

Resolving water conflicts is complicated by the nonexistence of an agreed-upon international legal framework to govern the use and development of international rivers by riparian countries. At least four major legal doctrines concerning shared waters in international river basins are available. The first is ***absolute sovereignty*** over waters flowing within a country. This implies that other riparian countries have no right to constrain a country's use of a river within its own boundaries. This is obviously preferred

Table 1. *Downstream Effects of Upstream Water Use*

	Downstream effect	*Nature of Externality*
Water use		
Hydropower		
Base load	Helps regulate river	Positive
Peak load	Creates additional peaks	Negative
Irrigation diversions	Removes water from system	Negative
Flood storage	Provides downstream flood protection	Positive
Municipal and industrial diversions	Removes water from system	Negative
Wastewater treatment	Adds pollution to river	Negative
Navigation	Keeps water in river	Positive
Recreation storage	Keeps water out of system	Negative
Ecological maintenance	Keeps low flows in river	Positive
Groundwater development	Reduces groundwater availability	Negative
	Reduces stream flows	Negative
Indirect use		
Agriculture	Adds sediment and agricultural chemicals	Negative
Forestry	Adds sediment and chemicals, increases runoff	Negative
Animal husbandry	Adds sediment and nutrients	Negative
Filling of wetlands	Reduces ecological carrying capacity, increases floods	Negative
Urban development	Induces flooding, adds pollutants	Negative
Mineral deposits	Adds chemicals to surface and groundwater	Negative

by upper riparians. The second principle is that *the river belongs to its riparians.* This is of great interest to lower riparians because it implies as much right to the waters for downstream as for upstream users. A third approach is *optimum development of the river basin.* This is attractive to technical water planners because it allows them to consider the basin as a single hydrological unit and plan accordingly. The fourth precept, *reasonable share* or *equitable use,* respects a riparian's sovereign right within its territory, but restricts its uses to ensure reasonable shares for the other riparians. This is the obvious choice for noninvolved third parties, but depending upon the stakes, it is less attractive to upstream riparians than to those downstream.

Another doctrine with widespread applications in the western United States has also been applied to international river basins—*prior appropriation.* Under it, water rights go to the first user in time—"first in time, first in right." Although this doctrine is not being specifically promoted for international water law, it is embedded in most of the definitions of "equitable use" when "past utilization of the waters" conditions the definition. It is also often explicitly used by the more developed and powerful countries in a basin to deny new uses to coriparians on the grounds that these will affect existing off-takes or uses.

In addition to the efforts of the Institute of International Law and the International Law Association, since 1971 the United Nations, through its International Law Commission (ILC), has been attempting to establish a set of rules pertaining to sharing of international water resources for purposes other than navigation. By 1984, the original six-article draft had grown to 41 articles categorized into six chapters. At press time, 27 of the articles had been provisionally adopted, but governments are cautious in creating or recognizing obligations.

There are, however, some encouraging developments in the legal situation. Substantial agreement on a set of important doctrinal issues has been reached. Despite the nonexistence of a "set of laws," five principles are widely used in water disputes: (1) prior consultation, (2) avoidance of significant injury, (3) equitable apportionment, (4) nondiscrimination and nonexclusion, and (5) provision for settlement of disputes. These principles are embedded in the Helsinki Rules formulated by the International Law Association in 1966 and are almost identical to the principles underlying the provisionally adopted ILC text. The World Bank's own operational directive governing policy on projects on international waterways, OD 7.50, is also based upon the two principles of "no appreciable harm to downstream riparians" and "equitable sharing by all riparians."

Economic Approaches

Economists have written extensively on the problems of allocating water in river basins, but they are quick to point out the limitations of their analysis given external effects. The general economic prescription to deal with externalities is to "internalize" them. The river basin itself is an ideal unit of analysis to achieve this goal: it can reasonably be assumed that most externalities are captured by analyzing the river basin as a single unit. This explains the popularity in the economics and planning literature of integrated river basin planning and river basin commissions.

Sorting out externalities among the several nations in one basin, however, can be more complex. An international river basin cannot be readily planned and developed as a single unit unless all riparians agree. Rarely has this been attempted, and a leading case, the Columbia River basin shared by Canada and the United States, yielded mixed results.

If the externalities among basin countries cannot be physically internalized, what are the alternatives? The economics literature is replete with proposals to tax externalities so that the individuals and groups benefiting from them will factor the costs to others into their calculations. Taxes, or fees, have been widely propounded by U.S. groups such as the Environmental Defense Fund and World Resources Institute to deal with transboundary air pollution. This approach, however, requires strong supranational institutions to impose the taxes, and such institutions do not now exist to control transboundary externalities in international river basins.

A promising practical approach to dealing with externalities in river basin planning, Paretian Environmental Analysis, was formulated by Dorfman and Jacoby (Dorfman et al. 1972). They applied Paretian analysis to upstream-downstream conflicts over the management of water quality; their example was within one country, but it resembled conflicts found in many international river basins. Pareto-Admissibility emerges as a condition that a water resources development plan for the basin must satisfy in order to be responsive to basin countries and to the goals of "reasonableness" and equity.

Dorfman and Jacoby sought a noncoercive strategy for a river basin authority that has to persuade its members to agree on a joint solution. The river basin commission could threaten that if no agreement were reached then the global optimum solution (the maximum benefits available to the entire system, ignoring jurisdictional boundaries) would be implemented. The basic assumption is that the upstream polluters and the downstream users would agree upon the reasonableness of the Pareto-Admissible strategy and agree to it without undue pressure. If they were unable to agree, however, the river basin commission would have the power to enforce the maximum net benefit plan for the basin as a whole. In the context of international river basins, where the individual countries may not wish to yield sovereignty (as required by the global optimum solution), but are seeking "reasonable" solutions, this approach has much to recommend it. Concentrating enough power in an international or bilateral agency to impose such a choice, however, is a difficult political requirement and at present is unlikely.

Other approaches to analyzing river basin conflicts can be discussed under the general rubric of decision theory. With the increasing emphasis on "reasonable and equitable share" in the legal approaches to international river basins discussed above, operational concepts of *equity* and *reasonableness* must be developed. Economists have recently devoted attention to building theories of "fairness," looking beyond allocative efficiency. *Superfairness* rests upon the Pareto improvement concept discussed above and the concept of "fair division." This is the old children's game of ensuring that two people will divide a cake fairly: one cuts the cake into two parts, and the other chooses.

Approaches based upon game theory, which deal with situations ranging from "pure" conflict to "pure" cooperation, do not directly yield norms for decisions regarding the conflicts found in international river basins. Consequently, the field has relied increasingly on process-oriented approaches, such as Alternative Dispute Resolution, which seek to get the parties to arrive at a negotiated solution, assuming that there is a solution to every conflict and that it can be arrived at by judicious use of several time-tested negotiating strategies ("win-win," "getting to yes," etc.) administered by a third party.

Despite early lack of success, game theorists have been pursuing various approaches that are potentially useful for shared international water resources. In particular, a series of recent studies applies some of the findings of game theory to practical problems of allocating benefits and costs among conflicting parties in river basins, based on the development and analysis of coalitions. To analyze a coalition structure in a game, the value of the game to each of the potential coalitions must be assessed with a single numerical index. Using this value, one can identify the benefits required by each player to ensure a stable political outcome. More research is needed to improve the quality of predictions based upon these approaches.

Political Bases

The decisions involved in international rivers are political and must ultimately be addressed in political terms; the problem is deriving a basis for political recommendations and action from political science.

Political imperatives differ from economic imperatives in three important ways:

1. They concretely evaluate the desirability of a policy or an investment on the basis of its value, positive or negative, to a large number of subgroups with varying degrees of interest in the matter;

2. They do not rely solely upon the simplifying quantitative economic measure of money, but are heavily influenced by nonmonetizable considerations as well;

3. They are pursued apart from economic objectives, with different personnel and rituals; recruitment to the political arena has a particular history, and admission confers a great deal of authority.

The most important work on the political bases for sharing international rivers is Le Marquand's 1977 book, *International Rivers: The Politics of Cooperation*, which discusses both the foreign and domestic policy implications of the decisions to negotiate river basin disputes. The book tends to relegate international river issues to the "middle range of objectives," dealing with satisfying domestic social and economic demands, rather than to the "core objectives" regarding a country's territorial integrity or self-preservation. Many countries view themselves as entering an era of jeopardized national sovereignty; some countries in the Middle East might claim that national survival is at stake.

Le Marquand suggested five aspects of foreign policy as the most influential determinants of a country's position on international rivers:

1. *image*. The concern with national image may be a vital factor in deciding how to deal with international water issues, particularly when the issues are considered middle-range objectives. The decision of the United States to build a desalting plant on the lower Colorado River may have been largely influenced by the desire to avoid the negative image of a large and powerful country pursuing its own national interest while ignoring the impact on a poorer neighbor;

2. *international law.* As discussed above, international law does not provide any strong incentives to behave in a particular way. There is now, however, broad consensus on a set of principles by which, depending upon the importance of image, a country may choose to abide. The developing and nonbinding international legal principles, therefore, can be important factors in enabling countries to become involved in negotiations;

3. *linkage.* Countries may be able to extract concessions from their neighbors through the linkage of river basin settlements to other bilateral or multilateral issues. To a certain extent, linkage has been used in most major river basin negotiations;

4. *reciprocity.* The desire for mutual commitment and obligation can often have bizarre manifestations in negotiating international river basin disputes. Le Marquand (1977) cited the insistence of Switzerland, a landlocked country, that treaties governing the protection of international watercourses against pollution be extended to cover pollution of coastal areas. This demand, however, was not irrational because it sought to ensure that the Netherlands, which would benefit from Switzerland's cleanup of its sewage discharges into the Rhine, could not dump its own untreated sewage into the ocean;

5. *sovereignty.* Sovereignty is the major impediment in resolving international river disputes. Countries prefer independent action over international cooperation because of the general loss of sovereignty and independence and the loss of control over domestic resources implied by collective or bilateral constraints.

Domestic policy formulation with regard to international river issues is influenced at three levels:

1. *bureaucratic.* Le Marquand (1977) claimed that most international river issues fall to bureaucrats in the ministry dealing with foreign affairs. In turn, they have to rely on bureaucrats in the technical water and other resource ministries, who often have substantive interest in a particular project, or set of projects, with interest group support. When the foreign affairs bureaucrats then have to deal with their counterparts in the other riparian countries, negotiations can drag on for years and "lowest common denominator" agreements are likely;

2. *executive.* When a head of state takes an active interest in the outcome of an international river issue, it is generally possible to circumvent recalcitrant bureaucrats and achieve rapid solutions. For example, President Escheverria of Mexico was able to press President Nixon into reaching a rapid resolution of the salinity problems of the lower Colorado River. The role played by President Ozal of Turkey may have given his "peace pipeline" a better chance of being implemented than if it had been left to the usual political channels in the Middle East;

3. *nonexecutive.* This essentially deals with "pork barrel" politics and coalition building, prominent elements of domestic U.S. water policy. Also included are the regulatory politics of environmental management that establish the ground rules for much domestic water policy. Redistributive politics may also be involved if central governments seek to use international agreements on water to regain control over regional water use and redirect it toward other social goals.

The most important political basis for sharing water is the "climate for agreement." The following conditions are favorable for successful international agreements concerning water:

- countries with the same technical perception of a problem;
- similar consumption of goods and services;
- when water quality is an issue, the use of similar industrial production technologies;
- an extensive network of transnational and transgovernmental contacts between countries;
- the participation of a small number of countries;
- the desire of one large country to have an agreement;
- the necessary development by one country of a good or service for its own use that may benefit other countries.

Conclusions

International river basins are a major problem that will become increasingly important over time. International law in this area remains weak, despite intensive work by the UN's International Law Commission. There is therefore a pressing need for mechanisms that bring parties in dispute together to negotiate resolutions. The Bank has previously been successful in this process and may be uniquely qualified as the only international agency that can host the parties and mobilize the requisite technical, economic, legal, and political skills.

Facilitated data sharing and river basin study groups are among current proposals for improving international river basin management. Transboundary effects, including those related to groundwater, should be an integral component of negotiations.

Based upon the papers in this volume and the general literature on international river basin development, careful research is needed on integrating the technical/scientific material with the economic/institutional material. Many countries face not one but several international river conflicts. This makes it difficult for these countries to focus on any one problem, and they may fail to achieve a satisfactory resolution to any of the conflicts by dividing their attention among all of them. The world community must confront these resource and environmental conflicts between nations.

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PROJECTS ON INTERNATIONAL WATERWAYS: LEGAL ASPECTS OF THE BANK'S POLICY

David Goldberg

This presentation is a synopsis of the legal aspects of Bank policy for projects on international waterways. Its emphasis is on drawing pragmatic conclusions. The policy set forth in the Bank's Operational Directive (OD) 7.50 is an internal policy approved by the Bank's executive directors and applicable to all projects on an international waterway, which is defined to include:

1. any river, canal, lake, or similar body of water forming a boundary between—or any river or body of surface water flowing through—two or more states, whether or not the states are members of the Bank;

2. any tributary or other body of surface water that is a part or component of any waterway described in (1) above;

3. bays, gulfs, straits, or channels, bounded by two or more states or, if within one state, recognized as necessary channels of communication between the open sea and other states, and any river flowing into such waters.

What are the legal underpinnings of the provisions of OD 7.50? First and foremost, OD 7.50 approaches the subject from the standpoint of an international cooperative institution—the Bank—that, in accordance with Article III, Section 4 (v) of its Articles of Agreement, has "to act prudently in the interests both of the particular member in whose territories the project is located and of the members as a whole" (a similar provision exists in the IDA Articles of Agreement). In this context, the Bank, in formulating its policy, has recognized the requirements of international law in this field to the extent that they are relevant to the Bank's role as a lending agency.

What are the sources of international law on this subject? Article 38 of the Statute of the International Court of Justice of The Hague (which is part of the UN system) enumerates, in order of precedence, the sources of international law that the Court must utilize:

1. the law of treaties, that is, the body of treaties and conventions ratified by governments;
2. customs;
3. generally accepted principles;
4. decisions of the judiciary and doctrines of qualified authors.

The law on international waterways is one of the most unsettled areas of international law, although much work has been undertaken by various international law groups, such as the International Law Association and the Asian-African Legal Consultative Committee, and by the International Law Commission of the UN, pursuant to a 1970 General Assembly resolution. The work of these bodies draws heavily on the sources of international law mentioned above.

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Two substantive principles receive the greatest acceptance in international law circles and are reflected in several bilateral and multilateral treaties. They are:

1. the principle of prohibition against appreciable harm by way of deprivation of water rights, pollution, or other means;

2. the principle of the right of each riparian of an international waterway to a reasonable and equitable share in the utilization of the waterway.

The first principle, that of prohibition against appreciable harm, derives from a Latin maxim: *Sic utere tuo ut alienum non laedas*: So use your own property as not to injure your neighbor. This principle seeks to facilitate "good-neighbor" relations between states by reserving the right of each state to use waters in its territory in accordance with its needs, provided that it does not appreciably infringe on the rights of other states. This principle, strengthened and safeguarded by several procedural requirements, has a particularly important role in emerging international law on this subject and in the Bank's policy under OD 7.50. The prohibition is not against causing *any* harm but harm that is appreciable, i.e., not trivial or inconsequential. The Report of the International Law Commission (40th Session, May 9 to July 29, 1988) states:

> As explained in the commentary to article 4, the term "appreciable" embodies a factual standard. The harm must be capable of being established by objective evidence. There must be a real impairment of use, i.e., a detrimental impact of some consequence upon, for example, public health, industry, property, agriculture or the environment in the affected State. "Appreciable" harm is, therefore, that which is not insignificant or barely detectable but is not necessarily "serious" (p. 85).

The second substantive principle, that of equitable utilization of the international waterway, means that each riparian of such a waterway has an equality of right with every other riparian to utilize the waters in a reasonable and beneficial manner. In this context, equality of right does not mean the right to an equal division of the waters, but rather that each riparian has an equal right to the division of the waters on the basis of its needs, consistent with the corresponding rights of the coriparian states and excluding from consideration factors unrelated to such needs. This principle is also reflected in several treaties, particularly regional bilateral and multilateral treaties, and is included in the latest draft articles of the International Law Commission. The 1960 Indus Waters Treaty between India and Pakistan is perhaps the most well-known of such bilateral treaties.

The 1988 Report of the International Law Commission describes the factors relevant to equitable and reasonable utilization:

> Utilization of an international watercourse [system] in an equitable and reasonable manner within the meaning of article 6 requires taking into account all relevant factors and circumstances, including:
>
> (a) geographic, hydrographic, hydrological, climatic and other factors of a natural character;
>
> (b) the social and economic needs of the watercourse States concerned;
>
> (c) the effects of the use or uses of an international watercourse [system] in one watercourse State on other watercourse States;

(d) existing and potential uses of the international watercourse [system];

(e) conservation, protection, development and economy of use of the water resources of the international watercourse [system] and the costs of measures taken to that effect;

(f) the availability of alternatives, of corresponding value, to a particular planned or existing use.

Whereas the injunction of not causing appreciable harm is an absolute and imperative prohibition, the right to an equitable sharing, although at times described as "complementary," is less readily conceived as self-standing because the practical result in each case must first be determined by an agreement between the parties or an award of a competent tribunal. In the Bank's approach under OD 7.50, whereas the "no appreciable harm" principle is firmly embodied in the OD, no reference is made to the equitable sharing principle. The Bank does not take a position adverse to this principle, but in the absence of an agreement between the parties or the judgment of a competent tribunal, either of which the Bank would respect, the right of each party to an equitable sharing is inchoate, and the Bank has neither the authority nor the competence to adjudicate such rights. In addition, the OD is intended for the practical guidance of Bank staff and not as a full statement of legal principles on the subject, and in this context the OD focuses on concerns to the Bank as a lender. However, it has been contended, as will be dealt with later, that the Bank's approach, by not equally recognizing the two principles at stake, is out of line with the requirements of international law. Such criticism is not valid. An examination of how the convergence of the two principles is treated in international law, as reflected in the 1988 Report of the International Law Commission, reveals the limits of the principle of equitable sharing. The Report comments that:

> A watercourse State's right to utilize an international watercourse [system] in an equitable and reasonable manner finds its limit in the duty of that State not to cause appreciable harm to other watercourse States. In other words—prima facie, at least—utilization of an international watercourse [system] is not equitable if it causes other watercourse States appreciable harm....
>
> Thus, a watercourse State may not justify a use that causes appreciable harm to another watercourse State on the ground that the use is "equitable," in the absence of agreement between the watercourse States concerned (p. 84).

This important issue of the interplay between the two dominant International Law Commission principles embodied in article 6 (equitable and reasonable utilization and participation) and article 8 (obligation not to cause appreciable harm) is discussed by Professor Stephen McCaffrey, special rapporteur of the International Law Commission, in his article "The Law of International Watercourses: Some Recent Developments and Unanswered Questions" (*Denver Journal of International Law and Policy* 1989). After referring to the approach of the International Law Commission (ILC), as discussed above, he remarks:

> First, the ILC's approach affords a measure of protection to the weaker state that has suffered harm. It is not open to the stronger state to justify a use giving rise to the harm on the ground that it is "equitable." A second, and related, point is that it is far simpler to determine whether the "no harm" rule has been breached than is the case with the obligation of equitable utilization. Thus, primacy of the "no harm" principle means that the fundamental rights and obligations of states with regard to their uses of an international watercourse are more definite and certain than they would be if governed in the first instance by the more flexible (and consequently less clear)

rule of equitable utilization. And, finally, the "no harm" rule is preferable in cases involving pollution and other threats to the environment. While a state could conceivably seek to justify an activity resulting in such harm as being an "equitable use," the "no harm" principle would—at least prima facie—require abatement of the injurious activity.

Before discussing issues that have arisen and been dealt with since the adoption of the policy in OD 7.50, its main provisions will be summarized. As already stated, the OD applies to various types of international waterways, including rivers, canals, or lakes flowing through two or more states (whether or not Bank members), as well as tributaries of such waterways. The most important procedural provision of the OD is that it requires Bank staff, as early as possible during the identification stage of the project cycle, to advise the prospective borrower that, if it has not already done so, it should formally notify the other riparians of the proposed project. If the prospective borrower wishes the Bank to give notification on its behalf, the Bank would do so, but if the prospective borrower objects to any such notification to other riparians of the international waterway concerned, the firm rule is that the Bank will discontinue further processing of the project. The notification should contain, to the extent available, sufficient technical and other necessary specifications and data that would enable the other riparians to determine as accurately as possible the potential for appreciable harm through deprivation of water rights, pollution, or other means. The concern is twofold, namely, that the project not adversely affect the interests of other riparians and that it not be adversely affected by the plans of other riparians for use of the waters concerned. A reasonable period of time, normally not to exceed six months, is to be allowed for the recipient state to respond.

There are two exceptions to the requirement for notification. First, where the proposed project involves additions or alterations via rehabilitation, construction, or other means to any ongoing schemes and, in the Bank's judgment, such a project will not adversely change the quality or quantity of water flows to other riparians nor be adversely affected by the uses of the water by other riparians, notification in the manner described is not required. Second, if the proposed project is a water resource survey or feasibility study, notification is not required, but the terms of reference for such a survey or study should include an examination of any potential riparian issues. Bank staff, however, are always advised to ascertain the agreements or arrangements that may exist among the riparians for the development of the waterway concerned and to try to secure compliance with such agreements or arrangements.

The OD provides that the senior vice president for Operations be kept informed of developments, particularly where other riparians have raised objections. If objections are received, the OD requires that a memorandum be prepared by the region in consultation with the Legal Department to be sent to the senior vice president for Operations and copied to the vice president and general counsel, detailing, among other things, the nature of the issues raised; Bank staff assessment of the objections and whether the project will cause appreciable harm or be harmed by uses that other riparians might make of the waterway concerned; whether the Bank should urge the parties to resolve their differences amicably; and whether the objections are such that it would be advisable to obtain an opinion from independent experts. With respect to the experts, a roster of eminent persons with knowledge of international water systems and international law is maintained by the vice president for Sector Policy and Research, in consultation with the regional offices and the Legal Department. Last, the OD contains instructions on the relevant information that should be included in the staff appraisal report and president's memorandum to the executive directors.

In the six years that the policy in the OD has been in operation, several interesting cases have arisen relating to the practical application of the Bank's rules. One question raised in several proposed projects relates to whether notification should be required in all cases, even where it is self-evident that no conceivable harm could be caused by the project, nor could the project be affected by any uses proposed by other riparians. In responding to these unusual instances, the Legal Department has dubbed them "no issue/no conceivable harm" cases. Many have originated in the Asia Region where there are large countries that are downstream riparians of important international river systems. Several of these cases relate to India-Bangladesh, China-Nepal, and India-China, although cases have also arisen in the Europe, Middle East, and North Africa Region (Lebanon-Jordan) and the Africa Region (Zambia-Zimbabwe-Malawi).

The typical situation arises where the proposed project is to be located on a tributary of an international waterway that runs exclusively in the territory of the prospective borrower and such prospective borrower is also the lowest downstream riparian. In such cases, and subject to the configuration of the waterway, it is normally clear that the project could not conceivably cause harm to the upstream riparians, nor could it be affected by upstream activity. Generally, in such cases, the Legal Department has taken the position that because there can be no issue there is no need to invoke the notification provisions of OD 7.50. It is, however, of utmost importance that it be self-evident that the project absolutely could not harm or be harmed by any other riparian nor raise any other international law issue. There may be concern that this "dilution" of the notification rule may steer us away from the certainty and effectiveness of the principle at stake. On the contrary, the result of this application of good common sense is quite compatible with the approach adopted by the International Law Commission in defining an "international watercourse system." The 1988 Report refers to this aspect:

> An "international watercourse system" is a watercourse system, components of which are situated in two or more States.
>
> To the extent that parts of the waters in one State are not affected by or do not affect uses of waters in another State, they shall not be treated as being included in the international watercourse system. Thus, to the extent that the uses of the waters of the system have an effect on one another, to that extent the system is international, but only to that extent; accordingly, there is not an absolute, but a relative, international character of the watercourse (p. 47).

In article 12 and onward of the International Law Commission text, a system of prior notification is only triggered by the criterion that the contemplated measures may, as perceived by the state planning the project, have an "appreciable adverse effect" upon other watercourse states. The planning state must, therefore, in each case undertake its own assessment of the impact of the project upon other states using the watercourse, and only if it concludes that there will be such an adverse effect does it need to provide notification. (If it does not provide notification, any other watercourse state learning of the plans in some other way may request the planning state to apply the provisions of article 12.) Thus, the Bank's current notification standards are more rigorous than those established by the International Law Commission because of the need to avoid any dispute in the advanced stages of project preparation.

Another issue that has arisen in the course of applying the policy in OD 7.50 is the charge by at least one Bank member that Bank rules are inherently biased against upstream riparians, which are obviously most prejudiced by the "no appreciable harm" rule without being able to receive any redress under the "equitable utilization" rule. Although this charge may have some validity, the application of policy is not the result of bias introduced by Bank rules, but rather of the relative impact and interplay of the two principles under international law, as discussed earlier. In short, without an agreement by the parties or a determination by a competent tribunal of the respective rights of the riparians in practical terms, the Bank cannot, nor is it required by international law to, permit claims of equitable sharing rights to impair the principle of "no appreciable harm." This may create great difficulties in certain cases for upstream riparians who have traditionally underutilized the waters in question, but the resolution of this problem lies outside the jurisdiction of the Bank. OD 7.50, in outlining the Bank's basic policy approach, clarifies that:

The Bank, therefore, attaches the utmost importance to riparians entering into appropriate agreements or arrangements for the efficient utilization for the entire waterway system or any part of it, and stands ready to assist in achieving this end. In cases where differences remain unresolved, the Bank, prior to financing the project, will normally urge the state proposing the project to offer to negotiate in good faith with other riparians to reach appropriate agreements or arrangements (para 1).

In one important respect, OD 7.50 goes beyond the concepts of emerging international law in focusing, as already indicated, not only on the appreciable harm that the proposed project may cause to other riparians but also on the potential harm that others may cause to the project. This rule is clearly derived from quite different considerations than the precepts of international cooperation, goodwill, and legal practice; rather, it flows from the self-interest of the Bank not to provide funding for a project that may not be viable or produce the expected economic benefits because of uncertainty regarding the quantity or quality of water flows needed for the project's success. The application of this rule has produced interesting developments in the proposed Baardhere Dam Project in Somalia. Briefly, this proposed project involves the construction of a dam, power generation installations, and irrigation works on the Juba River, which stems from an upper basin in Ethiopia. Another important tributary flows into Kenya. Somalia, which did not wish to deal directly with the other riparians (Kenya and Ethiopia), requested that the Bank notify the two riparians on its behalf. The Bank did so and provided the two governments with the necessary project details. The government of Kenya responded by requesting more information, whereas the Bank received a reply from Ethiopia raising objections to the proposed project for the following reasons:

1. the long-standing political and security differences with Somalia;

2. its own intention to utilize the flow of the entire river for irrigation and its plans for development of a hydroelectric scheme on the river;

3. its preference to hold direct negotiations with Somalia on water allocation.

Bank staff viewed that appreciable harm to the project from Ethiopia was improbable, but because of the uncertainty relating to Ethiopia's future plans, the Africa Region requested that the Operations Committee authorize an opinion from a panel of independent experts chosen from the roster maintained by the Bank. Three experts, including an international legal expert, were selected to review all riparian issues related to the proposed project. The panel's report supported the assessment made by Bank staff. This is the first case in which Bank management found it expedient to use the independent expert mechanism.

Questions have arisen about the notification requirement where an agreement exists between the riparians of the international river concerned or where an institutional framework has been established to deal with utilization of the international waterway involved. In such situations the OD itself states clearly that Bank staff should make efforts to secure compliance with the requirements of such agreements.

Questions have also been raised about the length of time that should be given to the other riparians to respond to a notification from a prospective borrower. The OD provides that riparians should be allowed a reasonable period of time, normally not exceeding six months. The amount of time that may actually be needed may vary according to the nature of the proposed project: for instance, a simple project may require a shorter time frame because the project details are not too complicated for the riparians to determine the possible effect of the project, whereas a complex hydroelectric or irrigation scheme may require more time. The six-month limit is consistent with the time limits found in notification provisions in most international agreements, and the International Law Commission—in its latest draft convention on the subject—has stipulated the same time limit. Often, where the Bank has a local office, its representative has played a useful role in obtaining as prompt a response as possible.

To date, OD 7.50 has served the interests of the Bank and its members well. Although, as with any new policy, there was some resistance to carrying out its provisions in the beginning, the principles contained in the OD are now well understood throughout the Bank and in member countries where riparian issues recur. It has also served to maintain a Bank policy that is fully in line with the most recent developments in international law.

COUNTRY AND RIVER BASIN STUDIES

OPPORTUNITIES FOR REGIONAL AND INTERNATIONAL COOPERATION IN THE NILE BASIN

Dale Whittington and Elizabeth McClelland

Continued lack of coordination in Nile River basin development is in no one's best interest. Today's decisions about investment in water development projects will have consequences far into the future when water resources are in much greater demand. This paper begins with a brief introduction to the Nile basin, followed by a review of the current legal regime and recent developments. It then examines three possibilities for cooperation in river basin development, emphasizing the importance of a basinwide perspective for future water planning and investment.

Background

Nile water appeared to be in plentiful supply after the completion of the Aswan High Dam in 1970. This period of water abundance is ending. Not only are water demands escalating as a result of rapid population increase and economic growth, but available water supplies are decreasing. There is increasing speculation that climatic change is reducing the available water supplies in the Nile basin. In addition, environmental degradation of the upper Blue Nile catchment increased throughout the 1980s.

Over the last decade little progress was made in planning for the coordinated development of Nile resources, partly because of the political upheavals and famines in Sudan and Ethiopia and an understandable reluctance on the part of major donors to become involved in a long-term planning effort when economic and financial conditions were so unstable. Much remains to be learned about the management of the river, especially how the water development plans of different riparian countries would be affected by alternative allocation schemes and legal arrangements. The unanticipated climatic and environmental changes of the 1980s have accelerated the need to make economic, political, and legal adjustments in the existing Nile management and allocation regime.

The Nile River Basin

The Nile River basin, which includes nine countries, encompasses the White and Blue Niles. Before it joins the Blue Nile at Khartoum, the White Nile flows through eight riparian states (Rwanda, Burundi, Tanzania, Zaire, Kenya, Uganda, Ethiopia, and Sudan). It proceeds northward into Egypt and the Mediterranean Sea. The Blue Nile, in contrast, rises almost exclusively from the Ethiopian highlands, and only three riparian states are involved with its management: Ethiopia, Sudan, and Egypt.

The problem of water scarcity is more critical in the Blue Nile than in the White Nile basin. The countries in the White Nile basin south of Sudan have considerably more rainfall than either Sudan or Egypt. The effects of water extractions by these upper Nile countries on the downstream riparians are currently mitigated by the Sudd swamps in southern Sudan. The economic development of these upper Nile countries is not currently limited by water availability. In contrast, approximately 86 percent of the

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annual river flow into Egypt comes out of Ethiopia, and the implications for Egypt and Sudan of any potential extractions by Ethiopia may be significant. For these reasons, this paper focuses on the opportunities for cooperation among the three Blue Nile riparians: Ethiopia, Sudan, and Egypt.

Overview of Current Conditions

Present Legal Regime: The 1959 Nile Waters Agreement

The 1959 Nile Waters Agreement remains the legal basis for the allocation of Nile waters between Egypt and Sudan. This treaty was based on the assumption that there would be a mean annual flow at Aswan of 84 billion m^3, of which Egypt was allocated 55.5 billion m^3 and Sudan 18.5 billion m^3. Ten billion m^3 were assumed to be lost to evaporation and seepage from the Aswan High Dam reservoir. The agreement did not reserve any water for upstream riparian countries. It did, however, establish procedures that Egypt and Sudan were to follow in settling the claims of upstream riparians for a share of Nile waters. The agreement notes that:

> Since the other riparian countries on the Nile besides the Republic of Sudan and the United Arab Republic claim a share in Nile water, both Republics agree to study together these claims and adopt a unified view thereon. If such studies result in the possibility of allocating an amount of Nile water to one or the other of these territories, then the value of this amount shall be deducted in equal shares from the share of each of the two Republics.

This procedure has never been tested. No other riparian country has submitted formal claims to Egypt and Sudan for an allocation of water from the Nile. Although most of the water that arrives at Aswan originates in Ethiopia (see table 1), to date Ethiopia has not exercised its rights under international law to a portion of the Nile waters.

Existing Water Use Patterns

Data presented in table 2 on current water use patterns in Egypt and Sudan show relatively abundant water supplies. Egypt has significant quantities of irrigation drainage water that could be reused to free up water for competing needs. Sudan is utilizing only about three-quarters of its allocation under

Table 1. *Comparison of Water Allocations under the 1959 Nile Waters Agreement and Origin of the Nile Waters (billion m^3)*

	Origin of water	*Allocation under 1959 agreement*
Egypt	0	55.5
Sudan	minimal	18.5
Ethiopia	72	0
Other riparian countries	12	0
Evaporation and seepage losses	n.a.	10
Total	84	84

Table 2. *Average Annual Water Use in Egypt and Sudan, 1980-86 (billion m^3)*

Country	Water use
Egypt	
Agricultural[a]	33
Municipal & industrial	2
Evaporation downstream of Aswan	2
Outflows[b]	20
Total	57
Sudan	
Agricultural	12-13

a. Crop water consumption is a derived figure, estimated as the difference between estimated inflows, minus outflows, minus consumption by other water users.
b. Includes drainage discharges, releases for navigation, and losses at end of control system.

the 1959 Nile Waters Agreement. Both countries could supplement their supplies with groundwater extraction. Nonetheless, numerous developments are anticipated basinwide that could result in a rapid transition to water scarcity.

Future Development: Demand

Population Growth

The populations of Egypt, Sudan, and Ethiopia have grown steadily since 1960. The famines and civil wars in Ethiopia and Sudan had only a slight dampening effect on this upward trend, and population growth is forecast to continue (table 3). In 1987, there were approximately 117 million people in Egypt, Sudan, and Ethiopia: by the year 2000 there will probably be between 160 and 170 million.

Population growth will affect water demand for human and livestock consumption and for industrial and commercial activities. The increased demand for food will require more irrigation water. The demand for food could be met by increasing imports. Egypt, however, is already heavily reliant on foreign cereals, thereby raising concerns about food security. Water for irrigation schemes, therefore,

Table 3. *Population Projections for Egypt, Sudan, and Ethiopia (millions)*

	Year		
Country	1987	2000	2025
Egypt	50	67	99
Sudan	23	33	56
Ethiopia	44	66	122
Total	117	166	277

Source: World Development Report 1989.

would become increasingly valuable for Egypt. This is also true for Ethiopia and Sudan, where relatively high-quality land exists for new irrigation schemes, but opportunities for industrial development are currently much more limited than in Egypt.

Economic Growth

Over the last 30 years Egypt has maintained its position as the dominant economic power in the Nile basin. Per capita GNP in Egypt was US$680 in 1987, more than twice that of Sudan (US$330) and more than five times that of Ethiopia (US$130). All three economies are weak and burdened with debt. In the late 1970s there was much talk about the tremendous development potential of Sudan, but the economy of Sudan has performed much worse than Egypt's, in effect collapsing over the last decade. Between 1980 and 1988, Ethiopia had an annual average per capita growth rate of minus 0.1 percent. The macroeconomic performance of these three major riparian countries during the 1980s severely constrained their ability to finance major new investments in the water and irrigation sectors. The Sudanese and Ethiopian economies are in worse shape than Egypt's, but even Egypt is unlikely to be able to access substantial additional capital in international markets.

Egyptian Land Reclamation Efforts

Ten years ago the conventional wisdom was that the use of Nile water in Egypt to reclaim desert land for agricultural cultivation did not make economic sense in most locations--even ignoring the opportunity cost of not using the water elsewhere in the Nile basin. One of the main drawbacks of desert reclamation projects from an economic perspective was that the cost of pumping water from the Nile Valley to the higher elevations in the surrounding desert was prohibitively expensive. It therefore did not seem that Egypt would need large quantities of new water supplies for agricultural expansion. Water required for urban and industrial growth appeared to be available from reuse of drainage water and improvements in the efficiency of the use of irrigation water. Drip irrigation technology particularly seemed to promise significant water savings.

The economics of desert reclamation now appear somewhat different to the Egyptian government for the following reasons: (a) greater involvement by the private sector has resulted in higher agricultural productivity than was thought possible a decade ago; (b) improved production and irrigation technologies are now practical (e.g., plastic mulch, pressure irrigation systems); (c) improved crop varieties have been developed that are better suited to desert conditions; and (d) real energy prices have fallen over the last decade, and Egypt now has excess supplies of natural gas to provide the energy for pumping water to new reclamation areas. Consequently, Egypt is now rapidly pressing ahead with this desert reclamation option, with the active support of the U.S. Agency for International Development.

The Egyptian Land Master Plan has proposed that 580,000 ha be considered for priority reclamation in the near to medium term. Egypt's available water supplies would permit the reclamation of about 340,000 ha. The estimated 6.5 to 8.5 billion m^3 of water annually required for the 340,000 ha would come from drainage water reuse and would not require water supplies in excess of Egypt's current allocation under the 1959 Nile Waters Agreement. Egyptian water experts have estimated that agricultural water use in Egypt will increase by over 10 billion m^3 by the year 2000, assuming an average water use in reclamation projects of 17,138 m^3 per ha. It is not clear, however, whether a desert reclamation program of this scale can be accomplished within Egypt's existing water allocation and still leave any water to meet new urban and industrial requirements.

The implementation of Egypt's current desert reclamation plans will make it difficult politically for Egypt to consider reducing its allocation of 55.5 billion m^3 to accommodate any upstream riparians. Desert reclamation will also make the management of droughts more difficult. The Egyptian government argues that the rapid growth of the country's population leaves it no choice but to push ahead with desert reclamation. The international community should, however, view Egypt's renewed desert reclamation efforts in a broader context. In particular, two aspects of the economic analysis should be considered: First, the economic argument for land reclamation assumes that the value of the Nile water used is zero, i.e., there is nó opportunity cost associated with the water for reclamation projects. From Egypt's point of view, this may be true because the projects rely largely on drainage water from the end of the delivery system. However, from the perspective of the entire Nile basin, it is clearly false. Water could be used elsewhere, for instance, in Sudan or Ethiopia. Second, within several decades, Egypt's supplies of natural gas will be depleted. The desert reclamation projects therefore do not appear sustainable given existing technology and natural resources.

One way to understand the opportunity cost issue is to imagine that Egyptian farmers hold marketable water rights to some allocation of water and to ask whether they should use their allocation for reclaiming land or sell it to the highest bidder who might live in another riparian country. In evaluating whether to proceed with a reclamation project, a farmer would evaluate the full costs of the project. Farmers holding a marketable water right should charge the reclamation project what they could have received had they sold the water instead of using it for the reclamation project. This is the real cost to them of using the water for reclamation. To be economically viable, the project must recover its full costs, including the opportunity cost of water.

The importance of considering the opportunity cost of water in the evaluation of desert reclamation projects is seen in the sensitivity of the economic rate of return of a representative farm in an Egyptian desert reclamation project to changes in the opportunity cost of water. If one assumes that the opportunity cost of water to the project is zero and that the project has to pay only the pumping costs of a 45-m lift, then the economic rate of return is estimated to be about 14 percent. However, as the opportunity cost of water rises, the economic rate of return declines significantly. If the opportunity cost of water is above about US$65 per 1,000 m^3, the economic rate of return is actually negative. (Irrigation water prices are significantly higher than this in parts of the western United States.) There are currently no reliable estimates of the value of water elsewhere in the Nile basin, but it is easy to imagine development scenarios for both Sudan and Ethiopia in which water for irrigation would have a significantly positive value. These calculations suggest that, from an overall economic efficiency perspective, the rates of return of Egyptian desert reclamation projects have probably been considerably overestimated.

Future Development: Supply

The Jonglei Canal and Other Upper Nile Projects

For almost a century, plans for the development of the Nile basin have anticipated cutting a bypass canal around the Sudd swamps to reduce evaporation losses. This would be accompanied by control works upstream to provide increased storage capacity. The estimated increase in "yield" to be made available through all upper Nile projects on the Egyptian drawing board is about 18 billion m^3. These figures, however, are guesses: little serious hydrological work has been done in the Sudd swamps over the last decade.

The Jonglei Phase I was to have been the first, crucial step in the development of upper Nile projects. The project would have increased the mean flow at Aswan by an estimated 3.8 billion m^3, to be shared equally by Egypt and Sudan. Construction began in 1978, but was halted in 1983 because of civil war in southern Sudan. It is difficult to foresee when, if ever, the Jonglei Canal might be completed.

Environmental Concerns

Growing population not only will increase water demand, but also may reduce the supply of high-quality water available at low cost as a result of increased pollution, as is already the case in Alexandria, Egypt. Population growth has also led to excessive deforestation, particularly in the Ethiopian highlands, where the ability of watersheds to retain rainfall has been seriously damaged, aquifers are being depleted, and erosion has increased river sediment loads and reduced the useful life of reservoirs downstream. The environmental degradation is likely to continue as increased numbers of people are forced to cultivate increasingly marginal lands.

The Sudd region of Sudan is the largest freshwater swamp in the world and is home to millions of migratory birds, as well as thousands of large herbivores. Water development projects on the White Nile that are designed to reduce evaporation losses in the Sudd swamps to increase flows downstream will decrease the size of the habitat available for such wildlife. There are many serious ecological consequences of the White Nile schemes, and increasing global awareness of the adverse environmental effects of draining freshwater wetlands would make the financing of these projects by donors highly unlikely.

Drought and Climatic Change

There was severe drought in the Nile basin during the 1980s. The Aswan High Dam allowed Egypt to cope with this extended drought remarkably well: although Ethiopia and Sudan experienced severe famines, Egypt's agricultural productivity actually continued to increase. Egypt survived this drought so successfully in part because Sudan was not taking its full allocation under the 1959 Nile Waters Agreement and because Ethiopia did not withdraw any water from the Blue Nile basin. Egyptian water planners are acutely aware that the consequences of the 1980s drought would have been entirely different had this not been the case.

It is impossible to know conclusively whether the 1980s drought signaled a new climatic regime for the Nile basin. However, riparian countries must increasingly consider the possibility that the long-term yield of the Nile may be significantly lower than commonly accepted as a result of global climatic change. This prospect puts increasing pressure on the riparian countries to manage available water supplies more effectively.

A Basinwide Planning Perspective: Three Opportunities for Cooperation

The Blue Nile Schemes

The Jonglei Canal Project has been the focus of intense international media attention over the last two decades, but from a water control perspective a series of dams constructed on the Blue Nile in Ethiopia would be a far more dramatic and important development for Egypt, Sudan, and Ethiopia. The first serious proposal for such dams was made by the United States Bureau of Reclamation in 1964. Between 1958 and 1963, the Bureau of Reclamation and the Ethiopian Ministry of Public Works and Communications collaborated on a major study of the development potential of the water resources of the Ethiopian portion of the Blue Nile for irrigation and hydroelectric power generation.

The Bureau of Reclamation's investment plan included 33 irrigation and hydroelectric power projects in the Blue Nile basin. The total area of the proposed irrigation projects was about 434,000 ha, and the irrigation projects were estimated to require 6 billion m^3 of water. Four major hydroelectric projects were proposed for construction on the Blue Nile downstream of Lake Tana. Together, these four dams would have an initial active storage capacity of about 51 billion m^3 and an estimated annual electricity generation of over 25 billion kilowatt-hours (about three times the actual production of the Aswan High Dam). The mean annual flow of the Blue Nile at the Sudanese-Ethiopian border is about 50 billion m^3; thus, the active storage capacity would be approximately equal to the mean annual flow.

The Bureau of Reclamation study presented some simple calculations that illustrated how these dams would affect downstream flows. The proposed dams on the Blue Nile would effectively eliminate the annual Nile flood: the flow of water reaching Sudan would be almost constant, both throughout the year and by year. The bureau also concluded that the total annual flows of the Blue Nile reaching Sudan would be reduced by 8.5 percent as a result of the development of the Ethiopian irrigation and hydroelectric power projects (both irrigation withdrawals and evaporation losses from the reservoirs). This means that flows to Sudan and Egypt would be reduced by about 4 billion m^3.

From a basinwide management perspective, there are four important implications of these Blue Nile reservoirs:

1. More water storage could be moved upstream into Ethiopia where evaporation losses would be greatly reduced because of the reduced evaporation rates at the reservoir sites and because of the improved volume-to-surface ratios of the Ethiopian reservoirs in the Blue Nile gorge as compared with Aswan. The reduction in system-wide evaporation losses means that more water would be available for all riparian countries. Detailed calculations suggest that the savings would be roughly equal to the total amount of water required by Ethiopia for all the irrigation projects in the Bureau of Reclamation's investment program[1];

2. The control of the Blue Nile flood would be particularly beneficial to Sudan. The added storage upstream is needed by Sudan for the long-term expansion of its gravity-fed irrigation area. Sudan currently has no over-year water storage capacity and is therefore unable to store water for use during droughts. The Ethiopian reservoirs would provide Sudan with this much-needed water security, provided that agreements could be reached on their operation that would ensure that Sudan received its water allocation in a timely fashion;

3. Many of the current problems of operating the Roseires reservoir would be substantially reduced. Instead of serving a seasonal storage function, Roseires could operate essentially as a barrage to raise water and as a hydroelectric generation facility. Its rate of siltation would be greatly diminished as would maintenance costs for the hydroelectric facility, both of which are currently adversely affected by the high volumes of silt flowing into the reservoir;

4. From the Egyptian perspective, potential reductions in its annual allotment of waters to provide for Ethiopian needs could be greatly mitigated by the water savings that would come from the evaporation savings and coordinated management of the Blue Nile. Further, improved cooperation established through these mutually beneficial developments could provide Egypt with much-needed data on rainfall and climate patterns in Ethiopia, allowing for better predictions of annual river yields and improved planning for optimal cropping patterns.

The opportunity for such joint gains provided by the Ethiopian reservoir schemes highlights the high costs of the present lack of coordination among Egypt, Sudan, and Ethiopia.

The White Nile Rehabilitation Project

Another opportunity for cooperation exists in central Sudan. The Jebel Aulia Dam on the White Nile is 40 km south of Khartoum and was originally designed to provide Egypt with additional water supplies for summer irrigation. Yet this seasonal storage had a high cost in terms of reservoir evaporation losses: approximately 2.8 billion m^3 per year, or 50 percent of the reservoir storage capacity. The construction of the Aswan High Dam made this seasonal storage reservoir unnecessary for downstream irrigation. Since the construction of the Jebel Aulia Dam, however, 174 pump irrigation schemes have been developed along the White Nile. These pump schemes require a certain water level, which has been provided seasonally by the Jebel Aulia reservoir. However, the pump schemes are operating at low efficiencies because of the low water level in the White Nile between April and September when the pump intakes are above river level. As a result, only 22 percent of the 182,000 ha in the original scheme areas are currently cultivated.

A 1989 report, prepared by Sir Alexander Gibb & Partners for the Sudanese government, outlined a proposal for the rehabilitation and modernization of the pump schemes. The proposed project would use electric pumps to draw water from the White Nile throughout the year, regardless of the river level. It would thus eliminate the need to maintain the high water level behind the Jebel Aulia Dam with the high associated evaporation losses. The rehabilitation project would enable the cropping intensity to be increased from the present 22 percent to 100 percent, thereby increasing annual irrigation water use from 350 million m^3 to 1,600 million m^3. The savings from reduced evaporation losses, however, would be substantially greater than this increased water use.

The total capital cost of the White Nile rehabilitation project has been estimated at US$279 million (in 1989 dollars). The project was estimated to have an economic rate of return of about 20 percent, even without placing a value on the water saved from reduced evaporation losses. If the water saved by reduced evaporation losses were valued at US$25 per 1,000 m^3 to downstream agricultural users, the value of the net water savings would be approximately equal to the total capital cost of the White Nile rehabilitation project.

The rehabilitation of the White Nile pump schemes is probably the most attractive project in the Nile basin for augmenting water supplies. Reducing evaporation losses from the Jebel Aulia reservoir can be achieved at little real cost because substantial economic benefits are also expected from the rehabilitation schemes. Yet the government of Sudan has not yet been able to arrange financing for this project, partly because a basinwide perspective is lacking.

Debt-for-Nature Swaps

A third example of possible cooperation involves not only the riparian countries themselves, but also the industrialized countries and the global community. Taking a basinwide perspective on river basin planning options requires that water resources planners and decisionmakers in the Nile countries think comprehensively about the value of water for different uses, in different locations, at different time periods, ensuring that water is put to its highest-value uses. For the riparian countries, water for irrigation has a much higher value than water for wildlife habitat preservation. This need not imply, however, that an economic analysis would favor water development and irrigation projects. An option to be explored is to have the industrialized countries pay Nile basin countries for the preservation of natural habitats such as the Sudd swamps (effectively protecting the southern range of Europe's bird life). In principle, such a trade might be similar to debt-for-nature swaps, except that water would be a key component of the natural resources that industrialized countries would want preserved. As environmental resources become increasingly valuable to the global community, water may be more precious to Nile basin countries for preserving wildlife than for growing food.

The four phases of the upper Nile projects (i.e., Jonglei I, Jonglei II, Machar Marshes, and Bahr El-Ghazal) under consideration would adversely affect natural habitats. Table 4 presents the projects' financial cost estimates. The costs would be about US$16-27 per 1,000 m^3 of water (in 1989 dollars), ignoring the environmental and economic consequences of the projects and the opportunities foregone by the inhabitants of the Sudd swamps.

It has been estimated that the economic returns to water in Egypt's old lands are about US$40 per 1,000 m^3. Returns to water in reclamation projects must be much less. If the value of additional water to Egyptian agriculture were US$50 per 1,000 m^3 of water (in 1989 dollars) and the cost of water from the upper Nile projects averaged US$25 per 1,000 m^3, how much would Egypt and Sudan need to be compensated not to proceed with these projects? The actual compensation for Sudan would be less than that for Egypt because Sudan is not yet utilizing its full allocation and the value of water in Sudanese agriculture is considerably less than in the old lands of Egypt; yet, if the value of water to Sudan from the upper Nile projects were equivalent to the value of water to Egypt, the compensation required by Egypt and Sudan per 1,000 m^3 of water would be US$25 (US$50 minus US$25) (this ignores hydropower benefits to Egypt from the release of additional water from the Aswan High Dam). Because the annual water yield of the four projects would be about 18 billion m^3, the total annual compensation required is about US$500 million, or a total lump sum (present value) of about US$5 billion.

This is not a lot of money to preserve the largest freshwater swamp in the world. It is on the same order of magnitude as the cost of one new aircraft carrier or two nuclear power plants. The cost per capita for everyone in Western Europe and the United States would be on the order of US$8.00, or about US$0.80 per capita annually. Moreover, these estimates are almost certainly too high because they do not reflect the value that Egyptian and Sudanese citizens themselves attach to the preservation of their ecosystems.

Compensation in the range of US$500 million per year is not large in terms of the current aid flows to or the outstanding foreign debt of Egypt and Sudan. Egypt received about US$1.7 billion in foreign aid in 1988, and Sudan almost US$l billion. Both Egypt and Sudan have large foreign debt, which could be used in a debt-for-nature swap, similar to those recently facilitated by the World Wildlife Fund and Conservation International. The approach could be potentially attractive as a means of reducing these countries' debt burdens, and it may be possible that all parties could benefit from such a deal.

Table 4. *Capital Cost Estimates of Upper White Nile Projects*

Phase	*Capital cost (LE million) 1981*	*Cost (LE million) 1989*[a]	*Cost (US$ million) 1989*[b]	*Annual cost (US$ million) (CRF = 0.15)*	*Water yield (billion m^3/yr)*	*Cost per 1,000 m^3 (1989 US$)*
Jonglei I	89	330	405	61	3.8	16
Jonglei II	118	435	534	80	3.2	25
Machar Marshes	160	593	727	109	4.0	27
Bahr El-Ghazal	244	905	1,110	167	7.0	24
Total	611	2,263	2,776	417	18.0	23

LE = Egyptian pounds; CRF = capital recovery factor.

a. Costs inflated at consumer price adjustment rates as provided in IMF, *International Financial Statistics Yearbook 1990.*

b. Converted at the official exchange rate: LE1 = US$1.227.

Source: John Waterbury, "Riverains and Lacustrines: Toward International Cooperation in the Nile Basin," discussion paper, Research Program in Development Studies, Princeton University, 1982; Dale Whittington and Giorgio Guariso, *Water Management Models in Practice: A Case Study of the Aswan High Dam*, Elsevier, 1983.

New Cooperative Agreements for Nile Waters Planning and Management

Perhaps the most striking thing about the three opportunities for cooperation described above is that none of them is under serious consideration by either the riparian countries or the international community. This is true despite the growing risk of conflict among the riparian countries over available water resources. Reservoirs on the Blue Nile in Ethiopia offer the greatest opportunity over the long term for dramatic improvements in the overall management of Nile resources, but serious discussions among the riparian countries have not yet begun on the legal and institutional arrangements required to implement these projects, which have far-reaching implications.

Egypt's attention is still focused on a century-old vision of projects for the development of the resources of the White Nile, projects that have far worse environmental consequences than the Blue Nile reservoirs. This is partly because the status quo of the last two decades has served Egypt's interests well. Both Sudan and Ethiopia have been too weak and unstable to initiate irrigation schemes that would have significantly reduced the quantity of Nile water arriving in Egypt. Moreover, Egypt has maintained its near monopoly on technical expertise in Nile hydrology and development projects.

It is not, however, in Egypt's long-term interest to alienate either Sudan or Ethiopia. In the long run Egypt is extremely vulnerable to unilateral water withdrawals by both Sudan and Ethiopia that might occur outside a comprehensive Nile waters allocation and planning framework. The worst situation for Egypt would be for Sudan and Ethiopia to strike a separate deal on Nile waters allocation that excluded Egypt. Egypt has more to gain than any riparian country from increased cooperation because it is highly dependent on a large and stable supply of Nile water.

Egypt's present position is that it is willing to discuss future water development plans with all upstream riparians, but that its water allocation of 55.5 billion m^3 as specified in the 1959 Nile Waters Agreement is not negotiable. It would like Ethiopia to acknowledge the legitimacy of the 1959 Nile Waters Agreement before starting any new discussions. Ethiopia, however, will almost certainly not be willing to do this, nor will Egypt officially repudiate the 1959 agreement in order to initiate discussions with Ethiopia. Egypt understands the necessity of making some concessions to upstream riparians, but it will view the emerging relationships with these countries (particularly Ethiopia) as reciprocal: Egypt will expect to receive something tangible (such as agreements to undertake joint investment projects, technical cooperation, or increased data collection and monitoring efforts) from such concessions.

From a river basin planning perspective, Sudan has a strong interest in developing a cooperative relationship with Ethiopia. The construction of dams on the Blue Nile in Ethiopia should be one of Sudan's top priorities in the water sector, provided agreements can be reached on the operation of the dams during droughts that guarantee sufficient quantities of water to Sudan and Egypt.

Sudan's interests in beginning discussions on basinwide cooperation are therefore different from Egypt's; the status quo that excludes Ethiopia is not to Sudan's advantage. The completion of any of the Blue Nile dams will take many years of planning and construction, and it is in the best interest of Sudan that this process begin as soon as possible. Sudan should attempt to convince Egypt to join in discussions with Ethiopia without preconditions. Sudan has significant leverage here because Egypt does not want Sudan to violate the terms of the 1959 agreement. At least initially, Sudan may be willing to maintain a "united position" with Egypt with respect to upstream riparians if Egypt agrees to join such discussions.

The present lack of regional cooperation on the development of Nile waters comes at considerable cost to Ethiopia. In principle, Ethiopia may wish to reserve the possibility of a massive unilateral water development program for the Blue Nile basin. In practice, however, there is no conceivable way it could finance such investments domestically in the short to medium term. It is possible to envisage a time in the distant future when Ethiopia would have the financial resources to develop the potential of the Blue Nile, but economic development and a reversal of the ongoing environmental degradation are needed sooner rather than later to sustain Ethiopia's increasing population. It is possible that Ethiopia could find itself in a downward spiral of ecological and economic problems from which it would be increasingly difficult to emerge.

Ethiopia needs financial and technical assistance now from the international community. The current Ethiopian policy of reserving the right to make future unilateral claims on Nile waters is risky. Not only is international funding of water development projects largely precluded, but delay in reaching new international agreements allows Egypt's desert reclamation policy to continue without considering the implications for the rights of upstream riparians. The continuation of Egypt's desert reclamation policy will greatly complicate future negotiations because it establishes a prior use of the water. Ethiopia has a strong interest in reaching agreements in the near to medium term so that international help can be secured and so that Egypt does not commit increasing amounts of water to new desert reclamation projects.

Conclusion

Egypt, Sudan, and Ethiopia are entering a period of increasing water scarcity, and conflicts over available water resources are inevitable unless a basinwide planning process is established. As outlined in this paper, opportunities exist for regional cooperation that will benefit all parties: Nile water management is not a zero-sum game. It is time for Egypt, Sudan, and Ethiopia to discuss establishing a process for moving toward a new era of cooperation on use of the Nile waters.

Note

1. See Guariso, G., and D. Whittington. 1987. "Implications of Ethiopian Water Development for Egypt and Sudan." *International Journal of Water Resources Development* 3(2).

WATER RESOURCES MANAGEMENT AND POLICIES IN EGYPT

M.A. Abu-Zeid and M.A. Rady

The Nile Delta is one of the world's oldest agricultural areas. Egyptian water management, dominated by agricultural consumption, is characterized by a rigid water distribution system extending over 1,000 km and by the continuous threat of salt-water intrusion into the Nile Delta. The country is arid, with the Nile River the sole source of surface water. Over 95 percent of agricultural production is derived from irrigated land. This paper discusses existing irrigation systems management, its major constraints, key water policies, strategies for water management improvement, and future scenarios. The paper also addresses the need for water pricing and cost recovery policies, yet underscores the limitations of applying such polices. The adverse health impacts of irrigation development have been mitigated, whereas salination and potential groundwater contamination remain major concerns. The paper presents several options for increasing the flows at the Aswan High Dam. Upstream water conservation, however, will not be possible until agreements with other Nile basin countries are reached. The sustainability of Egyptian agriculture in the 21st century will depend directly on new Nile agreements with other riparians.

Background

Egypt has an area of about 1 million km^2, located in the arid belt of North Africa and West Asia. Its population is 56 million, almost entirely concentrated along the coastal zones and the Nile Valley, representing a high density of 1,300 people per km^2. The population grows at 2.5 percent per year and is expected to reach 70 million by the year 2000.

Egypt is arid, with average annual rainfall seldom exceeding 200 mm along the northern coast. Rainfall declines rapidly from coast to inland and drops dramatically to almost zero south of Cairo, primarily occurring during winter as scattered showers. The Nile Valley consists of a floodplain and the Nile Delta. The delta is one of the world's oldest agricultural areas, under cultivation for more than 5,000 years. Historically, agriculture has been the dominant sector in the Egyptian economy. In the late 1950s and early 1960s, the Egyptian economy expanded to include industrial development. Agriculture's share in GDP fell from 34.3 percent in 1955 to 20 percent in 1990, with its share in employment also declining. Nevertheless, agriculture remains the economy's most important sector.

Water Resources Development

Egypt's water resources, dominated by agricultural consumption, are characterized by (a) a rigid water distribution system extending over 1,000 km, with 30,000 km of secondary canals; (b) the continuous threat of salt-water intrusion into the Nile Delta; and (c) the long time lag of 10 days between release of water from the Aswan High Dam and the time it reaches the main drainage outlets.

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Surface and Groundwater Use

The almost exclusive source of surface water is the Nile River, nearly 85 percent of which originates in the Ethiopian highlands. The Nile Waters Agreement of 1959 with Sudan clearly defines the division of the river water, based on the average flow of 84 billion m^3. The Aswan High Dam was constructed in 1968 with a live storage capacity of 130 billion m^3. Average annual evaporation and other losses in the dam's lake have been estimated at 10 billion m^3, leaving a net usable annual flow of 74 billion m^3. Of this, 55.5 billion m^3 were allocated to Egypt and 18.5 billion m^3 to Sudan. The Nile flow at Aswan could possibly be increased through the following actions:

1. The construction of the Jonglei Canal, agreed to by the Egyptian-Sudanese Committee, was expected to diverge the river in the Sudd region of Sudan and thus reduce the substantial evapotranspiration losses. Seven billion m^3 of water are expected after the completion of the project, and they will be shared by the two countries. (The first phase of construction was abandoned because of security problems in southern Sudan);

2. The discharge from the streams of the Bahr El-Ghazal basin is mostly lost in swamps. Conserving this amount of water could save 7 billion m^3 of water annually at Aswan;

3. The total evapotranspiration loss in the Machar swamps is about 10 billion m^3. Conservation schemes could save 4 billion m^3 of water at Aswan.

The above estimates add to a minimum of 18 billion m^3 of water from the upper Nile to the Aswan reservoir. Finalization of these schemes, however, still depends on agreements between the Nile basin countries and the availability of funds.

There are two sources of groundwater: The first is the Nile Valley and Delta. Current annual abstraction is 2.6 billion m^3, which can be increased to 4.9 billion m^3 (the annual safe extraction rate). The second source is the groundwater in the Western Desert, which lies at great depth and is not renewable. Use of this water depends on costs of pumping and depletion of storage. Investigations have indicated that about 1 billion m^3 of water can be extracted economically. More studies are underway in cooperation with Sudan and Libya to investigate this aquifer's potential.

Land Use

Egypt presently has an estimated 7.49 million acres of cultivated land, 7.21 million of which are in the Nile Valley. Nearly 650,000 acres—out of a total of 805,000—were reclaimed between 1960 and 1970 as a result of the construction of the Aswan High Dam. The 1986 Land Master Plan concluded that an additional 2.82 million acres could be reclaimed by using the Nile's waters and another 570,000 acres by using groundwater in the Sinai and New valleys.

There was a major policy shift regarding land use during the 1980s. The government realized that the overall performance of state farms was inefficient, unable to adopt new farming practices quickly and without new development to adjust to arid conditions. Accordingly, a policy was implemented to allocate 60 to 40 percent of new lands to economically disadvantaged groups and to private investors who had adequate capital to develop their own farms.

Utilization

Egypt's total annual water use is about 59 billion m^3, of which agricultural use accounts for 84 percent; industrial use, 8 percent; municipal use, 5 percent; and navigational use, 3 percent. Projections indicate that total water use will increase to 69.4 billion m^3 by the year 2000 (see table 1). The share of sectoral water allocation to the agricultural and municipal sectors will essentially remain the same, whereas that of industry will increase, with navigational use declining substantially. Studies indicate that the per capita share of water in Egypt will decrease substantially (table 2).

AGRICULTURE. Over 95 percent of agricultural production is derived from irrigated land. Surface irrigation systems are used in most cultivated lands of the Nile Valley and Delta. The multiyear regulatory capacity provided by the Aswan High Dam has stabilized the country's supply of water resources. The total agricultural water consumption in 1990 was 50 billion m^3, excluding 2 billion m^3 lost due to evaporation from the irrigation system. The sectoral share of water use declined gradually during the 1980s. Although surface water use efficiency is low, a substantial part of the excess irrigation water that contributes to groundwater can be reused through pumping. This brings overall water use efficiency to a reasonable level. The government controls new lands by dictating that modern irrigation systems (such as drip or sprinkler) be installed.

About 25 to 30 percent of irrigation water supply is allocated to rice and sugarcane. These crops seem profitable from the farmers' perspective, but are expensive from a social perspective in view of the free water supplied to farmers. Changing cropping patterns will be an important strategy affecting future water allocation.

DOMESTIC AND INDUSTRIAL USE. Domestic consumption was 3.1 billion m^3 in 1990. System losses are estimated at 50 percent of the water supplied. It is estimated that domestic water use could be kept at 3.1 billion m^3 by the year 2000 by reducing losses from 50 to 20 percent. Industrial water use is currently 4.6 billion m^3.

NAVIGATION. About 1.8 billion m^3 of water must be released between October and January for navigation when irrigation water releases are not sufficient to maintain an adequate water level. It is expected that by the year 2000 annual navigational water requirements could be reduced to 0.3 billion m^3 through better control of water levels and implementation of storage facilities in the northern lakes.

Irrigation Water Management and Constraints

Major Constraints

The traditional irrigation system that has evolved in Egypt has proved to be effective in dealing with the constraints of minor land irregularities. The present system, however, has the following limitations:

Table 1. *Water Demand, 1990 and 2000*
(billion m^3)

Sector	*1990*	*2000*
Irrigation	49.7	59.9
Municipal	3.1	3.1
Industry	4.6	6.1
Navigation	1.8	0.3
Total	59.2	69.4

Table 2. *Population and Water Resources (billion m^3)*

Year	*Population (millions)*	*Renewable water*	*Renewable water per capita (m^3)*	*Agricultural use*	*Other use*
1950	21	49.9	2,376	47.4	2.5
1960	26	56.9	2,189	54.1	2.8
1970	33	56.9	1,724	52.7	4.2
1980	42	56.9	1,358	51.6	5.3
1990	55	56.9	1,035	50.7	6.2
2000	70	56.9	813	46.7	10.2
2010	84	58.9	701	46.6	12.3
2020	100	58.9	589	44.3	14.6
2025	110	58.9	536	37.0	21.9

- Fragmented land and small and separate holdings have limited the establishment of efficient irrigation methods;

- The present rotation system is unsuitable for using modern technologies, such as sprinkler or drip irrigation, which usually require a continuous supply of water;

- Accurate water control under the present irrigation regime is difficult, especially with different water demands regarding frequency and quantity for different crops.

Water loss is another problem. Average conveyance losses between the irrigation outlets and fields are estimated at 11 percent, and those between the irrigation outlets and main canal intakes are about 25 percent. A contributing factor to these losses is that farmers abstain from night irrigation. Because irrigation networks are designed to operate 24 hours a day, a considerable volume of water wastefully drains at night when irrigation is not practiced.

Strategies and Actions for Future Irrigation Management

Strategies for future improvement of irrigation water management include:

- improving the efficiency of the present irrigation system in old lands and developing modern irrigation methods in new lands;

- planning irrigation schedules for different crops;

- improving drainage networks and reducing losses;

- recovering partial costs of irrigation improvement by collecting charges from farmers.

In 1985, a national program was launched to optimize water use to conserve water resources, reclaim new lands, and improve land productivity. The expected water saving through the implementation of this program is between 10 and 15 percent, with an average increase of 30 percent in agricultural productivity. Establishment of farmer organizations is also necessary for successful future operation and maintenance (O&M) of the irrigation system. Upstream water conservation is not possible until agreements with other Nile basin countries are reached. The evaporation loss in the High Dam Lake could be reduced by covering part of the water surface with polyethylene sheets or chemicals. The technical and economical feasibility of doing so, however, needs to be studied further.

Environmental Issues

In Egypt, there is no complete picture of environmental issues relating to water resources, such as water quality parameters, nor are there any accurate estimates on the costs of land and water degradation to the national economy. Environmental concerns are reflected in:

- *salinity*. The country has embarked on the construction of an extensive drainage system to alleviate salinity and waterlogging. For the long-term sustainability of agriculture, drainage should continue to receive priority;

- *water pollution*. A large percentage of wastewater from domestic and industrial use is untreated and discharged into the Nile, irrigation canals, and drainage ditches;

- *potential groundwater contamination*. Application of nitrogen, phosphate, and potash fertilizers increased nearly fourfold between 1960 and 1988. Groundwater is used extensively for drinking purposes and is more vulnerable than surface water to fertilizer and pesticide contamination;

- *impact of herbicide use*. Acrolein was used to control submerged weeds in canals, and ametryn to control water hyacinths in drains. Because of political and public pressure, use of ametryn has been discontinued for 1991. Acrolein will be used for another two to three years, after which only manual, mechanical, and biological measures will be applied for weed control. Extensive use of manual control, however, is likely to increase the incidence of bilharzia among laborers involved in weed removal. Expansion of mechanical control would require additional investment in imported equipment and spare parts, as well as road construction along canals and drains;

- *environmental health*. The increasing incidence of schistosomiasis, resulting from the expansion of irrigation areas, was a major concern. However, both data collected over the past two decades and a detailed evaluation carried out in 1985 indicate that, in many parts of middle and upper Egypt, schistosomiasis is no longer a serious public health problem. Between 1977 and 1984, prevalence rates were reduced from 30 to 8 percent, and serious disease indicated by a high worm burden became rare.

Because water is the major constraint to further expansion of agricultural areas, treated wastewater must be considered as a new source of irrigation water. Urgent steps should be taken to establish pilot projects on the use of treated wastewater in agriculture. In addition, dried sludge from sewage treatment can also be used as a soil conditioner for agricultural land.

Agricultural drainage water in upper Egypt is discharged back into the Nile River. This affects water salinity. The Ministry of Public Works and Water Resources (MPWWR) has imposed strict policies regarding the release of Nile water downstream of the Aswan High Dam. A potential decrease in drainage water quantity and an increase in its salinity will occur when irrigation efficiency is improved both in the conveying system and at the farm level. Surveys and monitoring of the quality and quantity of agricultural drainage water in the Nile Delta have shown that part of this water can be reused for irrigation by diluting it with fresh canal water when salinity is high. As salinity increases in the future, cautious approaches to increasing the use of drainage water are likely to be in the long-term interest of the country.

There has been a law governing water pollution control since 1982, but the water quality standards stipulated were too rigid. Shortly after the law was promulgated, the government was forced to grant dispensations to polluters because it was not possible for them to comply with the regulations. The law must be amended. There is also a need to establish and implement a water quality management plan.

Water Pricing and Cost Recovery

Currently, no irrigation water charges are collected from farmers. Farmers indirectly pay the state treasury. Part of the irrigation water costs are recovered through land taxes, which are periodically reassessed when inland productivity changes and new irrigation or drainage projects occur. During the 1980s, there were numerous studies on water pricing. Some fundamental issues need to be addressed before water pricing and cost recovery policies can be introduced: First, government finance in irrigation development and water delivery projects is historically and traditionally accepted in nearly all developing countries. Because farmers form an important and powerful group, the political implications of introducing water pricing should not be underestimated. Second, even in some places where certain water charges have been levied, the rate of charges does not generally depend on the volume of water but on the area cultivated under irrigation. Thus, in reality, it is a land tax on irrigated area rather a water tax. Not surprisingly, such taxes have not improved either water allocation or water use efficiency. Third, pricing water is not in line with Islamic precepts because water has always been viewed as a free resource. Other issues to be considered include ensuring food security, increasing rural income, and reducing migration to urban areas.

In Egypt, the MPWWR is responsible for operating and maintaining irrigation networks. There is neither an effective volumetric measuring system for individual farmer water consumption, nor an administrative framework to levy and collect water rates. Numerous studies have indicated the need to charge farmers O&M costs, at least for the on-farm system: this may make farmers more fully appreciate the value of water, but the above difficulties have prevented implementation of this policy (mostly under old land irrigation systems). As for new lands, the situation is much better because water can be measured at the point of delivery under modern irrigation systems.

The following questions merit consideration: On what criteria should water charges be based? Should consumers be charged for only the cost of storage and delivery, or should water charges also include external costs such as environmental damage? If the costs of environmental damage are included, how will they be determined? So far in Egypt, limited work has been carried out on irrigation water pricing and cost recovery. Annual irrigation water costs vary within the range of 10 to 20 Egyptian pounds (LE) per 1,000 m^3, or about LE 80 to 160 per acre (not including costs of hydraulic structures and pumping). The MPWWR, with assistance from the U.S. Agency for International Development, has begun serious work on water pricing. Water-pricing-related policies will be political decisions. Considerable resistance to implementing such policies can be expected from farmers; therefore, consultation with them is essential.

Institutional Aspects

Legislation

Egypt's water law was based originally on the Shari'a (Muslim religious law) and the Qawanin-hukm (decrees and ordinances issued by the governor). In addition to the water law, there are two related laws: the River Nile Water Control Law of 1982, which protects the river and waterways from pollution, and the Irrigation and Drainage Law of 1984, which controls water use (ownership, rights, and priorities).

Administrative Arrangements

The MPWWR is the only body that authorizes water use and is responsible for national water resources. It is represented at the governorate level through its 19 general irrigation directorates, which are then subdivided into inspectorates and districts. To ensure proper coordination among agencies involved in water resources (ministries of Agriculture and Land Reclamation, Tourism, Power, Transportation, Industry, and Housing and Reconstruction), two committees have been established: the Supreme Committee of the Nile, headed by the minister of the MPWWR; and the Coordinating Committee for Land Reclamation. Both committees meet monthly to direct and review different development plans, as well as to resolve conflicts. On the farm level, farmers bear the responsibility for the construction and O&M of all waterways and their related infrastructure.

Since the 1970s, the government has been substantially financially supporting research institutions. The Water Research Center (WRC) was established in 1975 under the MPWWR and consists of 11 research institutes, each with a different specialization. It is responsible for outlining, assisting in, and implementing long-term policies in water resources management; conducting research and investigations related to water resources assessment; and studying the main side effects of the Aswan High Dam. In the coming years, it will focus on improving the efficiency of water delivery and quality management.

Regional Cooperation

The sustainability of Egyptian agriculture in the 21st century will directly depend on new Nile agreements with other riparians. The international character of the Nile, with nine countries sharing its water, makes its management more complex. Early cooperation between Egypt and Uganda began in 1953 with the construction of the Owen Fall Dam, for which Egypt paid compensation for raising the water level. In 1959, Egypt and Sudan signed the Nile Waters Agreement and established a permanent joint technical commission on the Nile, a mechanism to formulate and implement cooperative projects between the two countries as well as with other riparians. The commission has the right to review Nile water uses according to their shares. The commission has been meeting regularly four times a year and has never been affected by the political situation between the two countries. In 1964, the commission began to cooperate with the countries of the Equatorial Lakes region. Eight riparian countries have fully participated, with Ethiopia the only observer. The commission established a comprehensive regional hydrological network, and in the late 1970s Egypt and Sudan proposed a comprehensive mechanism to provide continuous cooperation among all riparians. This objective, however, has not been achieved.

There is a possibility of increasing the yield of the Nile from the existing average 84 billion m^3 to 124 billion m^3, which will be sufficient to secure the needs of all the riparians sustainably. Zaire, Rwanda, and Burundi do not need water from the Nile, whereas Kenya, Uganda, and Tanzania may need 4 billion m^3 from the river after the year 2010.

Human Resources Training

Human resources development has been addressed by the MPWWR on two levels: (1) special projects to identify key areas within the MPWWR and to provide training, including upgrading of its staff's technological skills through both off-shore and in-country programs; and (2) non-project-related training activities, including overall assessment of training needs, modification of existing courses, and development of new courses. For effective results, training programs must address real needs, and results need to be followed-up to determine whether the desired objectives have been achieved. A system of monitoring and evaluating has been implemented by the MPWWR through provision of supervisors and training managers to collect information on the effectiveness of training activities. The information is then fed back to the training programs to improve course design.

The Irrigation Advisory Service and Water User Associations

The Irrigation Advisory Service (IAS) and the water user associations (WUAs) were created under the MPWWR. The IAS works closely with water users and improves communication between users and suppliers. It is an essential component to developing the organizational capacity of water users and providing them with specific services related to water delivery and use. The WUAs are legal, private organizations, involved in planning, operating, maintaining, and monitoring the field watercourses.

Major Water Policies

As Egypt progresses toward improving water use efficiency, existing water policies need to be reviewed and modified. Policymakers must first have a clear idea not only of a policy's costs and benefits, but also of the beneficiaries and those who may be adversely affected: this information is essential to water policy formulation and implementation. The Interministerial Water Planning Committee, established in 1977 and headed by the minister of the MPWWR with representatives from eight other ministries, will play a major role. It is responsible for reviewing the impact of proposed projects related to water use and has the authority to set or approve related policies.

In the coming years as Egypt seeks new sources of water, the reuse of treated wastewater and drainage water is likely to play a major policy role, with attendant health and environmental implications. Therefore, an effective monitoring system is essential for proper utilization. The criteria for and the long-term potential environmental impacts of reuse of drainage water should be considered before implementing any policy.

Environmental impact analysis of water resources projects is not currently conducted. It must be mandatory for new projects and for modification of existing projects. There is an urgent need to review the existing data collection process and data management systems. A water quality data monitoring and management system needs to be established. The corresponding institutions and the legal basis for controlling water pollution should be reviewed.

Future Scenarios

The MPWWR has formed a multidisciplinary technical committee for future water resources planning. The objective is to propose future scenarios for potential water supply and demand considering a reasonable growth rate in the demand of major water sectors, acceptable priorities among different water users, socioeconomic constraints, public participation, water quality deterioration, current O&M constraints, and efficient use of existing water resources. The scenarios assume that no upper Nile

Table 3. *Future Scenarios for Water Supply and Demand (billion m³)*

	1990	Scenario 1	2	3
Water resources				
Nile	55.5	57.5	57.5	57.5
Deep groundwater	0.5	3.5	3.5	3.5
Nile Valley & Delta groundwater	2.6	2.6	4.9	3.6
Agricultural drainage	4.7	4.7	8.0	5.0
Treated sewage	0.2	1.5	2.5	2.0
Total resources	63.5	69.8	76.4	71.6
Sectoral use				
Agricultural	49.7	43.5	49.7	46.6
Municipal	3.1			
Industrial	4.6	9.6	14.6	10.8
Navigation	1.8	0.3	0.3	0.3
Total demand	59.2	53.4	64.6	57.7
Resources balance	4.3	16.4	11.8	13.9
New land created (million acres)	0.9	2.9	1.9	2.4

projects would be implemented other than the Jonglei project. (Table 3 presents data on water supply and demand under the scenarios for the year 2025.)

In the first scenario, irrigation efficiency is improved to 75 percent and municipal use efficiency to 90 percent. This is the most efficient scenario with no adverse environmental impacts. It requires a reconsideration of future agricultural drainage reuse plans and groundwater development schemes in the Nile Delta and Valley. An estimated water surplus of 16.4 billion m³ could add 2.9 million acres of new land.

In the second scenario, current low efficiencies prevail with reinforcement of water reuse. This represents the worst case for efficiency improvement. Water resources would be supplemented through intensive reuse of drainage water, which could lead to more severe environmental and salinity problems. The estimated possible water surplus would be 11.8 billion m³ for new land expansion, which would reclaim not more than 1.95 million acres. Although this scenario seems easiest to implement in the short run, costs of drainage pumping and loss of potential crop yields resulting from deterioration in water quality may be more expensive in the long run.

In the third scenario, irrigation efficiency is improved to 65 percent and municipal use efficiency to 80 percent. This is the most feasible scenario and represents a gradual transition to the first scenario.

IRRIGATION WATER MANAGEMENT IN SUDAN

Elsayed Ali A. Zaki

Agriculture dominates Sudan's economy. Agricultural production is primarily limited by irrigation water, which is obtained entirely from the Nile. Investment in irrigation has declined considerably, resulting in deteriorating irrigation systems. The incidence of waterborne disease has increased. Although a new water-charging system has improved agricultural production, the country's food self-sufficiency policy still leads to mismanagement of irrigation water. Conflicts have arisen between irrigation and competing water users, as well as among riparians over international waters. After analysis of the above issues, this paper presents a summary of Sudan's key water policies.

Background

Sudan is one of the largest countries in Africa. It has an area of 2.56 million km^2 and a population of about 26 million, which grows at 2.8 percent annually. The economic growth rate is 2.1 percent. Per capita income is estimated at US$330, among the lowest worldwide.

The amount of rainfall in Sudan has been declining with increased variation over the last 30 years. The coefficient of rainfall variation increased from 0.13 in the 1960s to 0.33 in the 1970s and to 0.34 in the 1980s. These variations directly impact water resources use and management, as seen in increased crop failures; droughts; desertification; and reduced carrying capacity, resulting in overgrazing and decreased recharging. About 150 million m^3 of groundwater, out of a total yield of 4.7 billion m^3, are currently used, primarily to meet the domestic needs of cities and towns along the Nile riverbank. Groundwater quality is good.

Agriculture is the major sector of Sudan's economy. It contributes approximately 38 percent of GDP, employs about 80 percent of the country's population, and earns some 98 percent of total foreign exchange. The sector is composed of four subsectors: (1) irrigated agriculture (1.68 million ha, supplied by waters from the Nile and its tributaries); (2) mechanized rainfed agriculture (2.52 million ha); (3) traditional rainfed agriculture (4.2 million ha); and (4) livestock. The share of the irrigated and rainfed subsectors in agricultural GDP (excluding livestock) are about 45 and 55 percent, respectively.

Agricultural Water Use

Irrigation water represents the major limiting factor to agricultural production. In addition to Egypt, Sudan is the only country that depends entirely on Nile waters for irrigation. However, irrigation investment in Sudan has declined considerably—by 40 percent since 1982—resulting in poor maintenance of systems. Water control infrastructure has been built to harness the Nile waters. Four dams are currently regulating flows for power generation and irrigation water diversion. These dams face problems such as siltation and evaporation losses.

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New Water Charge System

Currently, the so-called individual accounting system of land and water charges is applied. The Sudanese government supplies irrigation water and provides technical assistance through the Ministry of Irrigation (MOI). Farmers pay land and water charges through deductions from the sale of their products. This individual accounting system of land and water charges replaced the joint accounting system of sharecropping in the early 1980s because the latter had led to inefficient utilization of water at the field level. The new system has improved agricultural production.

Food Security Policy

Sudan's policy of altering crops and cropping patterns seeks to achieve food self-sufficiency. This implies utilizing resources for production without considering the country's economic advantages. The policy has resulted in misuse and mismanagement of expensive irrigation water. A policy pursuing food security through increased resource productivity per unit and introduction of high-yielding varieties should be implemented to ensure the efficient use of resources, including irrigation water.

Intersectoral Water Allocation

Conflicts have arisen between irrigation water use and other competing users. For example, water demand resulting from the expansion of the wheat area during the winter would require that the Nile waters be released earlier, just before the start of the Blue Nile flow (between March and June), for the production of wheat. This reallocation of water from the energy to the agricultural sector would reduce hydropower generation. The electricity supply for industries and home services would be seriously curtailed, jeopardizing the normal functioning of the economy, which, in turn, would strain foreign currency resources. In addition, the area for cotton production in the preceding summer season would have to be reduced proportionately, affecting cotton production. Economic analysis has shown that the domestic resource cost (DRC) for cotton, i.e., the opportunity cost of domestic resource use in cotton production to earn one unit of foreign exchange, is 0.37, lower than that for wheat production (the DRC for wheat is 0.55). Final decisions about water reallocation have yet to be made.

Agricultural Development and Environmental Health

The introduction of irrigation has led to dramatic changes in aquatic ecology. One consequence has been the introduction of waterborne disease, most significantly malaria, schistosomiasis, and diarrhea. The effect of malaria on agricultural productivity can be detected quickly, whereas schistosomiasis is slowly debilitating. The following three elements are essential to controlling these diseases and improving human health:

1. *involvement of relevant government agencies*. During the planning and implementation phases of irrigation or agricultural projects, all relevant ministries should be consulted and involved in evaluating the adverse effects of projects that could lead to waterborne diseases. Health issues should also be viewed from social and economic perspectives;

2. *provision of safe water*. Sufficient potable water and adequate sanitary facilities should be provided to minimize direct human contact with canal water;

3. *community awareness.* Health education at the community level is the most important component in controlling these diseases.

A comprehensive approach to controlling waterborne diseases is being applied under the Blue Nile Health Project and has been successful in the Gezira irrigated area. As a result of the project, the prevalence of schistosomiasis has declined from more than 50 to 13 percent, and diarrheal disease morbidity and mortality have decreased significantly.

International Conflicts

The main agreements on Nile waters involving Sudan are (a) the protocol of 1901 between Italy and the United Kingdom ensuring that no works be constructed on the Blue Nile, Lake Tana, or the Sobat River without the prior agreement of Sudan; (b) the 1919 agreement to ensure the prior approval of Egypt on any construction works on the Nile, its tributaries, and lakes, and the right of Egypt to operate construction works inside Sudan; (c) the 1925 agreement with Ethiopia to establish the rights of Sudan and Egypt on the Blue Nile and its tributaries; and (d) the 1959 agreement between Egypt and Sudan. This last agreement has been the most significant one reached between Egypt and Sudan regarding the sharing and utilization of the Nile waters. Under it, Sudan's share measured at Aswan is 18.5 billion m^3 and Egypt's share is 55.5 billion m^3. About 10 billion m^3 are lost through evaporation from the Aswan High Dam. Presently, Sudan only utilizes about 13 billion m^3. The 1959 agreement included plans for conservation projects to reclaim lost waters. The White Nile total water resources from Bahr El-Jebel, El-Zaraf, Al-Arab, and the Sobat River are about 63 billion m^3; however, 34 billion m^3 are lost in the Sudd area. The Jonglei I project was the first to be implemented and could save about 4 billion m^3. Dividing this amount equally with Egypt, Sudan could realize about 2 billion m^3. Construction on the 70-percent-completed project, however, was terminated because of security problems.

The need for riparian cooperation is becoming increasingly obvious as water resources become more scarce. It is essential that all riparians participate under one international water agreement to facilitate the optimal development of water resources in the riparian countries. This agreement should also respect the rights of downstream users.

Irrigation Water Management

The management of irrigation schemes involves two separate authorities: the Ministry of Irrigation (MOI) and the Ministry of Agriculture (MOA). The MOI is responsible for operating and maintaining dams, reservoirs, pump stations, and primary canals. The MOA is responsible for the operation and maintenance (O&M) of tertiary and small canals.

Under comprehensive water resources management, the function of these institutions would be to provide services to facilitate irrigation and drainage, urban and rural water supply, water conservation and water quality control, investments for increased future supply of water, regulation of water demand, environmental preservation, drought and desertification control, and public awareness and support for comprehensive policies to optimize water resources utilization. Coordination among agencies is vital. Data, research, and feedback mechanisms are essential for proper functioning of institutions. Appropriate salary structures and adequate career and training opportunities (both in- and off-service) should be created to maintain trained staff levels.

Future administrative policies will be oriented toward (a) creating a coordinating body (water board) for the water sector, including all concerned organizations at both national and regional levels; (b) upgrading the planning, technical, and implementing capabilities of the concerned water institutions through training and provision of equipment; and (c) encouraging private sector investment in water-related projects.

Water Policies

Government policies with respect to the water sector may be summarized as follows:

- Long-, medium-, and short-term water planning is strategically important and should be developed within a framework of balanced economic growth for all economic sectors;
- Water projects should comply with government policies to utilize and develop natural resources and to preserve them from depletion and desertification; they should also ensure equity among regions and various social groups. Active community participation in the planning and management of water resources will be pursued to ensure sustainability;
- The flat water rate system should be replaced gradually by metering and a new tariff system to encourage water conservation and to generate income to cover O&M costs of water systems;
- Ecological and health measures should be considered within water resources development;
- Technologies suitable to the country should be introduced, and local manufacture of water equipment and materials and involvement of local expertise should be encouraged;
- Areas with high economic productivity should be given special attention to increase GDP;
- Arid areas should be given high priority for development.

Regarding financial policies, appropriate investment in water machinery and equipment should be emphasized. The current accounting system in the water institutions should be upgraded. Revenue collection to sustain water institutions and to create independent water units should be reviewed. A multidisciplinary approach and technical expertise are also necessary for optimal resource management.

PLANNING A NATIONAL WATER POLICY IN ETHIOPIA

Zewdie Abate

Although Ethiopia has abundant water resources, few have been exploited because of economic underdevelopment, poorly coordinated planning, and lack of sound policies. The country's economy is distorted, resulting in declining agricultural productivity. This paper reviews the performance of various water subsectors and proposes a framework for improving the sector's current institutional arrangements. The country has no comprehensive water legislation; however, draft water legislation has recently been prepared and is pending government approval. Use of pricing policy in water allocation has been ignored in Ethiopia. To implement cost recovery, a system of determining and collecting water charges needs to be instituted. The paper briefly discusses two methods of irrigation water pricing: one based on agroecological zones and the other on quantity of water abstracted. Water quality is an acute problem in Ethiopia, where overall sanitation is terrible. Irrigation projects are increasingly plagued by waterlogging, salinity, rising groundwater tables, and pesticide and fertilizer pollution. Uncontrolled deforestation and soil erosion are intensifying the effects of recurrent droughts. The paper suggests a framework for a planned national water policy to improve the current situation.

Background

Ethiopia has an area of 1.3 million km^2. Its arable land area is 63 million ha, 6 percent of which (3.7 million ha) are potentially irrigable. The current population is about 51 million and is expected to grow at 3.1 percent annually up to the year 2010.

Ethiopia has abundant water resources: 14 major river basins; numerous tributaries; and substantial groundwater potential, estimated at 2.6 billion m^3. Surface water availability is 111.6 billion m^3, of which about 54.4 billion m^3 can be utilized. Precipitation occurs mainly during three to four months of the year and varies from 3,000 mm in the southwest to 200 mm in the Red Sea coastal region.

Although Ethiopia has abundant water resources, few have been exploited because of economic underdevelopment, poorly coordinated planning, and lack of sound policies. The economy is distorted, partly because of the country's agricultural policies. For example, small farmers in Ethiopia hold 94.7 percent of the total cultivated area and account for 95.3 percent of national grain production. However, priority for most credit, irrigation water, and modern inputs and machinery supplies is given to state farms and cooperatives, which receive subsidized fertilizers, chemicals, farm machinery, transport, warehousing, and productive resources, as well as controlled prices for their products. These policies have resulted in a continuous decline in agricultural productivity. In addition, droughts affect vast areas of Ethiopia, with one-third of the country drought-prone. About 540,000 ha are flood-prone. These conditions have led to environmental degradation.

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Water Sector Review

Irrigation

The principal consumptive user of water is irrigation. Irrigation schemes in Ethiopia are classified as small-, medium-, or large-scale. Small-scale schemes normally cover an area of less than 200 ha, growing primarily subsistence crops. Medium-scale schemes often range from 200 to 3,000 ha, producing subsistence and cash crops. Large-scale schemes, usually owned by state farms, exceed 3,000 ha and grow mainly commercial crops such as cotton and sugarcane. Irrigation of larger schemes was introduced only recently in northern Ethiopia. The drought of 1984/85 created a strong impetus toward irrigation, which induced the government to further develop small- and medium-size irrigation projects to safeguard against rainfall variability. For some time there has been irrigation of small schemes in the country's arid and semiarid regions.

The cost of irrigation development in Ethiopia is generally high because of the (a) lack of adequate existing infrastructure, such as roads; (b) location of large-scale irrigation schemes in less densely populated areas; and (c) lack of both skilled and unskilled human resources. To further develop the full irrigation potential of 3.7 million ha, about 107 irrigation projects have been identified. The total investment is estimated at US$60 billion, or an annual investment of US$1.2 billion over the next 50 years.

Domestic and Industrial Water Supply

Domestic water supply (see table 1) has lagged far behind demand. Only 17 percent of the country's total population receives potable water (47 percent of the urban and 8 percent of the rural population). In large cities, such as Addis Ababa and Asmara, current daily water consumption per capita is 80 liters, which is low compared with the African average of 80 to 145 liters. According to the standard set for developing countries by the World Health Organization, consumption should be increased to 150 liters. Moreover, substantial development of water supply systems will be required to satisfy the growing population. As for industry, the government envisages 12 percent annual growth over the planning period 1984/85 to 1993/94. (Water demand for various industries is shown in table 2.)

Hydropower

Existing hydropower facilities provide an annual total of 1,480 gigawatt-hours, with an installed capacity of about 400 megawatts. Despite its substantial hydropower resources, Ethiopia has one of the lowest levels of per capita electrical energy consumption worldwide.

Table 1. *Domestic Water Supply: Surface and Groundwater*

Population location	*Population served ('000)*		*Water supplied (million m^3)*		*Percentage served*	
	Surface	*Ground*	*Surface*	*Ground*	*Surface*	*Ground*
Urban	3,024	1,262	56	9	70	30
Rural	2,447	1,252	6	3	66	34
Total	5,471	2,514	62	12	68	32

Source: Ethiopian Valleys Development Studies Authority/Water and Power Consultancy Services Ltd. (India), 1990.

Table 2. *Industrial Water Consumption per Unit of Production*

Industry	*Unit*	*Water consumption (m^3/unit)*
Sugar	Ton	100.0
Paper	Ton	250.0
Steel	Ton	150.0
Artificial silk	Ton	1,000.0
Refining oil	Ton	180.0
Bricks	Ton	2.0
Thermal power	MW	3.6
Cement	Ton	3.5
Textiles	Ton	175.0
Tannery	Ton	118.0
Oil mills	Ton	67.0

Source: Development Projects Studies Authority.

The use of water resources for hydropower generation is the responsibility of the Ethiopian Electric Light and Power Authority. All costs incurred (construction, installation, distribution, etc.) are covered by this authority. Consequently, water sector authorities are not responsible for the management, control, and collection of water charges in hydropower production.

Fisheries

Ethiopia has promising fisheries potential. Fish yields from various inland water bodies are estimated at US$7 million. A 1986 FAO report defined Ethiopia's fish farming zones based on water temperature and quality and on climatic conditions. The hot lowlands are suitable for warm-water species, such as tilapia and prawns, whereas the highlands and central highlands are suitable for cold-water fish, such as trout. The investment required in a typical Ethiopian fishery project is estimated at US$12,000, plus an additional annual operational cost of US$4,300.

Economic Issues

Water resources in Ethiopia are the collective property of the Ethiopian people and are entrusted to the state, which is responsible for taking proper and necessary measures to implement the various water policies. Water allocation priorities are drinking water; ecology (including livestock and wildlife); irrigation; hydropower; industry; and navigation. These priorities may vary by region.

Cost Recovery

Despite wide recognition that pricing policy is useful in water resources allocation, it would be ineffective for Ethiopia given the current scenario (i.e., the toppled regime's economic resource pricing was centrally determined, thus creating price distortions). Investments in the water sector should be based on sound economic, social, and environmental principles, as well as on an analysis of the opportunity costs, based on shadow prices for labor, materials, and capital. Prices should indicate real economic cost and effect efficient allocation of scarce resources. In reality, though, because water supply costs in Ethiopia are usually greater than the values generated from water use and because there is an urgent need to promote irrigated agricultural development to increase food production, pricing policy has been virtually ignored. This has resulted in the following:

- As water resources have become more scarce, water supply has become more costly;

- The construction of capital-intensive water projects has strained government budgets;

- The indiscriminate use of irrigation water has led to a drastic decrease in land productivity.

For domestic water supply, the related authorities set a tariff level for urban supplies, attempting to recover the full cost of services. For urban water consumption, however, an arbitrary tariff rate of about US\$0.48/m^3 (plus \$0.48/meter for private connections), regardless of the cost recovery objective, was established. This rate has been applied to the country's major cities. In most of them, the tariff is uniform, with no differentiation among service standards or amount of consumption for residential, commercial, industrial, and public users.

For irrigation water supply, pricing policy has received little attention. The actual volume of water consumed by each user is almost never accurately measured. Recently, a cost recovery study was carried out on selected projects to establish the real cost of irrigation water supply. The evaluation was based on three models representing different irrigation conditions: gravity, self-supply pumping, and small-scale irrigation schemes. It was found that different conditions result in large cost variations. These variations occur primarily because of organizational and social factors rather than the topographical or physical characteristics of water supply systems or irrigated areas. The study also found that the lowest cost of water supply, both per unit of area irrigated and per unit of water supplied, was for small-scale projects because of the relatively small investment involved. The capital costs of large-scale irrigation works in Ethiopia are currently more than US\$10,000 per hectare. Large incremental grain yields would be required to justify such large investments, and it is unlikely that the desired incremental yields can be achieved given current agricultural and organizational practices. To implement the policy of cost recovery, a system of determining and collecting water charges needs to be instituted. There is also a need to find new and inexpensive water supply technologies.

Proposed Methods of Irrigation Water Pricing

Irrigation water abstraction charges are currently being reviewed by the National Water Resources Commission (NWRC) and the Water Resources Development Authority (WRDA). The charges involve three elements: annual costs of legislative control, contribution to new financing and development, and investment costs. These charges should reflect the impact of abstraction of water resources, encourage efficient water use, and provide flexibility when necessary. To increase societal welfare and the efficiency of water resources allocation to irrigation projects, the following methodologies of irrigation water pricing are proposed:

- *pricing based on agroecological zones.* If irrigation areas were divided into agroecological zones, a water price would be defined for each zone. The O&M costs could determine the lower limit of prices. The maximum ability to pay, assessed on the net worth of farms or enterprises, could be fixed at a certain level, which would then be considered an upper limit on the price. The objective would be to produce aggregated water revenue equal to total project reimbursable costs (i.e., capital depreciation, O&M);

- *pricing based on quantity of water abstracted.* For small abstractions with no significant impact on water systems, water charges and a withdrawal permit would not be required. For medium abstractions, which include industrial and public supplies, a fixed rate per unit of water abstraction would be applied. The rate applied to a particular user depends on the following factors: quantity, abstraction season, and quality of source and of returned water. For large abstractions (mainly irrigation users), a two-part charge is proposed: a base charge and a variable charge. The base charge would be applied to a certain proportion, perhaps 50 percent, of the maximum annually permitted quantity of water abstraction. It would raise a fixed amount each year, providing the rate of charge remained constant. The variable charge would be based on the actual quantity abstracted.

Institutional Aspects

Except for a few provisions established in the 1960 Civil Code, which mainly concern private water user rights, Ethiopia has no comprehensive water legislation. Draft water legislation has been prepared and is pending government approval. The basic level of administrative structure for the implementation of the draft legislation and regulations is the district water authority. In addition, a water quality advisory committee advises the implementing authority on water quality.

The main government agencies involved in water resources management and quality control are the Ethiopian Valleys Development Studies Authority (EVDSA), the Water Resources Development Authority (WRDA), and the National Water Resources Commission (NWRC). Currently, the EVDSA is responsible for planning water resources development and management, conducting studies and research pertaining to natural resources, collecting related data, and identifying development projects. It also prepares national master plans for the water sector, including follow-up and supervision of plans. The WRDA is responsible for the design of water abstraction facilities, water charge collection, and irrigation projects' O&M. The NWRC is responsible for the preparation of surveys, designs, and specifications, and for the implementation of water resources development construction. It also studies water charges.

Other related institutions are the Water Supply and Sewerage Authority and the Ethiopian Water Works Construction Authority, both concerned with the provision and operation of water supply and sewerage services, and thus not directly involved in river basin management functions. There are also the Addis Ababa Water and Sewerage Authority; the Ethiopian Electric Light and Power Authority (discussed previously), responsible for studies and hydropower development; the Ministry of Agriculture, responsible for agricultural development; and the Ministry of State Farms Development, responsible for state farms' O&M.

Four frameworks have been proposed to improve the current institutional organization of the water sector. The ideal framework should have the following components: All water resources planning, allocation, protection, regulation, and charges should be carried out by one institution; the two primary functions of resources planning and utility operation should have separate reporting lines to the higher level; and there should be limited disruption to existing institutions. Of the four frameworks, the following is favored: the responsibility for water resources management is transferred to a new body, the Natural Resources and Environmental Commission (NREC), under which fall various river basin authorities and subbasin units. The NREC, with its own reporting line to the Council of Ministers, would take an integrated approach to planning and regulating the development of all natural resources. It would set guidelines for and monitor performance, acquire and distribute funds, and supervise and coordinate with basin authorities. In parallel, a second new commission, the Water Services Commission (WSC), is proposed to deal with the utility services of water supply, sewerage, and sewage treatment. The utility services would collectively be reporting through the WSC to the Council of Ministers.

Environmental Issues

Ethiopia faces environmental problems such as deforestation, soil erosion, and sedimentation. Development and utilization of water resources for irrigated agriculture, hydropower, water supply, and fisheries require construction of dams, weirs, reservoirs, and canals, which directly or indirectly affect the environment. Uncontrolled deforestation and soil erosion have intensified the effects of recurrent droughts. Most rivers have sedimentation problems as a result of soil erosion. The use of pesticides for agriculture has impacted human and livestock health, and resulted in fish kills in the Awash and Bilate rivers. In the Rift Valley, most of the lakes are saline, and there is an indication of high fluoride content in most groundwater resources. Irrigation projects are increasingly plagued by waterlogging, salinity, rising groundwater tables, and pesticide and fertilizer pollution.

Overall sanitation in the country is appalling. To meet the objectives of the International Drinking Water Supply and Sanitation Decade Program (1981-91), adequate drinking water facilities are to be provided to the entire population (both urban and rural) and sanitation facilities provided to 80 percent of the urban population and 25 percent of the rural population. The water demand from rural areas is expected to increase sharply as a result of economic development. The demand for water from thermal and hydropower generation and other industrial users is also likely to increase substantially. Consequently, water, already a scarce resource, will become even scarcer.

Technological Issues

Some technological problems deserve special attention, such as the study of groundwater quantity and quality in the arid zones and the development of dryland farming and crop yield increase mechanisms in limited-moisture regimes. Other issues meriting attention include:

- *irrigation efficiency*. In some areas water loss reaches 40 percent. Lack of irrigation water control during nights and weekends causes additional losses. Most canals are not protected against erosion. When floods occur, the head of the canal can be washed away. One solution is lining the canal systems in selected areas. Efficiency measures through command area development and modernization of old irrigation systems should be recommended;

- *technology transfer*. Applied research and improved local technologies should be encouraged. Developing local consultancy services is effective if done through training of national human resources rather than direct transfer of foreign experts. Efforts should be made to transfer the new agricultural technology to end users or farmers. Cooperation among African countries on the transfer of advanced and adoptable technologies should be promoted;

- *drainage*. Adequate drainage facilities should be provided to reclaim waterlogged land. Soil conservation measures should be undertaken to reduce siltation in reservoirs and canals;

- *hydrological data collection*. A well-planned program of data acquisition is necessary to meet the objectives of water resources development. It could be categorized into general or basin-specific information for development planning;

Planning a National Water Policy

Objectives

The objectives of a national water policy in Ethiopia are to (a) improve water resources management and planning to implement cost-effective and environmentally sound water projects; (b) ensure national water conservation and environmental quality control; (c) establish appropriate institutional mechanisms for water planning and management (from data collection to monitoring and evaluation); and (d) introduce appropriate technology and encourage technology transfer and human resources training. A centrally planned national water policy with well-formulated objectives should be financially viable, economically feasible, and politically and socially acceptable. It needs to be supported by and integrated with other economic policies.

Under Ethiopia's toppled regime, there were four major constraints to the design and implementation of such a policy: (1) inability to value economic input and output; (2) inability to evaluate consumer preferences and feedback regarding selected objectives, primarily because of the political situation; (3) inefficient information systems; and (4) institutional and financial constraints.

To attain the broad objectives outlined above, the following policy is suggested:

- A standardized national information system should be established for water resources. The prime prerequisite for water resources planning is a well-developed information system. There should be a free exchange of data among various agencies, and duplication should be avoided;

- Water resources planning must be undertaken for hydrological units such as basins, and appropriate organizations should be established for basin development and management. Special multidisciplinary units should be set up in each basin to prepare comprehensive plans, not only considering the needs of irrigation, but also harmonizing various water uses. Groundwater potential and quality should be periodically reassessed;

- Water resources development projects should, as far as possible, be multipurpose, with an integrated and multidisciplinary approach to their planning, formulation, and implementation. Integrated and coordinated development of surface and groundwater and their conjunctive use should be envisaged at the project planning stage. The provision of drinking water and the reduction of adverse impacts on human settlements should be essential components of all project planning;

- In the planning, implementation, and operation of water projects, the preservation of environmental quality and ecological balance should be a primary consideration. Adverse impacts on the environment should be minimized and offset by adequate compensatory measures. Reuse of water should be an integral part of water resources development;

- There should be a master plan for flood control and management of each flood-prone basin. Sound watershed management should be promoted to reduce the intensity of floods through soil conservation, catchment treatment, forest preservation, increase in forest areas, and construction of check-dams. Nonstructural measures, such as flood forecasting, warning, and flood plain zoning, should be emphasized.

Recommended actions include the immediate preparation of river basin master plans. For the regulation of water abstraction and the protection of water quality, a revised institutional framework should be implemented to deal with river basin management. In establishing this framework, a single organization should be created with responsibility for all aspects of water resources development, including planning, design, construction, development, management, and regulatory functions. Water zoning of the country should be introduced, and economic activities should be guided and regulated accordingly.

The regulation of water abstraction and effluent discharges can only be effective if supported by laws. Such laws would essentially be available through implementation of the draft water resources legislation and include a definition of societal rights and obligations with respect to resource ownership and use.

The government has recently responded to the above issues through policy changes to encourage the development of water and land resources. Accordingly, several laws have been passed to implement the new policies, including a new investment law and regulations to provide licenses for agricultural activities. The following measures have been initiated, and some have been implemented: adopting a mixed-economy policy; allowing and motivating national and private investors to invest actively; opening areas for investment; and introducing an efficient administrative system for investment.

Human Resources Training

Ethiopia has an overall shortage of trained personnel, especially in hydrology, hydroecology, hydraulic engineering, and soil and environmental sciences. The situation is exacerbated by the "brain drain" of well-qualified and experienced professionals. To alleviate this situation, the government needs to identify priorities for personnel training at all levels in water resources development, to provide funds to establish and strengthen local training institutions, and to develop incentives to retain trained personnel.

International River Basins

Most of the major rivers in Ethiopia are international. To avoid upstream-downstream conflicts, agreement should be reached among riparian states on the principle of equitable utilization according to international law. Because all riparians have competing interests in the river basins, they can benefit from agreement reached according to equitable accommodation. Multilateral organizations, such as the World Bank, could assist in and promote basinwide development cooperation, as with the Indus basin involving India and Pakistan. The Bank could assist in defining common problems and alternatives to resolve conflicts, and it could offer technical assistance in sharing water resources for equitable utilization and environmental pollution control.

THE JORDAN BASIN: POLITICAL, ECONOMIC, AND INSTITUTIONAL ISSUES

Thomas Naff

The Jordan River basin embodies the systemic, political, and socioeconomic interconnectedness of water issues, which inherently makes piecemeal planning and investment strategies counterproductive in the long run. Although diminutive in comparison with the Euphrates or Nile basins, the Jordan is nonetheless as politically complex and even more conflict-prone. In the Middle East, where aridity, scarcity, and some of the world's most atavistic rivalries exist, it is an inescapable reality that there is little hope for the resolution of water-based conflict—or for the achievement of cooperation—without sustainable political settlements.

Background

There are four riparians in the Jordan river basin—Jordan, Israel, Syria, and Lebanon. The basin drains an area of about 18,300 km^2. Annual precipitation in the basin ranges from less than 50 to over 1,000 mm, with an average of less than 200 mm on both sides of the Jordan River.

Jordan's population is increasing at about 3.8 percent annually; Israel's, at about 2 percent; and Syria's, at about 3.6 percent (data are not available for Lebanon). In addition, the immigration of Soviet Jews will add in absolute numbers about another 1 million Israelis during this decade. The West Bank and Gaza together have a population of about 2 million, growing at an estimated 3.8 percent a year and projected to reach about 4.2 million, if present conditions prevail, through 2020.

About 80 percent of the basin is situated in Jordan, Israel, and the West Bank. From surface, ground, and marginal sources, Israel normally has about 1,950 million m^3/yr of renewable fresh water supplies. However, because of shortages stemming mainly from drought, Israel can presently count on only about 1,600 million m^3/yr. For the same climatic reasons, Jordan, which has usually derived about 900 million m^3/yr of usable water from all sources (including the Yarmouk but excluding the lower stem of the Jordan River because of excessive salinity), is only drawing 700 to 750 million m^3/yr. The Occupied Territories (the West Bank and Gaza) have a normal total water productive capacity of about 650 million m^3/yr, but the supply has been diminished to an estimated 450 to 550 million m^3/yr, again mainly because of drought. (These figures include all sources that originate in the Territories, as opposed to only those groundwater sources that do not flow from the Territories across the border into Israel.) Israel depends on water resources originating in the Occupied Territories for about one-third of its national supply.

Serious problems of scarcity and quality exist in the Jordan basin. The basin's principal riparians, Jordan and Israel, have been consuming about 108 percent of their total usable water stocks. The prognosis through the years 2015-20 is for persistent water shortages and the continuing tendency to overexploit unless immediate and drastic corrective actions are taken basinwide, involving economic restructuring, basinwide administration and data sharing, reduction of irrigated agriculture, alterations in crop patterns, sustainable population growth, and greater efficiency through greater application of

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water technologies and conservation. These essential steps will be politically and economically difficult without considerable outside mediatory and financial assistance.

The new supplies of water that Israel needs do not exist within the country. A massive desalination effort involving sufficient quantities of sea water would (1) cost an exorbitant amount, depending on the technology and capacity adopted; (2) not produce enough water before the turn of the century to meet already critical needs; and (3) be expensive for all consumers unless heavily subsidized (Israel already provides off-budget water subsidies of US$250 million a year). In these circumstances, accessible sources of water outside Israel—such as the Litani in Lebanon or the costly importation of water from Turkey—take on serious economic, strategic, and legal implications. Jordan, more so than Israel, experiences the debilitating effects of scarcity because it does not have the economic resources or access to outside financial assistance that Israel does to deal with the problem—especially since the Gulf war, which decimated Jordan's economy.

Effects of Water Deficits

The existence of long-term deficits for the entire basin is perceived differently by various specialists, depending on what data are used and how they are interpreted and extrapolated. This paper claims that the effects of ongoing water deficits, already exigent in the Jordan basin, are cumulative and could quickly become irreversible. Both Jordan and Israel have already accumulated a water debit equivalent to at least one year's supply. Neither known natural sources nor water technologies available now or by the end of the decade have the capacity to generate new usable water in needed quantities at an affordable cost. Without a solution to this scarcity, both Israel and Jordan will have to curtail their social and economic development. The result is likely to be heightened competition among riparians and among domestic sectors within each country for decreasing amounts of degraded water, with concomitant, destabilizing internal and regional repercussions. Scarcity and environmental degradation will also impact other water-related resources in the basin.

A further complication is the relationship that links energy, water, and oil. Significant amounts of energy are needed to extract and move water in the Jordan basin. For example, Israel uses about 18 percent of its total national energy supply to pump and transport water, and Jordan's water-energy ratio of about 9 percent is proportionately not far behind. In both countries oil is the principal source of energy, thus linking water issues with petroleum.

If current policies and patterns of consumption in Jordan and Israel persist, a mounting series of water crises could be touched off before the end of the decade, particularly if economic conditions deteriorate further or present drought conditions persist or worsen (a distinct possibility, given the drought history of the basin). Between 1995 and 2005, Israel, Jordan, and the Occupied Territories might begin to experience acute and progressively worsening perennial water shortages and quality degradation analogous to the three areas running out of renewable sources of fresh water. Consequently, rather than outright warfare among the riparians (which is possible), internal civil disorder, regime changes, political radicalization, and instability are more likely to ensue, particularly where there is a combination of water and economic problems as in Jordan and Syria, and, to a lesser extent, potentially in Israel.

Israelis, Palestinians, Jordanians, Syrians, and Lebanese all invoke a variety of legal principles to establish their claims: first-in-use-first-in-right, customary or equitable utilization, absolute sovereignty (or the Harmon Doctrine), beneficial use, basic justice and fairness, good neighbor relations, and prior use. But the reality, both historic and contemporary, is that the Jordan basin's actors do not resort to law to settle water disputes; these issues are determined by the relative power relationships in the basin at any given time. Only if the hegemonic power—at present Israel—chooses law as a means of introducing change and settlement will law play such a role. Only with political settlements in place can there be an adequate array of effective legal instruments for solving international disputes over shared water resources. However, although law cannot provide all the needed answers (and is contingent on political settlements), it is nevertheless essential to the stable maintenance of solutions—if legitimate, stable solutions can be found.

Economic Restructuring

One of the most effective ways to alleviate the basin's problems of water scarcity and overpopulation is through the restructuring of economies away from heavily irrigated agriculture toward other sectors, such as service and industry—a difficult but not impossible task given proper incentives and dedicated assistance. In most parts of the Middle East (and other arid regions worldwide), typically 75 percent of all water supplies are used for irrigation. If Jordan and Israel, for example, were to reduce their irrigated farming by about 40 percent, they would, at the very least, roughly break even in water supply and demand, assuming simultaneous improvements in efficiencies and conservation. The Israeli government has responded to the current drought crisis by reducing the 1991 allocation of water for irrigation by 30 percent. Some Israeli experts would like to see this reduction become permanent, but concede that in the present political climate that action is unlikely.

As for energy expenditures, in some Middle Eastern countries the ratio of fossil fuel expended per calorie of food delivered to a household is greater than that of the United States because of the high consumption of water for irrigation combined with poor soil quality. Under present patterns, the growing energy subsidies (including water) to Middle Eastern agriculture are largely fixed because of the enormous cost of conducting intensive agriculture in a climate that generally is highly unsuited to such exploitation.

For some time experts have argued that Middle Eastern governments should realize that their energy resources would serve them better if they were exchanged, through an appropriate market situation, for foodstuffs produced with far lower energy and water subsidies in locales with climates better suited to agriculture. This strategy would enable Middle Eastern water authorities to transfer enormous quantities of water from inefficient agriculture to far less consumptive industrial applications, which presumably could simultaneously increase GNP: the contribution of light industry to GNP is about 30 times greater per unit of water used than the contribution of agriculture.

Transitional Support

Understanding and easing the transition from agriculture to light industry will be complex for many reasons, not the least of which relates to the political dimensions involved. The shift from farming to industry (or, for example, to transportation or service) is difficult because agriculture is culturally embedded, highly symbolic, and militarily significant. Investment in research and practice oriented toward encouraging and enabling the smooth transition would yield high dividends. The United States, the EC, various governments, and the World Bank could provide incentives for planning and implementing economic restructuring and for mitigating the attendant hardships.

Demonstration Models

Perhaps the best way to initiate economic restructuring is to provide incentives for one country to act as a demonstration model for others, not only in the Middle East, but also in other parts of the world. Jordan might be a good candidate because of its pressing economic and water-related problems and its perceived willingness to be innovative. The program would have to be implemented gradually, with rigorous periodic evaluations, flexible planning, and built-in measures for easing transitional hardships. Should this endeavor enjoy even mild success without exorbitant cost, it could be attractive to other basin actors, with a region-wide or even global impact. A positive impact could even result from the success of simply the project's initial stages. This is a undertaking that lends itself to collective endeavor, so many governments and agencies could act jointly, thereby spreading the risks.

Technical Infrastructure

Important technical developments are constantly emerging, such as new methods of desalination; "Medusa bags" for transporting water overseas by towing the bags behind ships; technologies that improve purification, efficiency, and conservation; and arboreal solutions (such as the Finnish suggestion of using eucalyptus trees to reforest and establish a paper industry in the Middle East). Seeking and selecting such new ideas need to be done continually and systematically. Investment in new, promising developments, particularly those that are unlikely to be funded by standard sources, should have a high priority.

In the Middle East, as well as in many industrial nations, transboundary fresh water use, allocation, and preservation involve a lack of inter- and intrabasin cooperation; poor data; and uncoordinated, piecemeal approaches that result in fragmented policies and action. Because it is unlikely that cooperation can be coerced or induced at the highest political levels, another approach must be found. The most promising is encouraging cooperation—at a lower but still significant level—among officials and technical experts. If officials and scientists in the region communicate sufficiently to develop shared understanding of the water situation, available technologies, and potential solutions, they could become a strong force for cooperation—a community of informed officials and experts throughout the region to press for and guide effective water policies.

Another possibility would be to promote cooperative desalination at basin or regional levels. Such arrangements, although requiring considerable political agreement, would yield great economic, political, and social benefits, especially in such landlocked countries as Jordan. The key to achieving these goals—and, in some respects, the prerequisite to successful economic restructuring—would be the establishment of a technical infrastructure for hydropolicy that addresses problems at three levels: basin, regional, and global. Specifically, this would involve the establishment of three interrelated types of water institutes: (1) an institute for each of the three major river basins in the region—Euphrates-Tigris, Jordan, and Nile; (2) a comprehensive Middle East regional water institute; and (3) a global water institute, perhaps under the auspices of the World Bank.

These institutes, comprising staff, fellows, trainees, and other personnel from the world's major basins, would perform several critical functions: (1) provide expertise, research, educational opportunities, and data necessary to develop the entrepreneurial, human, and technical resources presently lacking; (2) generate data bases and hydrological, economic, and other social/scientific analytical tools; (3) act as conference settings; (4) serve as centers for accurate recordkeeping and information dissemination; and (5) foster interaction among basin or regional specialists.

Conclusion

Water is the earth's most essential resource: no other substance carries greater potential for conflict and disaster when it is scarce or poorly distributed. Thus, approaches, concepts, and actions must be commensurate with the magnitude of the problem—and where water is concerned, the problem entails nothing less than survival. By far the greatest risk for all concerned actors would be to avoid taking risks.

WATER RESOURCES PLANNING AND DEVELOPMENT IN JORDAN: PROBLEMS, FUTURE SCENARIOS, AND RECOMMENDATIONS

Maher F. Abu-Taleb, Jonathan P. Deason, Elias Salameh, and Boulos Kefaya

Jordan has an arid climate and can be classified as water-poor. About 85 percent (730 million m^3) of total utilizable water resources are being exploited. Despite a well-conceived hydrological data base, the aridity and irregular rainfall distribution contribute to uncertainty in overall water management and planning. The water system also experiences heavy water losses. The country intends to utilize nonconventional sources such as treated wastewater, rainwater harvest, and desalinated seawater to cope with increasing water demand. Environmental problems in Jordan are a direct externality of water supply-demand imbalances. Water mining practices and waste seepage are the two main sources of groundwater contamination, and the government is considering initiatives for protection of groundwater. This paper discusses the planning process and policies of Jordan's water sector, as well as its new water investment policy, which requires comprehensive economic feasibility analyses. The policy instruments most applicable to Jordan are quantity regulation, price regulation, and conservation subsidies. The paper also examines the current institutional framework and the strengths and weaknesses of the centralized control of the water sector. Finally, four alternative scenarios are presented and compared. An underlying factor in the Jordan River system has been contention over international water rights, with the Arab-Israeli conflict further complicating cooperative uses of the river system.

Water Resources Development

Jordan's area is 90,000 km^2. It has a population of 3.3 million (1991), over 90 percent of whom live in the northern highlands and the Jordan Valley. About 75 percent of the population is concentrated in the urban belt around Amman and Zarqa. The population grows at 3.8 percent per year.

System Characteristics

Jordan is arid. Average annual precipitation is less than 200 mm in about 94 percent of the country. In the northwest, precipitation varies from 350 to 650 mm and occurs only in winter. Major surface water sources are the Yarmouk and Zarqa rivers and the side *wadi* (a watercourse in a valley that flows in the winter), all flowing westward into the Jordan River leading to the Dead Sea. Although high evaporation rates cause low annual stream flows in surface water resources, the high infiltration rates common to many areas of Jordan result in relatively high rates of groundwater recharge. Safe yields from major renewable sources, however, are being exceeded by an average of 32 percent. The aridity and irregular rainfall distribution contribute to uncertainty in overall water management and planning.

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Jordan's water resources system is characterized by:

- *water poverty*. If a "water poverty line" is defined as 1,000 m^3 per person annually, below which water scarcity occurs, Jordan can be considered a water-poor country, with an availability level of 240 m^3 per person;

- *political involvement*. The Jordan and Yarmouk rivers are shared with other riparians, with numerous political ramifications;

- *well-conceived hydrological data base*. Jordan is not a "data-poor" country. The data base has always been considered sufficient for planning purposes. The country has over 230 meteorological stations, some with records going back to 1923. Data for the past 30 years are available for measured stream flows. Groundwater potential is continually monitored and updated, based on the physical models developed for the 1977 National Water Master Plan. Data on soils, land classes, and geology are well documented.

Utilization

Currently, about 85 percent (730 million m^3) of total utilizable water resources are being exploited. The maximum economically exploitable surface water quantity, after all potential dams are built, will be 474 million m^3, out of a total surface flow of 750 million m^3 (approximately 300 million m^3 are being utilized). With an estimated 388 million m^3 per year of safe yield from groundwater, utilizable water resources total 862 million m^3. Of this amount, however, only 730 million m^3 are being exploited. It is only after the completion of the Al-Wahdeh Dam, with a storage capacity of 200 million m^3 per year (effective additional supply to Jordan will be 75 million m^3), and other supply augmentation projects that the quantity of water being exploited will approach 862 million m^3. Extraction of groundwater is currently 110 percent of total available renewable supplies.

SECTORAL WATER USE. Total water consumed in 1990 was about 730 million m^3, of which 520 million m^3 (71 percent) were distributed for agriculture, 175 million m^3 (24 percent) for domestic use, and 35 million m^3 (5 percent) for industry.

The total land under irrigation is 55,000 ha, primarily in the Jordan Valley and Southern Ghors. Water supply to these areas is provided by surface gravity systems (45 percent) and pressure pipe systems (55 percent). The irrigable land area is expected to increase by 36,000 ha by the year 2000, mainly in the Jordan Valley because irrigation projects in the highlands utilize only groundwater supplies. Future land development in the highlands, therefore, is limited. Water loss in agricultural use is about 58 percent. Irrigation efficiencies range from 38 percent for surface distribution systems to 70 percent for direct pipe distribution systems. High evaporation rates from open irrigation canals in the Jordan Valley and seepage losses from those canals contribute to inefficiencies. In addition, high subsidies to Jordan Valley farmers imply that more irrigation water is used than is necessary.

The loss in municipal and industrial use is 25 percent. Over 85 percent of the urban population and about 20 percent of the rural population are served through house connections, resulting in coverage of about 70 percent of the total population. The remainder have access to the water supply system through public standpipes. The consumption per capita ranges around 50 to 300 liters per day (lpd), with an average of 150 lpd. The municipal supply systems experience huge losses because of aging pressure pipes, inaccurate meters, and illegal diversions of water to bypass meters. Jordan's small industries use municipal water supplied by the public sector. The major industries, including petrochemical refineries, cement, pharmaceuticals, phosphates, potash, glass, and fertilizer, obtain water mainly from private groundwater wells.

An important consideration in water resources planning is the development of a lower limit, below which water supplies would not be allowed to fall. The most practical method is to use a ratio of accepted levels of water for each individual to maintain health, sanitation, and hygiene. Jordan's Ministry of Water and Irrigation (MWI) is considering 190 lpd per capita (including losses) to cover total municipal demand.

NONCONVENTIONAL WATER SOURCES. Nonconventional water sources include wastewater reuse, desalination of seawater or brackish waters, cloud seeding, rainwater harvesting, and water importation. Current treatment plants in Jordan produce approximately 40 million m^3 of effluent annually, which is expected to increase to 70 million m^3 in the year 2000. The Khirbet Al-Samra wastewater treatment plant located near Amman provides treated water to irrigate forest trees. The possibilities for desalination of seawater exist only in Aqaba, Jordan's only seaport. Desalted brackish water could provide 145 to 220 million m^3 for municipal supplies annually.

INVESTMENT IN THE WATER SECTOR. Water supply and public investment in the water sector during the past two decades are illustrated in table 1. Most investment went to the construction of dams, wastewater treatment facilities, water supply networks, and irrigation works.

Future Water Balance

The deficit projections in table 2 review the various available demand and supply schemes, considering the economic feasibility of various supply augmentation projects. They are based on an estimate of 190 lpd per capita for municipal and industrial demand, and an annual irrigation demand of 10,000 m^3 per hectare, assuming a constant annual population growth of 3.8 percent between 1990 and 2005. Possible actions envisioned by the government to cope with these deficits include desalination, exploitation of deep water aquifers, initiation of conservation programs, control of water supply losses, search for water sources outside Jordan, artificial recharge of groundwater aquifers, and wastewater use in irrigation. Future development of marginal sources of surface water could range from an estimated 4 to 4.5 Jordanian dinars (JD)/m^3 (US$6 to $7/$m^3$). The development and evaluation of the alternatives using proven integrated planning technologies could be instrumental in enabling policymakers to deal with the situation more comprehensively and effectively than in the past.

Table 1. *Water Supply and Public Investment*

Period	*Average water supply (million m^3/yr)*	*Investment* Public investment (million JD)	*Investment* (% of govt. budget)
1976-80	550	520	16
1981-85	625	245	10
1986-90	678	280[a]	9

JD = Jordanian dinars.
a. Planned.
Source: Ministry of Planning.

Table 2. *Water Deficit Projections, 1990-2005 (million m^3)*

	1990	*1995*	*2000*	*2005*
Water demand	740	890	1,045	1,200
Water supply	730	862	862	862
Net annual deficit	10	28	183	338

Water Planning Policies

At the national level, planning in Jordan is mainly undertaken and implemented by the Council of Ministers, who present their plans and budgetary requirements to the elected Senate and House of Representatives for review and approval. Thus, popular participation in the decisionmaking process is guaranteed, albeit not in the implementation stages. At the sectoral, or ministerial, level, plans are formulated on the basis of trends and the extent to which previous objectives have been achieved in each sector. The final decisions are made by high-level officials based upon judgment and experience. During the 1980s, Jordan water sector management was based on the 1977 National Water Master Plan. In 1988, at the request of the Jordanian government, the World Bank undertook an extensive survey of the water sector and developed forecasts and guidelines, one of the cornerstones upon which decisionmakers predicate their plans.

The following policies will be adopted shortly:

- water supply cuts in the municipal and irrigation sectors. These rotational cuts can only be applied as a physical control in the short run. In the long run, cuts may be detrimental to public health and productivity;

- suspension of new applications for groundwater well licenses for 1991, until further evaluation and monitoring are completed;

- stringent monitoring of private sector groundwater extraction.

Environmental Concerns

Environmental problems in Jordan are a direct externality of water supply-demand imbalances. Because of the generally low flows, surface streams have low assimilative capacities. The treatment level of wastewater is inadequate given the low assimilative capacities of receiving water bodies, with subsequent adverse impacts on downstream uses. With groundwater, overpumping degrades water quality. Although Jordan is aware of the importance of environmental protection and has undertaken significant measures in response, much remains to be done.

Among the three main rivers—the Jordan, Yarmouk, and Zarqa—the water in the Jordan River is highly saline because it receives (a) the return flows from irrigated fields on both sides of its banks, and (b) the flow of the saline springs diverted into the Jordan River by Israel. The latter action was undertaken unilaterally by Israel to conserve the quality of Lake Tiberias, a substantial water resource for Israel. This practice has made the Jordan River unsuitable for use in its present condition. The quality of the Yarmouk River waters is good. The Zarqa River, however, is an environmental disaster. During summer, the river's flow consists almost entirely of sewage effluent, discharged from industrial and municipal users.

Water mining practices and waste seepage are the two main sources of groundwater contamination. Contamination resulting from water mining leads to the general propensity of saline water to intrude into the higher levels of aquifers, in addition to greater extraction rates than the natural recharge of the aquifer. Contamination from waste seepage, for instance in Amman, comes from septic tanks in some parts of the city and from industrial activities. Groundwater provides about 90 percent of municipal supplies. National policymakers consider the following initiatives high priorities for the future protection of groundwater:

- prevention of mining in groundwater basins;
- development of wastewater infrastructure for a large segment of the population;
- improvements in the operations of wastewater treatment plants;
- careful selection of landfill areas;
- monitoring of pesticide and fertilizer use;
- development of a sound industrial licensing policy and related laws and guidelines.

The institutions involved in monitoring the chemical and biological components of water are the Water Authority of Jordan (WAJ), the Ministry of Health, the Royal Scientific Society (RSS), and the Water Research and Study Center (WRSC). Established in 1970, the RSS is a nonprofit research institution providing scientific and technical assistance to both the private and public sectors for development projects in Jordan. The WRSC was founded in 1983 at the University of Jordan and seeks to contribute to national efforts in developing water resources and water conservation to protect against environmental impacts. Together, these institutions set the standards for wastewater, drinking water, and irrigation water in accordance with World Health Organization specifications and U.S. Environmental Protection Agency standards.

Economic and Financial Policies

Water Pricing

Water prices in Jordan follow a progressive rate system. As consumption of water exceeds certain limits, the price of additional units increases. The old water price system also demanded progressively higher prices for higher consumption, but with less delineation in the block limits. The new system, adopted in 1990, adds more blocks, resulting in a revenue increase from JD 16 million to JD 25 million. Table 3 presents the new block structure and the progressive rates by region for domestic uses. For agricultural use, the rate is fixed at JD 0.0065/m^3. The rationale behind this new system is that higher prices can encourage conservation by large users while increasing revenue from—but avoiding adverse impacts on—the majority of the population. For example, 12 percent of residential use is over 70 m^3/quarter. Therefore, the water prices for this block were increased to promote conservation on the part of these high-use consumers and to increase revenue for the water sector, without increasing prices for more conservative users. The economic structure of the water sector is an important mechanism that allows decisionmakers to formulate, analyze, and compare alternative development plans.

Cost Recovery

The Ministry of Water and Irrigation recently required that any new investment plan for the water sector address the following criteria as part of overall economic feasibility analyses: (a) operating costs, (b) maintenance costs, (c) capital cost recovery, (d) benefits, and (e) maintenance of adequate service levels. Detailed cost-benefit analyses based upon the above framework are now required for all new

Table 3. *Domestic Water Pricing Rates (Jordanian dinars)*

Water quantity (m^3/quarter)	*Amman*	*Outside Amman*	*Jordan Valley*
Up to 20	0.100	0.065	0.065
21-40	0.190	0.090	0.065
41-70	0.400	0.300	0.115
71-100	0.500	0.500	0.250
>100	0.600	0.600	0.400

projects. Although benchmark figures for cost recovery have not been explicitly specified as a cutoff point below which projects will not be implemented, the following cost information provides the context within which such determinations are made. The average cost of a cubic meter of water for irrigation (amortized capital cost recovery + operation + maintenance) is JD 0.20 per year for a typical 50-year lifetime project at a zero interest rate. At an interest rate of 5 percent, this figure becomes JD 0.41/m^3. These costs are used for evaluations of proposed projects on a cost comparison basis. In comparing these figures with the average price of irrigation water in the Jordan Valley of JD 0.0065/m^3, one sees that the government is heavily subsidizing irrigation in that area. On average, this subsidy reaches 75 percent of farmers' costs in the Jordan Valley. In the highlands, however, farmers have to pay all of their investment and operating costs, raising the issue of equity among different water user groups.

Institutional Arrangements

Institutional and Legislative Framework

The organizational development of the water sector can be categorized into three major periods. During the first period (pre-1984), the water sector was managed by several independent organizations, including the Natural Resources Authority, the Water Supply Corporation, the Amman Water and Sewerage Authority, and local municipalities. The main problems associated with this arrangement were the inability to implement comprehensive development plans and the duplication of effort. In 1984, the water sector was reorganized under the direction of two independent, ministerial-level authorities, the Jordan Valley Authority (JVA) and the Water Authority of Jordan (WAJ). Each is headed by a board of directors reporting to the minister of water and irrigation. The WAJ is solely responsible for providing water for municipal uses and extracting groundwater. The JVA is responsible for the development and use of water resources for irrigation in the Jordan Valley. In 1987, the WAJ and JVA were placed under the central control of the Ministry of Water and Irrigation, and the government reinforced laws and guidelines regarding groundwater extraction, allocation of water for different uses, and effluent reuse.

Relevant laws delineate the responsibilities and duties of the two boards and regulate their financial affairs in accordance with accepted government practices. Development plans and policies must be annually presented to the Council of Ministers for approval. The laws also outline the penalties for committing unlawful acts, such as polluting water sources or drilling wells without a license. These laws deal with the issue of water rights. The underlying premise is that water is a public good allocated by the government for the equitable development of the country's various regions.

There are advantages and disadvantages of centralized control of the water sector. The most significant advantage of central control is the ability to relatively easily implement integrated approaches that promote efficiency and equity. In addition, the need to integrate the water resources sector with other sectors can be addressed effectively with the current organizational structure because the governing boards of the JVA and the WAJ consist of a wide spectrum of high-level officials from the ministries of Planning; Agriculture; Municipal, Rural, and Environmental Affairs; Health; and Industry and Trade, as well as from the Natural Resources Authority and the Budget Department. Both boards are chaired by the minister of water and irrigation. The bureaucratic procedures involved in this central control system, however, result in slow implementation.

Future Water Policies

Four alternative scenarios are formulated, summarized, and compared heuristically:

1. *the status quo*. This refers to the continuation of present trends without new development. It implies that the allocation of water will continue to the various sectors through an enormously inefficient network, at an average of 132 percent of annual safe yields. Water quality deterioration will damage some aquifers, consequently decreasing supply. The likely outcome of this scenario is an impending water crisis, with production levels falling and health standards gravely affected;

2. *irrigation water use priority*. Water is allocated to the irrigation sector as a priority. This does not require major changes in government policy. Most surface water development projects proposed by the MWI are irrigation-oriented. At least 10,000 ha can be developed further for agriculture in the Jordan Valley, where the basic infrastructure is already available. The net effect of this scenario on agriculture would be (a) more irrigated areas; (b) greater production for internal and external consumption early on, tapering off and probably declining because of the increased deterioration in water quality; (c) greater income to farmers and to those employed in agriculture-related services; and (d) more agricultural workers. The effect on the industrial sector is that expansion in production cannot occur, and current production will probably decline, negatively affecting the overall economy. A side effect of this policy is that health standards in the municipal sector will be harmed. To pursue this policy successfully, new sources would have to be found to supply water for municipal and industrial demand at cost, for instance through desalination at Aqaba. This scenario would require development projects, such as the Al-Wahdeh Dam, to expand the irrigated areas. These tradeoffs must be considered before any major decisions are made;

3. *municipal and industrial (M&I) water use priority*. Agriculture would receive water after M&I demands are satisfied. This is the recently stated government policy, in which M&I demand is expected to rise by over 200 percent in the next decade, whereas irrigation demand is expected to increase 20 percent. Reallocation from agricultural water supplies to M&I, therefore, would be forthcoming in any case. This would curtail agricultural development significantly, and, without efficiency enhancements and resource conservation, many farmers would lose their means of livelihood;

4. *increased efficiency and water conservation*. If the government can keep inefficiencies to a minimum by investing in the rehabilitation of supply networks, potential water savings could be as much as 100 million m^3 per year. In comparison with other supply augmentation projects, this "rehabilitation scheme" would most likely be favorable in terms of costs and benefits.

Comparison of Scenarios

The status quo scenario, under which no funding is available to undertake the necessary development and maintenance projects, would have detrimental impacts on the country. The irrigation priority scenario may prompt the argument that the best-quality irrigation water should be diverted to population centers where it is mostly needed. The M&I priority scenario raises the question of falling food production and, consequently, food security. The increased efficiency scenario, in conjunction with a water conservation scenario, is the most feasible. If the economic situation in Jordan is boosted by international support, the MWI can then implement projects on a priority basis, employing efficiency and conservation policies. If the economic outlook remains grim, however, the reallocation of water from irrigation to M&I would be required sooner rather than later. The effects of this reallocation would cause a downward trend in all facets of economic and social development in the country.

Policy Instruments and Their Implications

The policy instruments most applicable to Jordan are quantity regulation, price regulation, and conservation subsidies. Through quantity regulation, the government informs affected farmers of reductions in water supply and encourages them to reduce irrigated lands, invest in water-saving technologies, or change cropping patterns. Ideally, this would rationalize water supply and improve environmental quality. The extent of these favorable consequences could be determined by using economic models. Through price regulation, price increases could have the same effect as quantity regulations. Detailed economic studies have to be undertaken before decisions can be made on such a policy.

Conservation subsidy policy implies that the government subsidizes farmers on water use reductions. These subsidies are offered only to induce water conservation, not to promote water conservation technologies because the latter may lead to an expansion of irrigated lands without any decline in water use. Detailed studies for each agricultural area should be undertaken to determine subsidy rates.

The effect of a water efficiency and conservation strategy on the supply-demand balance would be to delay the impending deficit by about 10 years. Table 4 illustrates the potential savings in water resulting from the adoption of an efficiency-conservation policy, which could be substantial.

Riparian Issues: International River Disputes

The most pressing international water rights issue is allocation of the waters of the Yarmouk River, which Jordan and Syria share. Since the beginning of the century, formal schemes have been

Table 4. *Water Deficit Projections under Efficiency-Conservation Scenario, 1990-2005 (million m^3)*

	1990	*1995*	*2000*	*2005*
Water demand[a]	740	751	890	1,030
Water supply	730	862	862	862
Net annual deficit	10[b]	0	28	168

a. Reduced by 10 percent in water loss for M&I and by 50 million m^3/year for irrigation.
b. Net annual deficit for 1990-95 would remain positive until the efficiency-conservation policy has a full effect.

developed to estimate local population needs. For example, the Unified Johnston Plan of 1955, sponsored by the United States, mandated that Jordan's share from the Yarmouk be 275 million m^3. Its share from the Jordan River was fixed at 100 million m^3, to be stored in Lake Tiberias. This gave Jordan a total allocation of 375 million m^3. (Water allocation according to this plan is compared with current allocation in table 5.) Actual use of the Yarmouk by Jordan decreased from 130 million m^3 in the early 1980s to less than 110 to 125 million m^3 in 1990 because (a) other riparians' use exceeded the planned allocation, (b) Jordan does not receive any of the 100 million m^3 potentially stored in Lake Tiberias, and (c) there is no control of flood flow on the Yarmouk. Jordan and Syria ratified a plan in 1987 concerning construction of the Al-Wahdeh Dam and allocation of stored water.

Jordan would need the entire allocated 375 million m^3 to develop and permanently irrigate the entire Jordan Valley, estimated at 36,000 ha. By 1989, the developed area for irrigation included 22,800 ha, plus an additional 6,000 ha at the southern end of the King Abdullah Canal, totaling 28,800 ha. The 6,000 ha were intended for irrigation during the winter from stored flood waters of the Yarmouk. Because of the lack of availability of Jordan and Yarmouk river waters to Jordan, the area developed for irrigated agriculture is severely underutilized. Furthermore, the Deir Alla-to-Amman pipeline is running at one-third capacity because of water shortages in the canal.

Recommendations: An Integrated Approach

Demand will begin to exceed supply by 1995, even if all conventional sources are developed; thus, nonconventional water supplies must be developed. Conservation and efficiency enhancement measures within the water sector are needed, as are integrated water resources planning, development, and operations.

An integrated planning approach for Jordan is now being developed, based on (a) national objectives, (b) available options and strategies, and (c) determination of which strategies contribute the most toward the national objectives at fixed investment levels. This approach could ultimately lead to the formulation of a comprehensive decision support system to assist the Jordanian government in improving the planning and management processes in the water sector. This methodology may also be favorably applied elsewhere in the Middle East, where water resources constraints are similar to those of Jordan.

Table 5. *Annual Allocation of Yarmouk River Waters (million m^3)*

Riparian	*Planned (1955)*	*Current (1990)*
Jordan	275	120
Syria	90	170
Israel	25	100

Source: T. Naff and R. Matson, *Water in the Middle East: Conflict or Cooperation?*, Westview Press, Boulder, Colo., 1984; and E. Salameh, "Water Resources of the Jordan River System and the Surrounding Countries," paper presented at the Third World Conference on Water Law and Administration, Alicante, Valencia, Spain, December 1989.

ISRAELI WATER SECTOR REVIEW: PAST ACHIEVEMENTS, CURRENT PROBLEMS, AND FUTURE OPTIONS

Jehoshua Schwarz

Israel's water resources are characterized by scarcity, with uneven temporal and spatial distribution and adverse withdrawal conditions. These features have led to the establishment of a highly flexible and integrated system for national water supply distribution. This paper briefly examines water pricing policies in Israel, including cost recovery, as well as institutional arrangements for water resources management. It also discusses the productive value of water use and salinity problems resulting from agricultural production. A new water master plan is introduced, which identifies major problems and proposals, emphasizing the economic and quality aspects of water resources management.

Water Resources Development

The amount of annual renewable fresh water in Israel is about 1,600 million m^3, of which 35 percent is derived from the Jordan River basin through pumping from Lake Kinneret. About 60 percent is drawn from groundwater sources, mainly from the two largest aquifers, the Yarqon-Tanninim and the Coastal Plain, which, together with Lake Kinneret, constitute the country's main water sources. The remaining 5 percent comes from floods intercepted and stored in groundwater reservoirs. There are other water sources, such as nonrenewable resources and reclaimed wastewater.

Three characteristics of Israel's water resources may be summarized as:

1. *scarcity with uneven temporal distribution*. Israel has a semiarid climate, with average annual rainfall ranging from 1,000 mm in the north to 25 mm in the extreme south. The total annual precipitation amounts to about 10,000 million m^3, of which only 18 percent is utilizable. Rainfall usually occurs between November and March and varies greatly by year;

2. *uneven spatial distribution*. About 80 percent of water resources are located in the north. Because 65 percent of arable land is located in the south, large quantities of irrigation water need to be conveyed over a distance of about 200 km;

3. *adverse withdrawal conditions*. The average surfaces of Israel's water resources have an elevation of 82 m below ground. Therefore, pumping water alone accounts for about 12 percent of the country's annual electric power consumption.

National Water Supply System

The above water resources features have led to the establishment of a highly flexible and integrated national water supply system. This system was completed and implemented in 1964, providing about 1,100 million m^3 of water supply annually. The supply network is implemented by the National

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Water Carrier (NWC) to carry out massive transfers from the north to the south of the country. The system is energy-intensive, with the unit cost of water supply relatively high. The NWC has also developed several regional branches that either receive water from the NWC in the summer or contribute water to the NWC during the winter, depending on demand and the groundwater level in local aquifers.

Utilization

There are three major water users: domestic, industrial, and irrigation.

DOMESTIC. Total domestic consumption is 450 million m^3, having increased over the past decade at an average annual rate of 2.5 percent. Per capita annual consumption is now an average 100 m^3 and has been increasing at 0.6 percent annually over the past decade. Almost the entire population has access to drinking water supply and has individual water meters.

Immigration to Israel has increased dramatically in recent years, and the population is expected to reach 6.4 million by the year 2000. Low population growth is projected in the center of the country and in the densely populated urban centers such as Tel Aviv and Haifa. A policy of accelerated growth has been adopted for the peripheral northern and southern regions. Overall average per capita consumption is expected to increase in the coming years at an annual rate of 0.7 percent, reaching 110 m^3 in the year 2000, when Israel's total domestic water consumption will be 780 million m^3 per year.

INDUSTRIAL. Annual industrial consumption is estimated at about 110 million m^3 and has been increasing at about 4 percent annually. A future increase of 1.4 percent per year is expected, bringing industrial water demand to 135 million m^3 by the year 2000. Nearly 27 percent of industrial water is brackish, with chlorides exceeding 400 mg/l. Much of the cooling water is supplied by either seawater or recycled water. The average amount of water consumption per unit value of industrial production has steadily declined as a result of water-saving measures, such as recycling, and the growth of less water-consumptive industries, such as electronics.

IRRIGATION. Temperatures are high in the dry summer, when few crops can grow without irrigation. Irrigation is highly developed in Israel. Out of a total cultivated area of 430,000 ha, one-half is irrigated. Water consumption has remained relatively constant during the past 10 years, ranging from 1,200 to 1,450 million m^3 per year, depending on rainfall.

Because of water scarcity, Israel eliminated gravity irrigation in favor of more efficient drip and sprinkler systems, which made it possible to increase the irrigation area without increasing water use. Average water use per hectare has dropped from 8,700 to 5,800 m^3, while agricultural production per hectare has increased.

In Judea and Samaria, irrigation water supply is estimated at 80 million m^3 per year for an irrigated area of 10,000 ha. In the Gaza region, the irrigation water supply was 67 million m^3 in 1985. The amount of water withdrawn annually from the aquifers of this region has exceeded the safe yield of 65 million m^3. Consequently, the water tables are low, with seawater intrusion inland. Salinity exceeds 500 mg/l in most of the region.

Supplying a total of 1,180 million m^3 to agriculture in the year 2000 depends on an investment program of US$100 million per year between 1988 and 2000, including the expansion and upgrading of wastewater use.

Water Pricing Policy and Cost Recovery

Pricing Policy

Two conflicting objectives affecting Israeli water pricing policies are social equity and population dispersion on the one hand, and economic efficiency and water conservation on the other. In the past, government policies in water resources development favored the former. As a result, substantial water supply has been subsidized by the government, and water demand exceeds available resources. Revisions of water pricing policies have recently been suggested in view of economic efficiency and water conservation, including real pricing of water and mobility of water according to economic demands. These revisions, however, have not yet been accepted.

In line with population dispersion policy, water charges for domestic consumption are fixed at the national level. Currently, the charge for municipal use is fixed at 26 cents/m^3. The charge for individual domestic users is subject to progressive rates to encourage water conservation. For instance, consumption of the first 8 m^3 of water is charged 32 cents; the next 8 m^3, 75 cents; and any level above, 123 cents. An additional sewage disposal charge of 32 cents is added to the rates per m^3 of water consumed. For irrigation, 80 percent of the allocated water is charged at 12.5 cents/m^3, and the remaining 20 percent at 20 cents/m^3. Any consumption above the allocated amount is charged at 26 cents/m^3. The charge for industrial use is 15 cents/m^3. Water charges are collected by Mekorot, a national water company.

The current average cost of water production and supply is 19.5 cents/m^3, which is calculated according to present practice without adjustment for inflation and investment interest. If full capital costs were considered, including adjustment for inflation, the average cost would rise to 33 cents/m^3.

Productive Value of Water Use

Between 1954 and 1978, the marginal productive value of water per unit increased by 4.5 percent. However, with the dramatic decrease in the profitability of the agriculture sector, a recent survey indicated that 25 percent of high-yield and 61 percent of low-yield farms have a lower productive value per unit of water used compared with the cost of water production per unit. Even if the subsidized water charge is applied, about 8 percent of high-yield and 42 percent of low-yield farms would still have a productive value lower than the water charge. These figures raise questions about the future policy of irrigation water supply. These questions should be examined in view of future trends in Israeli agricultural production and in world markets, but not in terms of the present crisis situation.

Cost Recovery

Operational costs are recovered partly by water charges and partly by government subsidies, whereas capital costs are recovered only negligibly without adjusting for inflation. Claims for full cost recovery have been vigorously opposed by the agricultural sector—the main water consumer—which has offered the following reasons: (1) the capital costs of the national water supply system should be considered a public infrastructure investment, and therefore should be borne by the entire public through government outlays; (2) subsidization of the agricultural sector is accepted worldwide; (3) it is unjustified to recover investments in security and sabotage prevention from water consumers, as well as to recover from the agricultural sector the costs of safeguarding drinking water quality and ensuring supply reliability for domestic users; and (4) the cost of the inefficiency of Mekorot, with a monopoly as the national water supplier, should not be borne by water consumers. The agricultural sector's reasons have been accepted, and therefore water charges have not been raised significantly. Consequently, full cost recovery seems impossible.

Environmental Issues

Salinity

Salinity is a major problem in water resources management in Israel. The quality of supplied water varies greatly, from 10 to 12 mg/l chlorides in the upper Jordan basin to 1,500 mg/l in wells in the Negev. About 18 percent of pumped groundwater contains more than 250 mg/l chlorides. Based on the extrapolation of past salinity trends, this percentage is expected to increase to 25 percent within 10 years. The increasing salinity in both the coastal and Yarqon-Tanninim aquifers constitutes a significant threat to their future use. The salinity level in Lake Kinneret, however, has declined steadily over the past two decades because of the diversion of saline springs to the lower Jordan River.

Although part of Israel's cultivated area is under salt-tolerant crops, most of it is still sensitive to salinity. In the Yizre'el Valley, for example, the reuse of drainage water has led to excessive salt concentrations in soil. Excessive irrigation and leakage from reservoirs also contribute to waterlogging. Two types of damage have occurred: (1) the increase of chloride content in the soil water reduces crop yields; and (2) a high sodium adsorption ratio destroys the texture of clays, resulting in the devastation of arable lands. Projections indicate that 6,000 ha will be threatened by salinity by the year 2000 if no corrective action is taken. To overcome salinity problems, salt-tolerant rootstocks and dual-water-supply networks should be introduced to permit selective water supply according to crop requirements.

Artificial Groundwater Recharge

The objectives of artificial groundwater recharge are to store surplus water in the aquifer for the long term, to upgrade water quality, and to improve the hydrological situation in the aquifer. Two methods used are the spreading and injection of water through wells. Selection of methods in a specific case depends on geological and hydrological conditions and on the nature of water available for recharge. Over the last three decades, Israel has acquired extensive experience in aquifer management, effluent treatment, and utilization of underground storage capacity.

Institutional Arrangements

Water is public property subject to state control. The Water Law of 1959 grants each individual the right to use water, contingent upon beneficial use. The law places the responsibility for the water sector with the Ministry of Agriculture. The Water Commission, under the Ministry of Agriculture, implements the provisions of the law. It is responsible for the planning, management, and supervision of all water-related matters. Within the commission, different divisions are responsible for different activities such as allocation, licensing, data collection and management, and efficient utilization. The minister of agriculture is also advised by a National Water Council, two-thirds of whose members represent the general public, with government representatives constituting the remaining one-third.

Two other organizations related to water management are (1) Tahal—Water Planning for Israel Ltd., the official water planning agency with responsibility for long-range planning (such as water master plans). Tahal consults with the water commissioner on water management policies; and (2) Mekorot Water Co. Ltd., the national water company providing about 65 percent of the country's water supplies. Mekorot is responsible for the construction and maintenance of water supply systems, the operation and maintenance of the NWC, artificial recharge, cloud seeding, desalination facilities, design of desalination plants, and operation of regional supply systems.

The Water Master Plan

Between 1986 and 1988, a new master plan for the water sector was developed. The plan emphasized the economic and quality aspects of water resources management. Five key problems were defined:

1. Demand exceeds annual replenishment of water resources;

2. Long-term storage is exhausted;

3. Water quality is deteriorating;

4. Increasing population will increase demand for fresh water by 30 percent;

5. Replacement of old water systems is necessary in the near future.

Possible water resources management measures were identified in the plan to alleviate these problems and include conjunctive use of surface and groundwater; reuse of sewage effluent; cloud seeding and control of outflows of floods and groundwater to the sea; control of water losses and encouragement of water saving; reduction of low-profit and water-consumptive agricultural production; pollution control; and conservation and rehabilitation of aquifers.

The ultimate solution to water problems in the Middle East in general, and in Israel in particular, is the large-scale desalination of seawater. Because of the high cost of this process, however, marginal resources (such as the reuse of wastewater), floodwater utilization, cloud seeding, and water resources management need to be pursued.

THE FUTURE OF THE EUPHRATES BASIN

John Kolars

The Euphrates River and its basin companion, the Tigris, account for almost the same flow of fresh water in the Middle East as the Nile, but differ from the Nile in that they rise and flow entirely within the Middle East. They offer a regional opportunity for either agreement or discord over the sharing of their waters. Agreements concerning their use involve a limited set of actors (Turkey, Syria, and Iraq), but such negotiations may have important secondary effects on neighboring nations outside the immediate basin, for example, Jordan, Israel and the West Bank, Saudi Arabia, and Iran.

The Euphrates Basin

The mean annual flow in the Euphrates is 32.7 billion m^3, and that of the Tigris is 49.2 billion m^3. Once past the Khabour tributary in central Syria, the Euphrates receives no additional waters in its course through Iraq to the Persian Gulf. Table 1 presents a brief description of the Euphrates basin and the amount of water contributed by each riparian.

Overview of The Three Riparians

The Euphrates river has three main riparians that utilize its waters: Turkey, Syria, and Iraq. Its role in the economies of the three nations, however, differs markedly.

Turkey

Turkey dominates the supply of flows to the basin. It is petroleum-poor, but is rich in rainfed agriculture and has surplus water. About 18.5 percent of the country's GNP comes from agriculture and 27.8 percent from industry. The country has attained food self-sufficiency, but it needs substantial revenues to buy fuel for its expanding economy. The country plans to harness the two rivers to increase electricity generation and to cultivate irrigated crops for export. To date, Turkey has focused its developmental efforts on the Euphrates, but plans to develop the Tigris in the future.

The Turkish government has made serious investments in and commitments to promoting water resources development, and has recently taken a major step in regional development through the Southeast Anatolia Project (GAP). The GAP consists of 13 hydropower production and irrigated farming subprojects, and 21 dam construction subprojects. The project's installed capacity of 7,500 megawatts will produce 25,000 gigawatt-hours of hydropower annually. Approximately 1 million ha of land will be irrigated using the Euphrates waters and another 600,000 ha using the Tigris. When completed, the GAP will double the country's hydroelectric production. If all 1.6 million ha of planned irrigation are developed, the irrigated land in the country will be increased by 49.2 percent. The government also hopes to improve the poor local economy in southeastern Anatolia through the GAP.

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Table 1. ***Riparian Contributions in the Euphrates Basin (percent)***

Riparian	*Land*	*Water*
Turkey	28	98
Syria	17	2
Iraq	40	n.a.
Saudi Arabia	15	n.a.
Total	100	100

Syria

Syria is water-poor. It remains heavily dependent on agricultural resources, which are limited by the arid climate. Food imports have increased, and deposits of petroleum and gas in terms of quantity and quality are uncertain, with Syria dependent on the Tabqa Dam on the Euphrates for much of its electrical energy. The country is divided climatically into four zones: a Mediterranean littoral zone with long dry summers and limited arable land; a north-south range of mountains running parallel to the coast that is too rough for agriculture; a central desert core southeast of the Euphrates River with less than 300 mm annual precipitation; and a semiarid zone running parallel to the mountains and extending to the north that is suitable for rainfed agriculture, but subject to highly variable seasonal and annual precipitation. Syria's population of 11 million (1987) is concentrated in the west and is sparsely distributed in steppe and desert areas in the east.

Prior to 1950, the waters of the Euphrates were used little in Syria. Traditional lifts, often camel-powered, brought water to fields on the river banks. Following independence, speculation in cotton led to a rapid development of gasoline pumps drawing water from the river. Consequently, the amount of irrigated land along the Euphrates and its tributary, the Khabour, increased.

A pilot project was initiated in 1973 on the left bank of the Euphrates in the Raid area. The purpose was to resettle 60,000 villagers who had been flooded by Lake Assad and to develop 38,700 ha of irrigation land. However, there were unexpected problems following project implementation. According to studies by the U.S. Agency for International Development, the Euphrates basin soils are largely gypsiferous, crusty, erosion-prone, and suitable only for careful irrigation. In 1982, the collapse of an irrigation canal was reported, causing a loss of 5 m^3 of water per second into the ground. In 1984, "cracks" occurred in the Balikh canal as a result of the deterioration of the gypsiferous soil on which the canal was built. In the Rasafah area, 25,000 ha had been earmarked for irrigation, but the entire area has now been abandoned because of gypsiferous soils.

The loss of agricultural land, the substitution of government-irrigated land for previously irrigated private parcels, and the struggle to achieve the original planned hectarage have been so frustrating that the Syrian government has recently deemphasized development along the river and has given greater attention to the management and improvement of arid land agriculture. Although the Euphrates is by far the largest perennial source of water for Syria, its use for both irrigation and power generation has failed to meet the country's expectations.

Iraq

Despite its relatively small population of about 16.5 million (1987), among the three riparians Iraq has the largest number of inhabitants living within the Euphrates-Tigris basin. Rapid population growth (a 300 percent increase since 1947) has resulted in petroleum revenues being used to import food (2.48 million tons in 1980). Agriculture accounts for less than 10 percent of GNP. Iraq is the second-largest oil producer in the world and depends almost completely on petroleum exports for foreign exchange revenues. However, the Iran-Iraq and Persian Gulf wars severely curtailed its oil production.

The gulf war resulted in the disruption of electric power generation throughout the country, which halted the pumping of water for both agriculture and domestic purposes. Seed stocks, the means to produce animal vaccines, and local fertilizer plants were destroyed. It is difficult to present a full picture of the country's effective agricultural and social activities in relation to water use and is now impossible to assess the combined effect of the two recent wars upon Iraq's economy and resources. The comments below are based on conditions as they existed before the recent wars.

Data from 1971 show that between 1960 and 1969, an irrigated area of 1.3 million ha was estimated to be dependent on Euphrates water and an irrigated area of 2.4 million ha dependent on the Tigris, totaling 3.7 million ha for the entire country. According to UN documents, in 1975 of 7 million ha of "cultivated land," 2.9 million ha were irrigated, and of 3 million ha of "cropped land," 1.6 million ha were irrigated, totaling 4.5 million irrigated ha. Using these figures, 52 percent of the total flow of 31.8 billion m^3 entering the country is estimated to be used for irrigation.

It is ironic that Iraq, one of the world's oldest agricultural civilizations, and with the greatest amount of irrigated land within the basin of the twin rivers, faces the most severe agricultural and water-related problems of the three riparians. The country's topography and the variability of the two rivers have exacerbated the country's water problems.

Control of the river flows has become a major issue among the riparians. Storage of flood waters in Turkish reservoirs, with subsequent release during low water periods, could ensure predictable supplies of water downstream. Both Syria and Iraq agree with this mechanism in principle, but agreements are yet to be reached on the quantities to be released.

Water Quality and Health Aspects

The quality of Euphrates water in Turkey is considered good in terms of dissolved substances and infectious, waterborne diseases. Iraq should be considered the most favored of the three riparians in terms of its petroleum resources and its access to two major streams and vast arable lands. In reality, however, it is now experiencing severe wartime destruction and poorly managed irrigation practices. The country has been, is, and will be at greatest risk with regard to the quality of the waters it receives from both rivers, particularly the Euphrates. Numerous water and sewage treatment projects were underway prior to the Iran-Iraq and Persian Gulf wars. Although the eight-year war with Iran did not disrupt Iraq's domestic water supplies, the situation was dramatically reversed during the gulf war. As a UN report indicates, Iraq is faced with a health crisis of disastrous proportions. Estimates of the amount of land lost to or impaired by salinity range from 20 to 68 percent. Immediate steps should be taken to restore and expand the country's domestic water supplies.

Syria might be least well off among the three nations in terms of its water resources, especially given its rapidly growing population in inland cities. Though it now looks better off in comparison with war-ravaged Iraq, it shares Iraq's deep concern over the quality and quantity of the Euphrates waters available to it.

Utilization of the Euphrates River

Turkey

The Keban Dam was among the first developments on the Turkish Euphrates. The utilization of the reservoir is mainly for hydroelectric generation and irrigation of about 35,000 ha, scheduled to increase to 58,231 ha by the year 2000. Downstream of Keban, the Karakaya Dam was the second development project, under which there is no farmland under irrigation as yet, although by the year 2000 about 42,000 ha are planned for irrigation. The Lower Euphrates Project, which is the core of the GAP, is based on the Ataturk Dam.

Eight different irrigation projects totaling 1.1 million ha are designed for completion after the year 2000. After 2000, evaporation from reservoirs and evapotranspiration from irrigated fields throughout the Euphrates portion of the GAP may deplete the river by as much as 16.9 billion m^3 of water annually. This depletion does not include a possible return flow of 7.4 billion m^3, of which roughly one-third will return to the reservoir and the remaining 4.9 billion m^3 will flow into the Balikh and Khabour systems in Syria. A summary of reservoirs and irrigation areas and associated water losses is found in table 2.

Syria

Development is undertaken in both Syria and Turkey on the Balikh and its tributaries. The proposed irrigation projects in Turkey (covering 378,000 ha) would completely dry up the local water resources of the lower Balikh in Syria. However, the major challenge facing Syria will be to manage the return flow from Turkey, which will result from additional water brought to the area from Lake Ataturk via a vast tunnel and canal system. The annual return flow might reach 2.1 billion m^3.

The Khabour River draws from several Syrian springs as well as seasonal surface flows from Turkey. The Turkish aquifer supplying the Syrian springs has an annual recharge of 852 million m^3. Syria plans to irrigate as much as 137,900 ha in the upper Khabour basin, using 1.7 billion m^3 of water annually, almost the same amount as the total flow of the Khabour River. Although the return flow from Syrian fields can provide 804 million m^3 per year, the amount of water recharging the Khabour springs aquifer could still be reduced by Turkish pumping by four-fifths, or about 57 percent of the annual flow of the Khabour River. Thus, this area faces either a depletion or a waterlogging crisis, depending on future developments. In sum, and considering irrigated land planned for the main stream valley, it is estimated that Syrian activities both on the Euphrates and its tributaries eventually could reduce total flow of the river by perhaps 6.9 billion m^3.

Table 2. *Estimated Water Losses (Reservoir Evaporation and Irrigation) of Major Reservoirs (million m^3)*

Dam	Reservoir evaporation losses	1992 Irrigated area[a]	1992 Irrigation losses	1992 Total losses	After 2000 Irrigated area[a]	After 2000 Irrigation losses	After 2000 Total losses
Keban	986	34	227	1,213	58	409	1,395
Karakaya	435	0	0	435	42	387	822
Ataturk	1,470[b]	0	0	1,470	1,260	11,339	12,628[c]
Total	2,891	34	227	3,118	1,360	12,135	16,900[d]

a. In '000 ha.
b. After 1992.
c. Includes losses from small side streams and reservoirs.
d. Includes losses from smaller reservoirs and the Euphrates Border Project.

Iraq

The Euphrates is used in Iraq to irrigate more than 1 million ha. The complex interchange of Euphrates and Tigris waters, which also involves a major drainage project between the two rivers, has been discussed above, but further consideration of it must be deferred until a clearer picture of postwar conditions has emerged.

The Political Arena

As water becomes more scarce, a new paradigm is developing. Food production and security based on ample supplies of water are beginning to weigh as heavily as petroleum profits.

Turkey is the only country in the region with surplus water. Before the gulf war, Turkey had reached the penultimate stage in the construction of the Ataturk Dam and was faced with the need to cut off the flow of the river to begin filling the reservoir. In January 1990, river flows were stopped at the dam for 27 days. The reason given was technical, not political, necessity. Iraq and Syria confronted Turkey on this issue. Syria's hydropower generation was affected, and the Iraqis blamed Turkey for significant water shortages. Turkey argued that upstream storage in Turkey will in the long run smooth the variance in river flows to ensure predictable power supplies.

The ongoing development of Turkish and Syrian hydrological resources is a critical issue for all riparians, particularly Iraq. In separate bilateral agreements, Turkey and Iraq, and Turkey and Syria have agreed on a flow of 500 m^3 per second across the borders into each country. Iraq recently raised its demand to 750 m^3 per second. Iraq has insisted that the issue is political, and that no other matters between Iraq and Turkey, such as trade, pursuit of terrorists, etc., can be settled until the water issue is decided. Discussion of the matter stalled when the invasion of Kuwait eclipsed the issue, but it is now beginning to resurface.

These problems extend back to 1920, when a treaty between the mandated territories of Syria and Iraq was signed, limiting the extent to which Syria might alter the flow of the river into Iraq. In 1923, the Treaty of Lausanne noted that Turkey should confer with Iraq before beginning any activities that might alter the flow of the Euphrates. Syria was not mentioned in this document. Iraq raised the question of "acquired rights" to a share of the river in 1962, when it agreed with Syria to form a joint technical commission to exchange data on river levels and discharges. Because no major hydraulic works were undertaken, there was little effort to specify the nature of the shares. By 1967, Iraq was designated as having the right to 59 percent of the natural flow of the river at the Syrian-Iraqi border. In 1972, Iraq presented its needs, which were based on cultivated surface area (compared with Syria's, which were based on crop-water duties). Another attempt to reach an agreement was made in 1973. In both instances, Syria refused to sign an agreement. In 1980, Iraq, Syria, and Turkey established a tripartite technical commission.

Future Scenarios

The Status Quo

Water is the key to sustainable development in the Middle East and to the well-being of the region's population. Although proven oil reserves in the area will last 100 years, water supplies are already insufficient throughout the region. As shown below, the situation is serious enough to warrant the immediate attention not only of the three riparians, but also of neighboring Middle Eastern states and the entire world community. In the present scenario, successful cooperation remains elusive.

The Turks will continue to develop the GAP as long as their financial situation allows. The Ataturk reservoir will eventually be filled, and its water will be used for hydroelectric generation and irrigation according to the country's needs. Turkey will continue to take the lion's share of the Euphrates River. Although the demand for energy will continue to increase, petroleum costs may destabilize the country's economy.

Syria will attempt to expand its irrigated lands to 320,000 ha. Turkish return flows down the Balikh and Khabour will increase the volume of those streams, resulting in environmental imbalances. The population will continue to increase with increasingly insufficient water supplies. The country will focus more attention on the Yarmouk and the snow waters of the Golan Heights, which are managed by the Israelis as part of their own water supply. This will increase the potential for conflict.

Iraq's reconstruction will be hampered by decreased and polluted downstream flows. Scarce water supplies will inhibit efforts toward desalination and may seriously impede the natural flushing of waste and salts from the mainstream of the river. Syria may again form an uneasy detente with Iraq to bargain with Turkey, but no lasting water treaties will emerge. Tensions will increase as Iraq recovers its ability to make demands rather than pleas. Waters of the Tigris may be partly transferred to the western part of Iraq, but may still prove insufficient for increasing agricultural needs.

Intrabasin Agreements

The difference between the status quo and this second scenario is the possibility of bilateral agreements being formed. As needs change over time, there could be a continuous shifting of alliances, possibly providing short-term solutions to problems related to the sharing of the Euphrates and Tigris waters. A series of intrabasin bilateral agreements may be reached and may ameliorate immediate tensions. Under these circumstances, neighboring states outside the basin would have little influence on water-related decisions made unilaterally and/or bilaterally by the three nations in question. Although piecemeal solutions may be achieved, they would be unstable. Such solutions would do little either to meet the long-term needs of each nation or to facilitate an overall peace process involving the entire Middle East. The Middle East would continue to be subject to the manipulations of world powers.

Turkey would experience piecemeal development. The GAP would develop slowly and some, but not a majority, of the targeted area would be irrigated. Crops produced may not find willing Arab markets. This may slow the expansion of Turkish agriculture and delay downstream water shortages.

Syria would feel an increasing scarcity of water and may spend more revenue to meet domestic needs through reuse of water and reduction of irrigated agriculture. It stands between two stronger riparian neighbors and would find little incentive to seek peaceful solutions to related problems on the Yarmouk. Again, opportunistic and ephemeral bilateral treaties would prevent continuous and sensible long-term planning.

Severely encumbered by the need to recover from two wars, Iraq may find itself unable to establish and maintain claims to its share of the Euphrates and to achieve reasonable treaties with its neighbors.

Interbasin Data Management

Agreements on the basin's management not only involve the three main riparians, but also have important effects on neighboring nations such as Jordan, Israel and the West Bank, Saudi Arabia, and Iran. Viable negotiations among countries depend largely upon the availability of complete and accurate information regarding water resources. Regionwide comprehensive water management, with particular attention to agriculture, nutrition, and health conditions, could be a basis for cooperation among nations because of the mutual benefit that such cooperation would engender. Sustainable development along such lines could be accomplished at least cost by utilizing existing information and data handling systems.

Such systems could be incorporated into, for instance, a regional information clearinghouse (RICH), located either within the region or elsewhere on "neutral" territory. To identify specific problems in their early stages, a RICH would aggregate pertinent data from satellites and individual nations and tap into worldwide information networks to generate information on a real time basis. Nations would be encouraged to participate by having access to a timely, accurate, and politically neutral information system. A RICH would compile factual data bases and refrain from using them for political analysis, which would be the prerogative of nations sharing the data bases.

With river basin management, data regarding future water availability might be the basis for committing resources to the development of interlocking systems, such as the Turkish Mini-Peace Pipeline Project. Early in 1987, Turkish Prime Minister Ozal suggested the idea of a peace pipeline as an answer to the escalating water shortages of other riparians. The pipeline could carry water from southern and western Turkey, and from the Tigris River in eastern Turkey, to western Saudi Arabia and the United Arab Emirates. The initial estimate of water transfer was 1.28 billion m^3 per year, flowing south through a double western pipeline, and 0.91 billion m^3 per year flowing east. Costs were estimated at US$17-20 billion. Technologically feasible, these seemingly expensive lines could deliver water at one-third the cost of a similar desalinized quantity. The Peace Pipeline has attracted considerable interest. However, as yet no firm commitment has been made, nor has a feasibility study been undertaken. A smaller version of the peace pipeline carrying much-needed water only as far as Amman, Jordan, would be financially more attainable and politically less complex.

COMPREHENSIVE WATER RESOURCES MANAGEMENT: AN ANALYSIS OF TURKISH EXPERIENCE

Ozden Bilen and Savas Uskay

Turkey's socioeconomic structure is characterized by a transition from an agriculture- to an industry-oriented economy, shifting outward and inducing a changing public sector role—from leading economic growth to supporting private sector development. The country has abundant, though unevenly distributed, water resources. Its major water sector strategies are to decrease agricultural production's dependence on climate by introducing modernized irrigation techniques and to shift energy policy from imported oil dependence to indigenous resource development, including hydropower. This paper emphasizes that allocation of water resources cannot be separated from economic considerations. Allocation policy should also be flexible to adapt to new demands. The regulation of consumption through demand management tools, such as appropriate pricing policies, has recently received greater attention in Turkey. The paper also discusses the establishment of development objectives and the identification of constraints. In the coming decades, greater emphasis will be given to water pollution control and water resources conservation, recognizing that measures to increase water use efficiency are as important as finding additional sources of water.

Water Resources Development

Socioeconomic Factors

The nation's socioeconomic structure is characterized by a transition from an agriculture- to an industry-oriented economy. The share of agriculture in total output declined from 27.6 percent in 1977 to 18.1 percent in 1990; conversely, the share of the industrial sector increased from 19.8 to 29.2 percent during that period. Turkey is also experiencing a rapid increase in urban population. The overall population growth rate is 2.4 percent, whereas the rate of urbanization is 3.6 percent and is expected to continue at that level. In response to poor economic growth in the late 1970s, the government implemented several reforms, including shifting the orientation of the economy outward and changing the role of the public sector from leading economic growth to supporting private sector development, a policy that currently encourages private investment and decentralization to regional authorities.

Water Resources

The country, with a total area of 779,452 km^2, has a continental climate, characterized by cold, rainy winters and dry summers. Average annual rainfall is 643 mm. Although Turkey has an abundance of water, it is not evenly distributed over time and space. Precipitation varies from less than 400 mm in the inland areas of central Anatolia to over 2,500 mm on the eastern Black Sea coast, where rainfall occurs throughout the year. Of an average annual runoff of 186 km^3 and a safe groundwater yield of 10 km^3, an estimated 95 km^3 and 9 km^3 of water resources, respectively, could be developed for

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consumption. Currently, total annual consumption of groundwater is 5.4 km^3; actual consumption of surface water is 25.2 km^3, about 30 percent of the potential.

Sectoral Water Use

IRRIGATION. In the 1990/94 five-year development plan, the strategy is to decrease the dependence of agricultural production on climate by introducing modernized irrigation techniques. To achieve its objectives with respect to food security and exports, Turkish agriculture needs to grow at 4 percent annually. Irrigation infrastructure is indispensable because of the uneven temporal distribution of rainfall. About 8.5 million ha of land are estimated to be economically irrigable; 1.6 million ha have already been developed, and irrigation construction is underway for another 1.3 million ha (see table 1 for present and future sectoral water use).

HYDROPOWER. Hydropower is regarded as a major national energy resource, and its development is supported. Following the oil shocks of the 1970s, the Turkish government shifted its energy strategy from dependence on imported oil to indigenous resource development, including hydropower. The share of hydropower in total energy supply has increased substantially, from 30 percent at the beginning of the 1970s to more than 40 percent recently. Turkey has substantial hydropower resources, and the General Directorate of State Hydraulic Works (DSI) and the General Directorate of Electrical Survey Administration estimate the economically viable hydropower potential at about 35,618 megawatts. Only 20 percent of this potential has been developed so far, but this figure will rise to 33 percent within the next five years after construction of large projects at Ataturk, Batman, Catalan, Gezende, and Ozluce.

WATER SUPPLY AND SEWERAGE. Turkey plans to supply sufficient, safe water to all settlements by the end of 1993 and to make significant progress in sewerage and sanitation systems. Increase in drinking water access, comparing 1980 and 1990, is shown in table 2. By the end of 1989, 56 percent of the urban population was connected to modern sewerage systems. The construction of sewage treatment plants and marine disposal units has also been initiated to prevent environmental pollution.

Institutional Arrangements

Water rights are key to institutional arrangements. Legislation and organization and the relation between them are basic components of the institutional framework: organizations function well only if empowered by legislation, which is effective only if properly implemented by appropriate organizations.

Table 1. *Water Demand, 1990-2000*
(km^3)

Use	*1990*	*1995*	*2000*
Drinking and utility	5.9	7.4	9.0
Irrigation	32.3	37.0	41.8
Industry	5.1	6.2	7.3
Total	43.3	50.6	58.1

Source: General Directorate of State Hydraulic Works.

Table 2. *Percentage of Population with Access to Drinking Water, 1980, 1990*

	1980		*1990*	
	Urban	*Rural*	*Urban*	*Rural*
Home connection	64.2	62.0	97.7	85.0
Other means	21.8	20.0	1.8	12.0
No access to water	14.0	18.0	0.5	3.0

Water Rights and Ownership

A series of water laws and legislation has been established, such as the law establishing the DSI, the Groundwater Law, Drinking Water Supply Law, Provincial Bank Law, Rural Water Supply Law, and Law of Environment. Special laws for sectoral water uses have also been issued by introducing the prior-authorization system.

The basic principle governing surface water use is that it is a public good subject to rights of prior use. According to the Turkish constitution, all surface and groundwater, except privately owned springs, belong to the government. The development of water resources, therefore, is considered the responsibility of the state. Legislation regarding groundwater use is more comprehensive than that for surface water. Generally, the DSI needs to approve both the use and extraction rate of water for different activities. Water rights can be neither sold nor transferred. If any conflicts arise among users, various customary rules and local regulations apply. If these do not help in resolving the matter, rights are settled by court decision. When a prospective user intends to divert water, however, court adjudication can be rendered almost impossible because of the difficulty in identifying prior existing rights within provincial and district jurisdictions. New laws on water rights are therefore required. With water use for hydropower and thermal energy production, special legislation has been enacted requiring prior authorization for water use.

Water Sector Organizations

The organizational structure of the water sector in Turkey is not complex because of the limited number of authorities involved. The responsibility for water resources management and nationwide water planning is centralized within the DSI, which was established under the Ministry of Public Works in 1954. Based on economic factors and emergency situations identified by the Council of Ministers, the DSI establishes priorities for development and implementation of irrigation, power generation, flood control, and river training. The responsibility for drinking water supplies in rural areas was originally given to the DSI, but was later transferred to the General Directorate of Rural Services. The DSI is the only legal authority responsible for the exploitation, use, and allocation of groundwater.

At the national level, the DSI coordinates water use in cooperation with other agencies, which must obtain prior approval from the DSI for each project they undertake. These agencies include (a) the General Directorate of Rural Services, part of the Ministry of Agriculture, Forestry and Rural Affairs, responsible for carrying out on-farm works for state irrigation schemes, developing small irrigation schemes, and supplying drinking water to rural areas; (b) the General Directorate of the Bank of Provinces (Iller Bank), under the Ministry of Public Works, providing credit to finance and implement urban infrastructure; (c) the General Directorate of Electrical Power Resources Survey, under the Ministry of Energy and Natural Resources, responsible for carrying out hydrological studies, geotechnical investigations, and mapping activities to evaluate national hydroelectric potential and also involved in the planning and design of hydropower projects; and (d) the Turkish Electrical Authority (TEK), under the

Ministry of Energy and Natural Resources, responsible for generation, transmission, and distribution of electricity. Hydropower schemes constructed by the DSI are transferred to the TEK for operation.

Human Resources Training

The current lack of experienced, qualified personnel has tended to increase the cost of projects and to reduce project efficiency. Statistical information concerning human resources training is still not available in Turkey. Policies emphasizing human resources planning and training should be developed. Experience shows that the contribution of private consulting firms to the elaboration of water development projects has been positive: policies should promote an appropriate atmosphere to encourage the creation of such firms.

Environmental Issues

Legislation and Executing Bodies

Legislation was passed in 1983 on initiating environmental impact assessment (EIA) through the Environment Act, followed by detailed regulations in 1988. The legislation has provisions concerning the establishment, location, and operation of industrial and other activities. Operating permits will be denied to those enterprises that do not have, either individually or collectively, the required waste treatment facilities. Another policy related to environmental protection is the aggregation of industries in certain areas where the impact of their activities on the environment can be minimized. Several cities have started implementing this policy through the relocation of polluting industries.

The Ministry of Environment (MOE) is the main coordinating body for environmental management, responsible for formulating environmental policies and legal arrangements. It also coordinates all environmentally related national and international activities. Central and provincial environmental commissions have also been organized and are attached to the MOE. Nine regional directorates have been established.

Key Issues in Environmental Impact Assessment

INVOLUNTARY RESETTLEMENT. Two options are available for the resettlement of people displaced as a result of land submergence by a reservoir: resettlement through government arrangements or cost compensation for property lost (in which case people are free to settle wherever they like). In both cases, the major concerns are that (a) coordination among project-implementing agencies be arranged during an early project phase; (b) there be adequate information concerning compensation for affected groups; (c) resettlement sites be carefully selected; and (d) resettlement plans be implemented by expert teams.

WATERBORNE DISEASES. These are associated particularly with irrigation projects. Proper operation and maintenance (O&M) should be carried out to prevent development of swampy areas where water is permanently spilled via broken, prefabricated flume-type canals.

ECOLOGICAL IMPACT. The preservation of low-lying delta has ecological significance. This objective often conflicts, however, with the needs of land management, such as low water tables and drainage, salinity, and alkalinity control. Reclamation for agriculture and irrigation development put pressure on these ecologically sensitive areas. For example, in the deltas of the Menderes and Gediz rivers, irrigation development reduced the flow to marshes and endangered the life of wild birds, and drainage discharge threatened marine life.

Water Quality Management

Water quality management is reflected in the Water Pollution Control Regulation of 1988. This regulation identifies four water quality classes and specifies their uses. Classification was based on extensive water quality monitoring by the DSI. The regulation also identifies protection zones around reservoirs and lakes to prevent pollution. Industrial wastewater discharges are subject to different effluent standards, depending on industry type.

The following actions need to be considered in planning: water quality networks should be expanded; an accurate inventory of pollution sources should be compiled; technical and financial support should be available for industries to establish suitable treatment facilities; and environmental legislation, including penalties, must be enforced.

Water Allocation and Pricing

Intersectoral Allocation

Intersectoral water allocation involves allocation and reallocation of water among different users, such as irrigation, hydropower, urban supply, and in-stream recreation. Water resources allocation cannot be separated from economic considerations because transfer of water from one use to another indicates adjustment in sectoral economic activities. For example, transfer of water from hydropower to irrigation will increase income in the agricultural sector; hydropower generation, however, contributes to the entire economy.

The general approach to dealing with alternative uses of water requires the identification of the objectives of all interested parties and exploration of viable alternatives. Actions can then be determined on the basis of an evaluation of gains and losses, both economic and noneconomic, for each party. For example, in the Southeastern Anatolia Project three alternatives were presented representing different development schemes in different sectors. Criteria such as incremental capital output ratio, gross regional production, foreign currency requirements, and total public investment were selected as macroindexes for comparison.

Allocation policy should also be flexible to adjust to new demands. In the Gediz and Menderes river basins, water was overallocated to irrigation. Because no provisions were made in the original allocation plan for transfer of water rights from agriculture to higher-value uses, urban development in the region led to the exploitation of marginal water resources at a high cost.

Interbasin Transfers

Interbasin water transfer is being implemented on a large scale in Turkey. For example, 1.2 billion m^3 of water will be transferred annually from the Great Melen River to Istanbul to meet the growing water demand in the capital, at a cost of US$2.8 billion (US$2.3/m^3). Such large-scale transfers will affect the social and economic conditions of the population. It is therefore important to assess all the economic, social, and ecological consequences of such diversions.

Pricing and Cost Recovery Policies

In the past, water resources development policy was almost totally dominated by supply management. The regulation of consumption through demand management tools, such as appropriate pricing policies, has recently received greater attention. The pricing approaches selected affect the distribution of income, resource allocation, and level of investment.

IRRIGATION. In Turkey, irrigation water charges reflect the cost of operating and maintaining irrigation facilities plus an amount required for the recovery of capital costs, amortized over a period not exceeding 50 years. No interest is charged. Since 1989, O&M charges have been set to recover 100 percent of the actual costs incurred in the previous year. Over the past three years, however, collections have only amounted to about 37 percent of total assessments, due to inadequate penalties for late payment. Recent legislation has proposed an increase in the penalty from a flat rate of 10 percent to a monthly charge of 7 percent for delays.

Agricultural water use is heavily subsidized, with government irrigation schemes financed by the national budget. This represents a redistribution of income from urban taxpayers to farmers. This method of transferring income from the "richer" to the "poorer" regions contributes little to equitable income distribution, because at the scheme level flat rates apply to all farmers regardless of farm size, and charges are levied on a crop area basis with different rates for different crops. This system does not lead to more efficient water use. A volumetric charging system and participation of farmers in investment decisions regarding irrigation projects should be introduced to motivate water conservation.

WATER SUPPLY. Municipal water supply charges are determined by municipal assemblies, taking into account O&M and amortization of capital costs over 30 years, and constitute part of municipal budgetary incomes. Drinking water is charged in two ways: a fixed amount regardless of consumption and a variable amount depending on consumption. Additional water charges are also made in some large cities, such as Istanbul, Ankara, and Izmir, to cover sewage disposal costs.

Comprehensive Water Resources Planning

Two major components of comprehensive water resources planning are the establishment of development objectives and the identification of constraints.

Establishment of Development Objectives

Comprehensive water resources planning should first examine national development objectives. The main objectives of the sixth five-year development plan (1990/94) are to improve income distribution under sustainable development policies, to reduce unemployment, and to eliminate interregional differences in the level of development. In addition, strategies for the water sector include developing backward areas; avoiding water pollution; and preserving historical, cultural, and archaeological areas.

Identification of Constraints

There are three basic obstacles in water resources planning and development: population growth and urbanization, financial constraints, and environmental concerns.

POPULATION GROWTH AND URBANIZATION. The growth of urban areas and the creation of an urban middle class have changed household structures and social preferences, resulting in a rapid rise in per capita water consumption. Until 1950, Turkey was predominantly an agricultural country with about 75 percent of the population living in rural areas. Since then, modern technologies and marketing have been introduced in agriculture, resulting in a massive rural migration to urban areas. Sixty percent of the population lives in urban areas, and this figure is expected to increase to 70 percent in the year 2000. In rural areas, water consumption for domestic purposes is less than 50 liters/day, whereas it has reached 200 liters/day in urban areas. This rapid growth in demand has strained water resources and has also resulted in increased water pollution from sewage.

One of the most important concerns regarding population growth is meeting present and future needs for food and fiber. The options are an increase in the cropped area, an increase in yields, or a combination of both. The response in Turkey has been an expansion in irrigated agriculture.

FINANCIAL CONSTRAINTS. Financial management of the water sector (irrigation, hydropower, water supply, and sewerage) is fundamental to the integrated management structure, with financial policies playing an important role in achieving social and resource allocation objectives. Investment in the water sector ranks third, after transportation and energy, and from 1980 to 1991 accounted on average for 11.7 percent of total public investment.

The expansion of water sector investment could be achieved by introducing private sector participation and by selling revenue-sharing bonds to the public. In the hydropower sector, the government now encourages private sector participation in electricity generation through the removal of all legal constraints. The most extensive application model of this kind is the recent "Build, Operate and Turnover" scheme, under which private investors are encouraged to finance, build, and operate a given facility for a certain period, and then to transfer it to the government. Revenue-sharing bonds and the use of the proceeds to finance other projects with revenue potential have been successfully implemented in the hydropower sector since 1984. The impact of this policy is reflected in higher rates of hydropower investment.

There is a growing need to develop a rational financial plan to support development programs. The plan should address priority investments in the water subsectors; multiyear-based investment strategies; improvement of the investment data base; and improvement of investment-planning skills.

ENVIRONMENTAL CONCERNS. Recently, serious water pollution problems have arisen in certain areas of Turkey. Major factors contributing to pollution are the lack of adequate sewage treatment and industrial waste treatment facilities, and agricultural intensification. The reuse of polluted water resources will require high expenditure and advanced technical facilities.

Technological Aspects

A series of technological development activities has been initiated, including development of a flood forecasting and warning system for all watershed areas, a research project on introducing new irrigation techniques, and a study program on increasing irrigation system efficiency. The DSI controls all files and archives for hydrometric and meteorological information. It recently inaugurated a modern, computerized data base system for meteorological and stream flow measurement. Coordination with other organizations on water resources inventory data is encouraged by the DSI to establish compatible data banks. An autonomous institute could be set up to collect, store, and process these data.

International Water Issues and Cooperation

Nearly 22 percent (608 km) of Turkey's international borders with the former Soviet Union, Greece, Syria, Bulgaria, Iraq, and Iran are formed by rivers. Several agreements have been signed between Turkey and neighboring countries concerning border watercourses. A joint boundary water commission was established with the then-Soviet Union under the terms of the 1927 treaty on the beneficial uses of boundary waters. The commission consists of four government representatives, two from each country. Another agreement was reached in 1973, in which the commission prepared a plan for the redemarcation of the west boundary of the Aras River. Also in 1973 agreement was reached on joint construction of the Arpacay Dam and the equitable allocation of regulated river flows. Since 1986, the dam has been operated by a joint technical commission.

Table 3. *Population and Water Availability Projections*

Year	*Population (millions)*	*Water (m^3/cap/year)*
1990	56.5	3,471
1995	63.3	3,096
2000	69.8	2,808
2005	76.5	2,562
2010	83.4	2,350

The Meric basin is shared by Turkey, Bulgaria, and Greece. The upstream area is located in Bulgaria. In 1950, the Turkish and Greek governments jointly authorized a master plan to develop the basin's downstream areas, without considering the activities in the upstream areas. Several flood control facilities have been implemented along the river. Lack of control over river segments located upstream in Bulgaria, however, has affected downstream activities adversely.

In 1946, Turkey and Iraq signed a protocol for the control of the waters of the Tigris and Euphrates rivers and their tributaries. A joint technical committee for the regional waters was established according to another protocol between Turkey and Iraq in 1980. Syria joined the committee in 1983. Cooperation in hydrological data exchange has been beneficial to the three riparians. Through the committee's studies, technical rules will be further developed for reasonable and equitable utilization of water resources in the Tigris-Euphrates basin.

Future Outlook

Estimates of future population growth and water availability per capita are shown in table 3. Generally, countries with annual water availability between 1,000 and 3,000 m^3 per capita have major problems during drought years. As seen from the table, water conflicts in Turkey will become increasingly acute.

Recent estimates have suggested that in the Middle East average temperatures will rise by about four degrees centigrade as a result of the greenhouse effect. This would result in greater rates of evapotranspiration and increased irrigation needs. Consequently, drought management will become more important. Measures that increase water use efficiency are as important as finding additional sources of water. Irrigation water use per hectare could be decreased by almost 30 percent by improving water management at the farm level. Sprinkler irrigation at the farm level has been introduced in Turkey and is expected to grow as a result of financial incentives. In addition, quality may become more important than quantity in determining water availability in some river basins. In the coming decades, more emphasis should be placed on water pollution control and water resources conservation.

PLANNING AND MANAGEMENT OF WATER RESOURCES IN SYRIA

Yahia Bakour

With an uneven spatial distribution of limited water resources, Syria is unable to meet its increasing demand for water. Per capita water consumption has been declining significantly as a result of decreased discharge from international rivers and high increase in population. The government's recent policy has been to stress construction of water treatment plants, monitoring of pollution levels, and improvement of water use efficiency in the agricultural sector, focusing on identifying and reducing water losses. This paper emphasizes the urgent need for joint development of international rivers and discusses new strategies Syria has adopted to tackle its emerging water deficits.

Background

Syria has a total area of 185,000 km^2. Arable land represents 33 percent of the total; range and pasture lands, 43 percent; and forests, 3.9 percent. Slightly more than 11 percent of arable land is irrigated. There are seven main catchment basins in Syria: the Euphrates, Tigris and Khabour, Yarmouk, Orontes, Damascus, Badia, and coastal basins. Geographically and climatically, the country is divided into four regions: the Badia region, with 138 mm annual rainfall; the inner region, with 250 mm; the coastal region, with 1,061 mm; and the mountainous region, with 1,500 mm.

In 1990, Syria's population was 12.1 million. The annual population growth rate is 3.5 percent (4.1 percent in rural and 2.9 percent in urban areas). Between 1963 and 1989, per capita income in Syria rose by 60 percent. The 1984 food balance of payments deficit of 2.6 billion Syrian pounds (LS) decreased to LS 1.2 billion in 1989. The success of government policies in promoting exports and offering exporters tangible benefits is reflected in this decline.

Water Resources Utilization

The water resources available to Syria total about 80 billion m^3, of which 43.6 percent can be utilized. The annual discharge of groundwater is about 5.6 billion m^3, extracted from the upper water-bearing formations. Deeper aquifers, which have great potential and are of good quality, have not yet been developed.

Syria's main water problem is uneven spatial distribution. About 85 percent of total water resources are located in the unpopulated northern regions, causing shortages in areas where demand is greater. The country's annual per capita water consumption has declined, from 1,320 m^3 in 1976 to 791.7 m^3 in 1989, mainly because of a decrease in the discharge from international rivers and a high increase in population.

As for water use in the main sectors, most industrial development has occurred in basins that do not experience water shortages, for example the Orontes, where half of the country's industrial water is

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consumed. In the Euphrates basin, 36.3 percent of industrial water supplies are utilized. The water requirement for agriculture is estimated at 10.3 billion m^3, representing 47.4 percent of total water use. In areas where irrigation supplements rainfed agriculture, production and productivity are nearly four times higher than in unsupplemented rainfed areas. Domestic water demand is about 828 million m^3, which is expected to reach 1.2 billion m^3 by the year 2000. The current daily water consumption per capita is 200 liters, still below international standards.

Institutional Arrangements

Before 1982, Syria had no central coordinating agency for water management. The responsibility for the water sector was shouldered by several ministries, including the Ministry of Public Works, the Ministry for the Euphrates Dam, the Ministry of Municipalities and Villages Affairs, and the Ministry of Agriculture and Agrarian Reform.

Under a 1982 law, the Ministry of Irrigation (MOI) was established to take charge of activities related to the water sector. It was made responsible for managing water resources according to development plans approved by the Supreme Council for Planning and the Supreme Council for Agriculture. One of the main elements of the MOI's responsibilities was to propose an institutional framework to identify the functions and roles of different institutions working in the water sector. These functions and institutional responsibilities may be categorized as:

- *planning and monitoring*, carried out by the Supreme Council for Planning and the Supreme Council for Agriculture. The former approves water resources utilization plans and monitors their implementation; the latter approves the allocation of water to the agricultural sector;

- *surveys and research*, performed by (a) the Water Studies General Company, for examining groundwater aquifers and their utilization; and (b) the MOI, for establishing hydrometeorological networks for surface and groundwater, evaluating water availability, and appraising irrigation projects.

Responsibility for domestic water supply, sanitation, and drainage is assumed by a corporation in each province representing the Ministry of Housing and Public Utilities. The main problem with this institutional arrangement is substantial duplication of effort.

Legislative policies for the water sector follow basic legal principles established for the entire country. The detailed implementing regulations are generated by ministers. The first water law was prepared in 1925, stating explicitly that all water resources were publicly owned and that legal ownership could not be sold. The water law of 1958 defined the utilization of water resources for agricultural production. The law covered the procedures for utilization of surface water and extraction of groundwater and for legal drilling of wells and pumping facilities. The law limited the pumping of public water to those with official approval.

The Ministry of Public Works has published several regulations for the application of the water law. The regulations outline legal approval needed for water pumps installed on rivers, define the quantities of water allocated to agricultural schemes, and forbid water diversion from springs. The law also defines property rights for extending irrigation canals across private lands and describes water charges for landowners benefiting from irrigation schemes.

Environmental Status

The environmental status of the major basins varies. The Orontes basin is experiencing increased pollution hazards caused by fertilizer industries from nearby Homs Province, the Homs town sewerage system, and agricultural drainage. In the Damascus basin, the Barada River is seriously polluted during the summer when its flows are lowest. The waters of the Yarmouk, Badia, and Tigris and Khabour basins and the coastal area are clean, and pollution is under control. In the Euphrates basin the water is clean, and agricultural drainage is the only source of pollution.

Government policies stress the construction of water treatment plants in the major cities and the monitoring of pollution levels. Matters related to the prevention of water resources pollution are under the control of the State Ministry for Environment, which coordinates with the MOI and local agencies to implement these policies.

Water Charges

A 1972 law was the first to reflect new policies on water charges in which irrigation water users were charged. These charges are based on the area irrigated and not on the quantity of water used. A rate of LS 70/ha was applied, plus LS 5/ha for electricity consumption and operation and maintenance (O&M) of the irrigation network. In 1989, these charges were raised to LS 1,075/ha and LS 200/ha, respectively, due to inflation. Regardless, these charges cover only a small portion of the actual costs of water supply and are insufficient to motivate water consumption economies or to apply modern water-saving irrigation techniques. Accordingly, there is a need to revise the charges to cover, at a minimum, costs involved in supply. Such charges should be based on the quantity of water used as well as the area irrigated. (There is no charge for the extraction of groundwater, regardless of the quantities extracted or the depth of drilling.)

The government also assumes the costs of constructing dams and irrigation networks. The beneficiaries of government irrigation schemes pay nominal charges to cover O&M costs and fuel used in supplying water. The charges do not include the capital costs of water supply.

Domestic water charges have been regulated since 1990 by the Ministry of Housing and Public Utilities (see table 1). A fixed monthly charge of LS 36 is also assessed, regardless of the consumption level, as a contribution to the maintenance of the public water supply network.

Table 1. *Charges for Drinking Water Use* *(LS/m^3)*

Monthly consumption (m^3)	*Charge*
1-20	1.25
20-30	2.00
30-60	5.00
60 and above	6.00
Government departments	3.00
Industrial, commercial, and tourist	8.00

LS = Syrian pounds.

Policies and Actions for Improving Irrigation Efficiency

Government policies are directed toward improving the efficiency of water utilization in all sectors, especially in the agricultural irrigation sector, which is considered the most water-intensive. Consequently, the optimization of water use focuses on identifying and reducing irrigation water losses and losses from surface runoff flowing into the sea near the coastal regions.

In most schemes, the efficiency of irrigation networks is 60 percent. The current method of basin (or flooding) irrigation results in a 50 percent loss of water. Use of drip irrigation techniques can reduce water consumption by 45 percent, and use of sprinkler irrigation techniques can effect a 20 percent reduction. It is estimated that the total water loss could be decreased by 20 percent if network efficiency were increased to 75 percent.

Modern techniques (drip and sprinkler) have been introduced in water-deficient areas, with landowners encouraged to adopt them and to abandon old (basin irrigation) systems. Such modern irrigation techniques, however, are practiced only by the private sector on farms irrigated by groundwater. Areas using modern irrigation techniques in Syria do not exceed 1 percent of the country's total irrigated area.

Despite the importance of adopting modern methods of irrigation, the possibilities for large-scale adoption are limited by the availability of the necessary facilities needed to convert the old systems. The state's role in supplying the necessary foreign exchange for the purchase of the required equipment and parts should be studied.

New irrigation technologies will be pursued after crop requirements in the different climatic regions have been identified. There is also a need to investigate the ability of farmers to adopt modern irrigation methods and to use them efficiently. Following FAO's experience in this field, the Syrian government is transferring modern irrigation technology to the country's farmers. An agreement was signed with FAO to improve the means of irrigation, with the objective of providing farmers with new irrigation systems, such as drip and sprinkler networks. The systems will be purchased by farmers through subsidized, medium-term loans, to be paid back in three to five years. Syria's agricultural bank is involved in providing the necessary funds. The project includes elements for farmer training in system installation and operation. Experts will supervise the daily operation of the new system until the farmers can operate it efficiently.

International Basins and the Need for Joint Development

Local rivers in Syria have been almost completely utilized. Two international basins, the Euphrates and Yarmouk, are essential to the operation of Syria's economy. Most of the country's water resources are supplied by these two basins, in which rivers are shared by several countries.

Syria, Turkey, and Iraq are the main riparians in the Euphrates basin. The discharge of the Euphrates alone is twice as much as that supplied by all other rivers in Syria. The river irrigates 250,000 ha in Syria and supplies water for the domestic needs of several cities and villages along its coast. The development through irrigation of another 644,000 ha of new reclaimed land is planned. Discharges from the river, however, have been declining continuously (as a result of the expansion of Turkish irrigation development upstream), from 1,063 m^3/second in 1982 to 795 m^3/second in 1989, as measured at the border. This has hampered the generation of hydroelectricity and increased uncertainties regarding the future development and historical rights of both Syria and Iraq. To resolve the issue, a treaty to distribute the river waters among Syria, Iraq, and Turkey should be negotiated to facilitate accelerated development in the region. The Aleppo basin, a subsidiary of the Euphrates, encompasses both the Sajour and Queiq rivers, which originate in Turkey. An increase in the Turkish utilization of these rivers upstream has resulted in a decrease of flows measured at the border.

The Yarmouk basin is shared by Syria and Jordan. An agreement on the joint development of the basin has been signed by the two countries.

No treaties or agreements have been negotiated on the actual distribution of water in these basins. Such agreements need to be negotiated for the benefit of all countries. Agreements that honor historical rights and distribute the resources stably and equitably will lead to a rapid development of the entire region.

Future Strategies and Recommendations

With water shortages, new strategies should be adopted to tackle the current and emerging deficits. The most important are:

- utilizing groundwater resources (efforts should be directed at deeper drilling of aquifers [below 400 m], including the completion of feasibility studies and estimation of investment requirements);

- storing seasonal flood flows and surface runoff and constructing storage dams;

- building treatment plants for sewage and agricultural drainage;

- exploring possibilities for exploiting new water sources, such as desalinating sea water and harvesting rainwater.

The following recommendations may be considered:

- *water resources studies*. Data and other information systems need to be improved, especially those relating to the availability and quality of surface and groundwater resources, deeper aquifers, and proposals for alternative water uses. Studies should be conducted on the distribution and allocation of international river waters among riparian countries;

- *institutional structure*. Institutional improvements first require personnel training. A regional institution should be set up to coordinate activities among various regions and basins;

- *irrigation methods*. A method of supplementary irrigation could be introduced in the winter, utilizing dual-rotation patterns. It would reduce water demand by 30 percent, compared with summer rotation. It also could reduce water evaporation losses.

WATER RESOURCES MANAGEMENT IN INDIA: ACHIEVEMENTS AND PERSPECTIVES

M.A. Chitale

India's water resources are characterized by frequent droughts and floods. This paper reviews the country's water resources development, examining the features of its water system, basic infrastructure, and present and future water use. Basinwide master plans with specific objectives, such as irrigation or flood control, have been created for a large part of the country. The paper summarizes water pricing experience and discusses water allocation issues—at both interstate and sectoral levels—including political intervention, water supply dependability, energy supply, funding patterns, and cost allocation and adjustment. The paper also addresses environmental issues, including monitoring of surface and groundwater, health perspectives, and environmental appraisal of projects. The following major issues are identified: conjunctive use of surface and groundwater, implications of technological development, water conservation, and the trend toward integrated management.

Water Resources Development

Characteristics of India's Water System

Droughts and floods have been a regular feature of India's climate. About 80 percent of the annual precipitation is limited to a small monsoon period, generally spread over three months beginning in June. During the last 25 years, although there have been seven drought years, no famines have occurred. Migration during droughts in search of water or employment has almost been eliminated.

AVAILABLE WATER RESOURCES. India's total utilizable water resources are 1,110 billion m^3 (table 1). At the time of independence in 1947, per capita availability was 5,150 m^3, which has now shrunk to 2,200 m^3 because of population increase. Although the total available quantity of groundwater is expected to increase as more recharge facilities are developed, data from monitoring groundwater levels and water quality have revealed overexploitation in some areas.

DROUGHTS. The complex system of monsoon winds and the peculiar orientation of mountains have caused low rainfall in some regions. The regions with annual rainfall below 400 mm constitute 12 percent of the total area, and regions with rainfall below 750 mm make up 35 percent. Out of the total cultivated area of 176 million ha, 56 million ha are subject to inadequate and highly variable rainfall. According to criteria adopted in India, a drought occurs in an area when annual rainfall is less than 75 percent of the norm. When this situation exists for more than 20 percent of the year, the area is labeled drought-prone. About 51 million ha spread over 74 districts have been identified as drought-prone.

FLOODS. At the other extreme are floods, which occur between June and October as a result of cyclonic storms. They are more frequent in the eastern part of the Ganges basin and the northeastern

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Table 1. *Water and Land in India*

Water (billion m^3)		*Land (million ha)*	
Rainfall	4,000	Total area	329
Surface	690	Cultivable	185
Ground	420		
Total utilizable	1,110		

Note: India's population is 844 million (1991).

part of the country. Twelve percent of the country's total geographical area (equal to 40 million ha) is vulnerable to floods. A national flood control program was launched in 1954: by 1990, 15,675 km of embankments and 30,857 km of drainage channels had been constructed, providing protection to about 13.8 million ha of the flood-prone area.

Existing Hydraulic Infrastructure

HYDROPOWER. Ultimate energy generation from India's hydropower resources is assessed at 600 billion kilowatt-hours, from an estimated installed capacity of 50,400 megawatts at a 100 percent load factor. Of the current installed capacity of 18,750 megawatts, however, 71 billion kilowatt-hours are available. Thus far, the hydropower potential utilized and under execution is only 21 percent of that available.

Construction of dams with large storage capacity helps to substantially modify the monsoon hydrology of rivers by arresting peak flood flows: this will continue to be a critical component of the development program. The dams constructed so far have a live storage of 162 billion m^3, and the dams under construction will add 77 billion m^3, with future increases required.

Because structural measures for absolute flood control and protection of all flood-prone areas are costly, since the 1980s India has given priority to nonstructural measures such as flood forecasting, warning, and proofing by providing raised platforms, shelters, assured communication links, dependable systems of drinking water, and food grain storage facilities. The approach is to ensure an economical but reasonable degree of protection from flood losses and to ensure that life under flood conditions does not become impaired by the disruption of civil amenities. Activities in the next few decades will center around this strategy.

WATER SUPPLY AND SANITATION. The targeted coverage for urban populations with drinking water facilities was originally set at 90 percent: actual achievements by 1988 were about 84 percent. To achieve full coverage, 88.5 billion rupees (Rs) is required. The National Water Policy has stated that irrigation and multipurpose projects should include a drinking water component if there is no alternative source. Storage for drinking water supply will ensure uninterrupted supply even during canal closure. Guidelines have since been prepared by the Central Water Commission.

IRRIGATION. By 1990, India's total irrigated area was 80 million ha. This figure is increasing by 2 million ha annually. The irrigated area is expected to increase through improved recharge facilities for groundwater and introduction of water-saving techniques such as drip and sprinkler irrigation. The potential irrigated area is estimated at 163 million ha.

Irrigation projects benefiting drought-prone areas are priorities in the country's economic plans. A special program has been underway since 1973 in the arid and semiarid regions of the country. It seeks to restore the ecological balance of these areas through appropriate development of watersheds for the optimum utilization of land and water.

Present and Future Water Demand

Agriculture accounts for nearly 85 percent of total water demand. Demand from domestic and industrial sectors is increasing rapidly because of urbanization and industrialization. Rough estimates indicate that industrial water demand was about 10 billion m^3 in 1985 (less than 2 percent of the country's total water requirement) and will rise to 120 billion m^3 (over 11 percent of the country's total water requirement) by 2025 (table 2).

National Water Policy and Master Plans

The National Water Policy of India, adopted in September 1987, states:

> Water resources development projects should as far as possible be planned and developed as multipurpose projects. Provision for drinking water should be a primary consideration. The projects should provide for irrigation, flood mitigation, hydroelectric power generation, navigation, pisciculture, and recreation wherever possible. There should be an integrated and multidisciplinary approach to the planning, formulation, clearance, and implementation of projects, including catchment treatment and management, environmental and ecological aspects, the rehabilitation of affected people, and command area development. The integrated and coordinated development of surface and groundwater and their conjunctive use should be envisaged right from the project planning stage and should form an essential part of the project. There should also be a close integration of water and land use policies.

It was recommended that the strategy for development of water resources consider the river basin or subbasin as a natural unit. The National Water Policy has since asserted that water resources planning be undertaken for a hydrological unit, such as a drainage basin or subbasin. It has also advocated establishing multidisciplinary units in each state to prepare for comprehensive basinwide master plans.

Table 2. *Projected Sectoral Water Requirements (billion m^3)*

Sector	*Year* 1990	2000	2025
Domestic	25	33	52
Irrigation	460	630	770
Energy	19	27	71
Industry	15	30	120
Others	33	30	37
Total	552	750	1,050
(Surface water)	362	500	700
(Groundwater)	190	250	350

Source: Central Water Commission estimates, 1990.

Some states, such as Karnataka, Kerala, and Rajasthan, have already set up multidisciplinary units. Bihar, Gujarat, and Madhya Pradesh have redesigned their irrigation departments as water resources departments.

Although comprehensive master plans have not been completed, master plans for specific purposes such as irrigation or flood control have been drawn up for a large part of India. Most of the large states have prospective master plans for irrigation and some for hydropower generation. Altogether, 48 percent of India's area is covered by master plan activities in some form.

Water Allocation and Pricing

Interstate Water Agreements

Most arrangements for sharing river waters and cooperating on joint projects were mutually reached by the states themselves. Mediation by the central government was also sometimes necessary. There are currently 58 independent agreements: 39 for joint projects and 19 for the sharing of river waters. There are nine separate international agreements on river waters.

Special tribunals had to be set up to resolve interstate water disputes when the issues were highly contentious or water shortages serious enough that negotiation by the relevant parties, by itself, proved inadequate. So far, five tribunals have been established: decisions from three tribunals—Krishna (1976), Godavari (1979), and Narmada basins (1979)—have been implemented. Understanding and mutual accommodation must prevail because river waters are not just allocated, but are shared and managed jointly.

Another type of water dispute occurs between cities located along the ridge lines between two basins. Which basin should bear the increasing water demand? In Hyderabad (between Krishna and Godavari basins) and Bangalore (between Cauvery and Ponnaiyar basins), both the economics of supply and the cushion in natural availabilities of water in the neighboring basins finally affected the choice of the supply source.

Sectoral Water Allocation Policies and Practices

It is not sufficient to consider simply the allocation of waters to different areas in a river basin: it is necessary to further allocate among the different uses to optimize gains from the allocated quantities.

CROP IRRIGATION. A study was completed in the early 1960s by the Commission of Krishna-Godavari Basins on changes required in cropping systems to cope with water scarcity in the basins. It recommended limiting paddy irrigation to the rainy season, to areas of high rainfall, and to valley bottoms, taking advantage of seepage from upland irrigation. It suggested that states (a) adopt a crop pattern that would not require any stored water after February so that the reservoirs could be emptied by then to prevent the high evaporation losses that occur between March and May, and (b) limit crops to those areas where irrigation supplies required between, for example, January and May could be obtained from groundwater. This study was an early attempt at developing certain cropping principles related to water allocation.

Experience from irrigation water management can be summarized into three main areas:

1. It can be difficult to change the prevalent cropping system because it involves a large number of farmers. Individual farmers tend to maximize output by applying as much water as they can. Optimization is therefore closely linked with social awakening and transformation;

2. An alternative practice is to allocate water among farmers within an irrigation system, rather than to allocate to "crops," thereby leaving the issue of which crop to grow to individual choice. This could, however, strain the management organization in charge of distributing water;

3. The *warabandi* system, based on the rotational time sharing of water from irrigation canals, was widely promoted by the government in water-short areas. This system, however, can be sustained only when disciplined water use has become ingrained in the user community.

IRRIGATION PRICING POLICIES. The water rates charged for crops irrigated from the canal network differ considerably among states according to their individual financial policies and the role of individual crops in the regional economy. Water rates are charged on the basis of crop area and not the quantity of water supplied because farm-level measurement of quantity is difficult. For example for wheat, generally the water rate for the *rabi* crop ranges from Rs 30 to 75/ha, but in Gujarat the rate is Rs 110/ha, and in Andhra Pradesh it is Rs 222/ha.

Because the irrigation network is treated as social development infrastructure, and not as a commercial proposition, irrigation rates are fixed to cover annual operation and maintenance charges and leave a small surplus toward depreciation costs. Manipulating water rates alone is not sufficient to influence farmers' choice of crops. Such choices are governed by consideration of net benefits from each hectare of land, rather than by water charges. To influence the crop pattern, the canal administration can pursue revenue collection from the different crops in proportion to the volume of water consumed.

URBAN/INDUSTRIAL PRICING. How the water supplied to cities and industrial and commercial complexes should be treated in the context of a basin's water balance has been debated. Some have argued that whereas benefits from using water for irrigation are local-specific and limited mainly to the owners of the irrigated land, commercial centers, power stations, and industries have a much wider sphere of economic influence: the water supplied to these activities cannot be considered only a "charge" on the basin or on the area where the activities are located. Similar questions also arise when the diversion of water across the basin is involved.

A study was completed in 1990 on the pattern of water consumption, effluent generation, value added, and employment generation per unit of water supplied to various industries. It was based on analyzing the responses of 68 industries. The results (some of which appear in table 3) are broadly useful in helping to allocate water to industries in different basins.

The National Water Policy Directive states that water rates should convey the scarcity value of the resource to users and motivate economy in water use. The price of fresh water supplied to industries should also be linked to the amount of effluent generated. There are no specific guidelines, however, regarding this process.

The price of water has been based chiefly on supply costs and the financial policies of the water supply agency; it therefore differs by location. Studies show that almost all units in the paper and pulp industry receive water free or at negligible cost (Re 0.96/m^3 for paper mills), whereas some other industries pay as much as Rs 9.40/m^3.

WATER ALLOCATION POLICIES. Several water allocation policies are summarized below:

1. *dependability of water supply*. The dependability of water supply for various users is normally 75 percent for irrigation, 90 percent for hydropower, and 95 percent for domestic and industrial use. Experience shows that the dependability criteria for the irrigation sector need to be reviewed. Some states have planned their irrigation projects in drought-prone areas with only 50 percent dependability, which can often be improved by providing extra

Table 3. *Water Supplied to Various Industries*

Water use	*Employment (man-days per m³)*	*Value added (rupees per m³)*	*Price (rupees per m³)*
Industries			
Paper and pulp	0.12	5.1 to 102.3	0.96 (max.)
Fertilizer	0.23	49.8 to 109.4	0.68 (avg.)
Iron and steel	0.53	113.9 to 297.7	0.26 (avg.)
Chemicals	1.03	26.2 to 1,403.5	3.50 (avg.)
Municipal supplies	n.a.	n.a.	0.35 to 1.7

Source: Central Water Commission officers' report on identification of water-intensive industries and preparation of format for data collection, 1990.

capacity in the reservoirs carrying over water from a surplus to a lean year. Concurrently, small hydroelectric projects are planned with 75 percent dependability. Some states have argued that interstate water allocation should be based on average annual flows rather than on dependability criteria. Normally, the less dependability of supply, the greater the burden of annual adjustments in water allocation;

2. *political intervention*. Direct value added in agriculture per m^3 of water has generally been less than Re 1, compared with the value added of Rs 20 and above in most industries. The employment generated by industry per unit of water is also much greater than that generated by agriculture. Agriculture progressively yields to other uses, e.g., urban and industrial. Consequently, issues may have to be settled through political arbitration among interest groups: the development of water resources cannot be left to the market mechanism alone;

3. *cost allocation*. The "facilities use" method was generally recommended and incorporated in the Indian Standards Code's "Guidelines for Allocation of Cost among Different Purposes of River Valley Projects." Because of the regions' different use priorities, a common pattern of cost sharing for all regions has not been set;

4. *adjustments in water allocation*. Intersectoral water allocations cannot remain static because societal needs and priorities change as development proceeds. Because of fluctuations in the availability of water in a monsoon-type climate, allocations to different uses must be reviewed, even seasonally. Priorities in drought years differ from those in normal or wet years. In Narmada State, the Water Dispute Tribunal permits water carryover to a future year if the basic allocations could not be utilized in the given year;

5. *funding patterns and water prices*. The difference in investment fund sources is reflected in water rates. Irrigation projects are not proposed to recover the entire capital investment. The urban and rural water supply works are generally financed and operated by local bodies (municipal corporations, village institutions, etc.). The government provides liberal grants, loans, and technical support services. (Water development programs generally account for 20 percent of planned public investment.) The water charges should be much higher to meet the current operating expenses and part of the capital expenditure. The industrial water supply is tagged to municipal arrangements: cost will be recovered through water supply

rates. Although the investment for hydropower is expected to come from power corporations, experience has shown that considerable budgetary support is required to aid the corporations, partly with interest-bearing loans and partly with equity participation by the government;

6. *withdrawals from rivers*. With many pumps withdrawing water from a river channel, the management of river flows released from upstream reservoirs is possible only if electricity/energy for pumps can be regulated. Even if the share of water for development between upstream and downstream is settled, without a control on the power supply, distribution of water according to the agreed water-sharing formula is impossible. Provisions of the Indian Electricity Act and the Irrigation Act were therefore required to be complementary to enable states to intervene and to regulate the power supply for water drawing along rivers.

Environmental and Health Concerns

Environmental Status in Relation to Water

STATUTES. The Water (Prevention and Control of Pollution) Act (1974) and the Environment (Protection) Act (1986) deal with the prevention and control of water pollution. The latter is considered an umbrella act covering all aspects of the environment, under which the central government can take appropriate measures for (a) protecting and improving the quality of the environment; and (b) preventing, controlling, and abating environmental pollution.

MONITORING OF SURFACE WATER QUALITY. In most river basins, the measurement of water quality is being conducted simultaneously with hydrological observation by the Central Water Commission (CWC), which operates nearly 300 water quality monitoring stations in the major and medium river basins. The Central Pollution Control Board (CPCB), in collaboration with the state pollution control boards, has been separately monitoring aquatic resources at selected locations since 1977. To standardize procedures for collecting samples from the rivers, the Ministry of Water Resources (MWR) has set guidelines. Considering the varying interests and responsibilities of the different agencies, it was decided that work at different locations along rivers could continue to be undertaken by the different agencies, but practices would be made uniform so that the data from all the agencies could be compiled and published together to provide a complete picture of the river systems.

The status of surface water quality at the various monitoring locations is determined by comparing the observed values with the primary water quality criteria determined by the CPCB. The water quality rating at a location is defined as the one satisfied, at least 80 percent of the time, by all criteria. The major rivers have been classified, as shown in table 4, into five categories: (1) drinking water source without conventional treatment but after disinfection; (2) outdoor bathing; (3) drinking water source with conventional treatment followed by disinfection; (4) pisciculture and wildlife propagation; and (5) irrigation, industrial cooling, and controlled waste disposal. Among the major rivers, an assessment of pollution loads in the Ganges River was specially carried out by the CWC, which laid the foundation for the Ganges action plan. The plan was initiated in 1985 to reduce pollution in the river near the 27 main towns situated on its banks.

Because the continued presence of a minimum body of water is important, the MWR was advised that to maintain healthy and attractive waterfronts for the large cities located along the Yamuna and Ganges rivers, the minimum flow should be 10 m^3 per second. Similar assessment for other rivers has not yet been formally carried out.

Table 4. *Classification of Major Rivers*

River	*Total length (km)*	*Percentage of length in category*[a] 1	2	3	4	5
Ganges	2,525	–	11	56	33	–
Yamuna	1,376	–	36	64	–	–
Brahmani	799	–	23	77	–	–
Subarnarekha	395	–	–	90	–	10

a. See "Monitoring of Surface Water Quality" (p. 163) for category demarcations.

MONITORING OF GROUNDWATER QUALITY. Groundwater monitoring reports both the water quality and fluctuation in water levels. A map showing the quality of India's groundwater was first compiled by the Central Groundwater Board in 1977 and was revised in 1989. Because groundwater pollution can remain localized for a long period and escape detection, microsurveys are necessary, particularly near cities, industrial areas, or sewage irrigation farms. This feature has generally been considered when determining the location of monitoring stations.

Environmental Appraisal of Projects

Since 1978, all major irrigation, multipurpose, and flood control projects have required environmental clearance. India's Ministry of Environment was established in 1985. It set up the Environmental Appraisal Committee (EAC), with its 13 members drawn from professional institutes and the environmental expert community. The EAC scrutinizes projects from an environmental perspective and suggests safeguards to mitigate adverse environmental impacts. Since 1988, project authorities have been asked to furnish environmental impact statements and environmental management plans. No institutional mechanism has yet been developed, however, to undertake these responsibilities. Detailed guidelines will have to be formulated and technical staffing strengthened. A Directorate of Environment, established in the CWC to deal with the environmental aspects of water resources development, is now preparing these guidelines.

Guidelines on sustainable water resources development and management are expected to be ready by September 1992. A computer package is also being developed to consider comprehensive environmental impact assessment of water resources projects: this would assist the project-formulating agencies in performing environmental impact studies effectively. Selection of a panel of capable consultancy organizations is also being finalized by the CWC to help state governments in undertaking such studies.

A national environmental monitoring committee (EMC), under the Ministry of Water Resources, periodically monitors the implementation of environmental safeguards associated with water resources projects. It reviews the mechanism established by project authorities to monitor the ecology of the project area and suggests additional compensatory measures. To date, 69 projects have been selected to establish EMCs at the project level.

In 1985, the Planning Commission also issued guidelines for the formulation of river valley projects, including consideration of catchment area treatment, soil conservation, command area development, and afforestation, along with irrigation, flood control, and drainage. According to these guidelines, the direct environmental and ecological damage from a project is estimated and included in the project's total cost.

Rehabilitation

Submergence due to reservoir projects results in the displacement of people, who need to be resettled so that their socioeconomic conditions improve, to the extent possible, at the new site. One possibility is to settle them in areas benefiting from the projects. This becomes difficult when projects are predominantly for hydropower or industrial and municipal storage. Fortunately, this situation is rare in India because of the emphasis on multipurpose river valley projects.

Finding common norms for rehabilitation is problematic because of differences in agroclimatic regions, patterns of land ownership and tenure, size of farm holdings, landless populations in the submergence area, and the potential of the host areas to accommodate new migrants. This process must be worked out separately for individual projects. One example is the Sardar Sarovar project, a multipurpose joint venture among four states. It provides irrigation water, hydropower, and drinking water facilities to urban areas and villages. The total number of affected families is expected to be 22,180; among them, 6,140 families will be affected by backwater during flooding. Work on resettlement is in progress and is expected to be completed before the actual submergence. The land provided to the resettled people would be irrigable for agriculture, so that the ousted population could share in the benefits of the project. The entire rehabilitation program is expected to cost Rs 3.16 billion.

Health Impacts

Water resources projects provide a dependable source of drinking water, resulting in improved health. People from the irrigated areas enjoy better health and sanitation facilities, thus reducing the incidence of disease. A survey revealed that the Mula Irrigation Project had a substantial, positive impact on the incidence of illness, leading to a significant reduction in sick days. With the Indira Gandhi Nahar Project, the percentage of the reported relative incidence of waterborne disease to all disease dropped considerably over 12 years in the areas that received continuous irrigation facilities. Studies have also indicated, however, the increased incidence of malaria in some areas after irrigation is introduced, which normally occurs in relatively wet areas associated with high water consumption. The health position in dry areas has essentially improved.

Institutional Arrangements

Ministry of Water Resources and Related Bodies

The Ministry of Water Resources was established in 1985. It is responsible for development, conservation, and management of water as a national resource, i.e., for the general policy on water resources development and for technical assistance to the states on irrigation, multipurpose projects, groundwater exploration and exploitation, command area development, drainage, flood control, waterlogging, sea erosion problems, dam safety, and hydraulic structures for navigation and hydropower. It also oversees the regulation and development of interstate rivers. These functions are carried out through various central organizations, such as the Central Water Commission, Central Groundwater Board, and the National Institute of Hydrology. The National Water Development Agency (NWDA) carries out studies for the interbasin transfer of water.

Not all these central organizations are under the administrative control of the ministry: some are located in other ministries. With the need for an apex body to generate and review national policies for the development and use of water resources, the National Water Resources Council (NWRC) was established in 1983, with India's prime minister as its chair. The council is required to consider and review water development plans drawn up by the NWDA and the river basin commissions and to recommend acceptance and/or modifications. A National Water Board was set up in 1990 to review progress achieved in the implementation of the National Water Policy, before bringing matters to the NWRC.

River Basin Authorities

The objectives of overall integration and the specific activities in each basin determine the pattern of institutional arrangements. In India, most rivers flow through more than one state, and individual states cannot plan for the entire basin. Several basin-oriented organizations, therefore, have been established to examine specific aspects of river basin development. None of these organizations, however, except the Damodar Valley Corporation, is responsible for comprehensive basin development and management. Through mutual negotiations, individual states have reached agreement either on their share of river waters for projects within the state or on the scope of the interstate projects they must pursue jointly. As mentioned earlier, matters have sometimes been referred to the interstate tribunals. In 1988, the Parliamentary Consultative Committee for the Ministry of Water Resources recommended the establishment of river basin organizations to undertake comprehensive planning and development for Narmada, Brahmaputra, Ganges, Mahanadi, Godavari, Cauvery, and Krishna basins.

Cooperation with neighboring countries resulted in the establishment in 1972 of the Indo-Bangladesh Joint Rivers Commission, which has carried out a comprehensive survey of the river system shared by the two countries and formulated flood control projects benefiting both. The joint program also includes transmission of water-level information and exchange of discharge and rainfall data. The Indo-Nepal Subcommission on Water Resources, established in 1988, is headed by the secretaries of each government's appropriate ministries and deals with Indo-Nepal cooperation in water use, including flood forecasting.

Human Resources Training and Public Awareness

The Water and Land Management Institute provides broad training in a multidisciplinary environment to irrigation managers, land development staff, irrigation systems designers, and construction engineers, from junior to senior level. The next decade is likely to witness a transformation from irrigation-oriented management to an examination of watershed development as a whole. The educational pattern in civil engineering needs to be reorganized with this new focus. The India Water Resources Society actively promotes an appropriate climate for comprehensive water management through lectures, meetings, and workshops. It encourages the advancement of research, planning, development, management, and education by providing a forum for an interdisciplinary exchange among engineers, economists, agriculturists, and social scientists.

Since 1986, "Water Resources Day" has been celebrated annually in India during April or May. The themes chosen for 1989 and 1990 were, respectively, "People's Participation in Development and Management of Water" and "Water for the Future." The theme for 1991 is "Water Conservation," and events were organized at 800 locations.

Summary of Major Issues

Conjunctive Use of Surface and Groundwater

Seepage from irrigation canals can provide considerable recharge to groundwater. In the Sardar Sarovar Project, 11.1 billion m^3 of water from the canals are used, and 3.3 billion m^3 are used through the improved availability of groundwater in the irrigation command areas. India's Irrigation Act, however, requires that canal water and well water not be conveyed in the same channel. If such intermingling occurs, all of the farmer's land is liable to be charged at the rates set for canal water irrigation. The act is clearly outdated in the context of conjunctive use of surface and groundwater. Appropriate modifications will have to be made, which will also help considerably in the control of waterlogging in irrigated areas.

Implications of Technological Development

Reservoirs with large storage usually involve considerable land submergence and population displacement. The trend now is for the size of gates at the spillways to be larger to reduce the submergence areas as much as possible. With improved qualities of steel becoming available, combined with greater skill in structural engineering and development of dependable hoist mechanisms, the size of the spillway gates has been increasing. In many places in India, large gates are expected to be adopted, even for smaller storage facilities, to avoid excessive submergence of land. This gate structure, however, increases the risk of cumulative damages by upstream maloperation of the gates. In such cases, the individual operation of each reservoir will need to yield to the integrated regulation of all reservoirs in a basin.

Water Conservation

Considering costs and benefits, the best way to conserve water in the irrigation sector is on the farm rather than at the reservoir surface because evaporation losses from exposed farm surfaces are at least 10 times greater than those from reservoir surfaces. In industrial and urban water supplies, however, the greatest amount of saving can be achieved by controlling evaporation losses at the reservoir surface. Experience in evaporation control at reservoirs, adopted during the droughts of 1987/88, has shown that as much as 30 percent of the water, which would otherwise be lost through evaporation, could be saved by spreading chemicals or plastics on the reservoir surface. The cost would be about Rs 3/m^3, which is far less than the cost of transporting water.

In addition to loss prevention, recycling increases the availability of water. Recycling water is likely to be cheaper than providing additional water over long distances and relying on reductions of evaporation losses. Several cities, such as Pune, Ahmedabad, Madras, and Delhi, have begun to reuse sewage; however, there are no standard specifications currently available for the use of domestic and industrial effluent for irrigation farming.

Major savings in water will have to come from the agricultural sector, the largest user. If a 10 percent saving can be achieved in the sector, the availability of water for other sectors such as industry and urban development will be improved by more than 50 percent. The premium on water saving in the agricultural sector should not, therefore, be considered only on the basis of the productivity of the saved water in additional agricultural production: it should be evaluated on the basis of its contribution to the additional industrial growth that can be generated, particularly in areas where further development is hampered by a shortage of water. Subsidies required to disseminate water-saving devices—such as drip or sprinkler irrigation, plastic mulches, or plastic greenhouses—should be reanalyzed in this context.

Trend toward Integrated Management

In the initial period of Indian development, the speedy harnessing of water resources was the principal objective. The thrust was toward decentralization, with states encouraged to swiftly formulate and develop projects. Subsequently, concerns related to improving the efficiency of water use to realize the full benefits from investments emerged. During the 1970s, integration efforts were still essentially limited to the command areas of large irrigation projects. With the development of river basins and the sectoral demand for water increasing simultaneously, the need for a systematic integration of activities within a basin is increasing, leading to the integration of different uses. Consequently, central responsibilities are bound to increase considerably.

With multiple storage systems in a basin, operations can be managed to minimize the total surface area at risk of evaporation by transferring waters from one reservoir to another. As more storage arises, the operation of reservoirs has to be considered collectively. Currently, operational guidelines only exist for optimizing a particular reservoir's output. Operational guidelines will be required for a basinwide storage system. Modern tools such as satellite imagery for weather forecasts, wireless communications, and computerization will play an increasing role in the management of river basins.

A practical problem in an integrated water resources development project, which normally involves several sectors, is cost sharing. Even after the shares are settled, it still must be determined whether the participating sectors are willing to invest at the same time. Experience shows that the sector with the greatest urgency for harnessing has to finance at earlier phases to accelerate the project.

A weak area in the comprehensive development of water resources is inland fisheries, mainly because of constraints in trained personnel and inadequate financial resources. Presently, land submergence caused by hydroprojects is considered a loss. It could be converted into a gain by systematic development of pisciculture. Many employment opportunities could also be created. The World Bank is considering assistance to a project on inland fisheries and brackish-water fisheries development in Uttar Pradesh, Orissa, and Andhra Pradesh.

WATER RESOURCES MANAGEMENT IN MEXICO

Manuel E. Contijoch

Mexico's climate varies considerably, from arid regions in the northeast to tropical zones in the southeast. This diversity is reflected in an uneven spatial and seasonal distribution of rainfall and in frequent torrential rains and tropical cyclones. The major problems facing Mexico's water sector are excessive withdrawals from aquifers, water contamination, and acute conflicts among water users. The current government policy of subsidizing the water sector has been straining the federal budget. Recently, the institutional framework for water resources management was adjusted through public administration reform, dividing the government's responsibilities in the water sector among diverse institutions and stressing decentralization toward municipalities. This division, however, has also caused considerable difficulty in coordinating water policies. Operating agencies are being strengthened to encourage public participation and to ensure that water revenue is used in improving systems. The Mexican Congress has proposed amending legislation to reinforce the water charge system, increase water supply revenue, and implement more rigid regulations regarding groundwater extraction. To tackle pollution, the government has launched a "Clean Water Program," encompassing the "polluter pay" principle. This paper discusses these issues and proposes guidelines for future water policy.

Characteristics of Mexico's Water Resources

Mexico is a federal republic composed of 31 states and a federal district. It has an area of about 2 million km^2 and a population of 80 million. In 1990, the country's GDP grew at a rate of 3.9 percent.

Mexico's climate varies, from arid regions in the northeast to tropical zones in the southeast. The annual distribution of rainfall is irregular, with almost 80 percent occurring between July and September. These variances are reflected in the country's water resources, which are unevenly distributed. Annual surface runoff is estimated at 410 billion m^3 and renewable groundwater at 31 billion m^3. Nineteen percent of runoff is in the north and highlands, which account for more than half of the country's territory and which are inhabited by two-thirds of the total population. About 70 percent of industry and 40 percent of agricultural land are located in these areas. In contrast, nearly 67 percent of surface water is in the southeastern part of the country, which covers less than one-fourth of total territory, with 24 percent of the population and little industry.

Another climatic characteristic is the Pacific Ocean's FENOS (El Niño-South Oscillatory Phenomenon), whose intermittent anomalies generate torrential rains. Tropical cyclones also cause great damage, estimated at US$50 million to US$167 million annually.

Major Water Problems

The major problems faced by Mexico's water sector are excessive withdrawals from aquifers, water contamination, and acute water conflicts among users. In the overpopulated central highlands, both

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surface and groundwater are becoming increasingly scarce given the need to support the demands associated with economic development and the rapidly growing population. Water pollution and ecological damage are also problems, caused in part by intensive development of oil extraction operations and refineries in recent decades. Population growth and the corresponding growth in demand for agricultural products mean agricultural production must increase: this requires restoring the productivity of agricultural lands, improving the efficiency of the existing infrastructure, and encouraging more public participation in water conservation.

Financial constraints have been another major concern. The existing government policy is to subsidize the water sector, creating low water billing and thus burdening the government budget. Insufficient funds have led to the deterioration of water systems, loss of productivity, and technical inefficiencies. Irrigation efficiency, for example, decreased from 65 percent in 1979 to 62 percent in 1988 and to 40 percent in 1990, indicating that more than half of the water supplied is lost before reaching the farmgate. The problem will become more severe as the population increases. Expanded water services will be needed to serve an additional 3 million people annually, indicating an average annual investment of US$1 billion (57 percent for large cities, 35 percent for medium and small cities, and 8 percent for rural communities).

Institutional Development

Legislation

Various pieces of legislation and administrative decrees regarding the use of water have been passed in Mexico, with water considered a national asset under only the federal government's control. Major laws include the Federal Water Law and Regulations, Agrarian Reform Law, General Law of Ecological Balance and Protection of the Environment, and Organic Law for Federal Public Administration.

Institutional Framework

The demand pressures brought about by population and economic growth are exacerbated by institutional inefficiencies, e.g., lack of a single water authority, different criteria regarding water administration, and user sectors' limited knowledge and lack of participation.

The institutional framework for water resources management has been adjusted over time to adapt to economic development conditions. Several government agencies have been created, including the National Water Commission (NWC), National Irrigation Commission, Ministry of Hydraulic Resources, National Water Plan Commission, Mexican Institute of Water Technology (MIWT), Technical Council of the National Water Commission, and Urban Water and Sewage Subcommittee. In 1976, public administration reform changed the government's responsibilities in the water sector: The Secretariat of Agriculture and Livestock merged with the Secretariat of Hydraulic Resources, and there was a division of functions among diverse governmental institutions, with federal responsibilities decentralized toward municipal administration. An urban water and sewage subcommittee was established in every state with representatives from federal and operating agencies. This division, however, also generated considerable problems in coordinating water policies, among them insufficient attention to continuity and performance objectives, a separation between the operation and conservation of hydraulic works, excessive regulations, and lack of an enforcement capability. The following actions are being considered to strengthen the operating agencies: to provide them with autonomy, decisionmaking authority, legal status, and independent funds; to encourage public participation, for instance, on the board of directors of a water-related entity to provide information and public influence in the decisionmaking process (the board of directors can establish water rates and encourage self-financing to improve technical and management conditions); and to ensure that water revenue be used in improving systems.

National Water Commission

The NWC was created in 1989 and is the only institution authorized to conserve, distribute, and manage the country's water resources. Its director is also the director of the Mexican Institute of Water Technology, a newly decentralized unit of the Secretariat of Agriculture and Hydraulic Resources. The NWC's objectives are to promote public participation in implementing government policies, to encourage coordination among institutions, and to authorize rational water resources management. The NWC is subdivided into four directorates with separate responsibilities:

1. *hydroagricultural infrastructure*: standards for and studies, maintenance, and construction of federal hydraulic infrastructure (including flood control, drainage, and irrigation facilities);

2. *urban and industrial hydraulic infrastructure*: management of water supply and sewerage systems, and promotion of efficient water use in urban areas and industry;

3. *water administration*: water resources planning, regulation, and control, and promotion of conservation and quality control programs;

4. *planning and finance*: supervision of the implementation of national hydraulic programs and cost recovery.

There are also six regional offices to coordinate the country's six river basins. There is an office representing the NWC in each of the country's 31 states to provide coordination with the federal government, municipal authorities, and user organizations.

The Mexican Congress has proposed changing legislation to give the NWC complete authority in managing both water quality and quantity with the possible participation of the private sector. This change is expected to reinforce the water charge system, to increase water supply revenue, and to implement more rigid regulations regarding groundwater extraction. The NWC faces two main challenges:

1. *political issues involved in water management*. The country's current trend toward greater democracy and public participation in decisionmaking will influence the NWC's function as the country's water authority. In solving conflicts associated with water use, the NWC will have to negotiate with various authorities, institutions, and user groups. Its success will depend on its leadership and negotiating abilities. Negotiation, participation, and decentralization are elements of a political process with which the NWC has to deal;

2. *decentralization and effectiveness*. The transition from a centralized agency with an existing bureaucracy to a decentralized organization implies improvements in effectiveness and technological capacity. The structure of the NWC should be flexible in the delegation of authority and responsibility: for instance, decentralization would be difficult if the NWC's own internal decisionmaking processes were too centralized.

Intersectoral Water Allocation

Mexico's water allocation priorities are (a) domestic use; (b) public services; (c) livestock needs; (d) irrigation; (e) industry (power generation for public services first and other industries thereafter); (f) aquaculture; (g) power generation for private purposes; and (h) drainage. All priorities, except those related to domestic use, are subject to change by the government. Water is allocated according to the public interest. About 65 percent of the mean annual runoff is currently allocated to hydropower generation, 29 percent to agriculture, and 6 percent to industry in urban areas. A total of 28 billion m^3 of groundwater is extracted annually, of which 68 percent is used for irrigation, 20 percent for urban domestic use, 7 percent for industry, and 5 percent for rural domestic and livestock demands.

Water Policy Guidelines

Future water policies will aim to coordinate the NWC's objectives with those of overall water management at local, regional, and national levels and to encourage decentralization of irrigation services toward independent enterprises. They will also seek to strengthen the financial system through cost recovery, by which water users pay for the operation, conservation, maintenance, expansion, and improvement of the water supply infrastructure, and to promote the establishment of self-financing enterprises with technical and management autonomy. Efficient water use will be encouraged, including recycling and quality control, development of new technologies, and new social attitudes toward efficient use through community participation. Last, to provide adequate services, the hydraulic infrastructure will be expanded.

Revenue Collection

The federal water revenue collection system, established in 1989, has considerably increased the NWC's budget funds. For instance, estimated revenues for 1991 are US$500 million, equivalent to 60 percent of the NWC's annual budget (table 1). Irrigation practices are closely linked with water rates and cost recovery. In 1950 the cost recovery rate nearly reached 100 percent. It declined sharply to 50 percent in the 1960s, and increased to 65 percent in 1970. During the 1980s, it fell to 25 percent. Generally, water rates are set by the local government congress, without considering the system's operation, expansion, and maintenance costs. The low rates fail to encourage users to save water or industries to recycle treated water. There is therefore insufficient revenue to maintain the service system.

Table 1. *Revenue of the Federal Water Rights Collection System, 1988-91 (million US$)*

	1988	*1989*	*1990*	*1991*[a]
Aqueducts	n.a.	105.9	77.2	133.9
Private enterprise	n.a.	36.9	143.4	215.6
Public enterprise	n.a.	39.8	101.7	127.0
Irrigation	n.a.	18.1	30.2	23.9
Total	43.7	200.7	352.5	500.4

a. Estimated.

Sanitation and Sewage

Sanitation problems have had adverse impacts on human health, the environment, and economic development. Total irrigation discharge, highly contaminated by pesticides and fertilizers, is 265 m^3/s. About 80 percent of urban and industrial wastewater returns to various water bodies contaminated by organic and industrial waste. Annual industrial discharge is an average 82 m^3/s, of which the sugar industry alone discharges nearly 40 percent and the chemical industry 21 percent. Domestic wastewater discharge is about 110 m^3/s. Only 15 percent of total wastewater discharged is treated. Currently, there are 256 water treatment plants with a capacity of 14 m^3/s: only 35 percent of municipal treatment plants, however, are operating.

Despite government efforts, more than 30 percent of the population lacks access to drinking water supplies, and half of the population lacks access to sewerage. Operational agencies are unable to take full responsibility for water supply services, and most agencies operate under obsolete guidelines.

Future Perspective

The government has implemented a "Clean Water Program" to tackle pollution. The program's objectives are to establish water quality standards, to rehabilitate the water disinfection infrastructure, to construct sewage treatment plants to cover 65 percent of total wastewater, to improve water monitoring and supervision, and to establish technical capacity to implement the program. The "polluter pay" policy will be implemented by the end of 1991.

The NWC is essentially an agent of change, inducing change in water use and management and in the characteristics of government intervention that will shape the new water culture. The NWC must emphasize the development and transfer of the knowledge and technology required to solve Mexico's water resources problems, utilizing innovation to increase water use efficiency.

WATER RESOURCES DEVELOPMENT IN CHINA

Zhikai Chen

Although China's water supply capacity ranks second worldwide, its water resources are characterized by low availability per capita and uneven regional and seasonal distribution. These features result in frequent droughts and floods, unstable agricultural production, and an imbalance between water demand and supply. Sustainable socioeconomic development is facing greater challenges than in any other part of the world. Water is an acute problem because of overpopulation, compulsory development of irrigated agriculture, rapid increase in municipal and industrial water demand, environmental degradation, and deficient funds. This paper presents proposals for future water policy, such as enforcement of water-saving facilities, coordination between economic and water development, interbasin water transfer, and water resources protection. Population control through family planning is the key policy to balance population and natural resources, especially water and land, to achieve sustainable development in China.

Water Resources in China

China, with a territory of 9.6 million km^2, has seven main rivers: the Yangtze, Yellow, Pearl, Huai, Hai, Liao, and Songhua. It has a monsoon-type climate, cold with little precipitation in the winter, and warm and humid with abundant rainfall in the summer. About 45 percent of the northwest inland area is arid, and agricultural development depends entirely on water resources projects. Being close to the ocean, the southeastern part of the country is humid with abundant rainfall and is a main agricultural production area. Over 90 percent of the population and cultivated land are concentrated in the eastern monsoon areas.

The mean annual precipitation is 648 mm (equivalent to 6,190 km^3 of water), about 20 percent less than the world average. About 56 percent of precipitation is consumed by evapotranspiration and 44 percent by river runoff. The total amount of the mean annual runoff is about 2,710 km^3, of which the discharge from groundwater is about 678 km^3. The mean annual amount of water flowing into the ocean and out of the national borders is 2,456 km^3.

Water resources in China are characterized by:

1. *low water availability per capita.* The total amount of annual runoff in China ranks sixth worldwide. Because of the vast land area and huge population, however, both water per capita and water per unit of cultivated land are less than the world average (about 25 and 76 percent of the world average, respectively);

2. *uneven regional distribution.* Regarding regional populations and area under cultivation, both precipitation and runoff are unevenly distributed. About 81 percent of the country's water resources are concentrated in the Yangtze River basin and the areas south of the river, although the cultivated area is only 36 percent of the national total. In the four basins of the

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Yellow, Huai, Hai, and Liao rivers, the cultivated area accounts for 42 percent of the national total, but the total amount of water resources is only about 9 percent of the national total. Consequently, the south has surplus water and less cultivated land, and the north has less water and more cultivated land—indicating a serious water shortage;

3. *uneven seasonal distribution*. Precipitation in most parts of China varies greatly within a year and by year because of monsoons. The amount of precipitation and runoff during flood season accounts for 60 to 80 percent of the total for the entire year. This degree of seasonal concentration is higher than that of Europe and America, but similar to that of India.

These characteristics result in frequent droughts and floods, unstable agricultural production, and a serious imbalance between water demand and supply.

Water Resources Development and Utilization

In 1980, the total amount of water supplied by hydroprojects was 444 billion m^3, accounting for about 18 percent of total available water resources. Of supplied water, 86 percent (382 billion m^3) was obtained from surface water, and 14 percent (62 billion m^3) from groundwater. Water supply capacity ranked second worldwide, behind the United States. Of the total supplied water, 88.2 percent was for agriculture, 10.3 percent for industry, and 1.5 percent for urban use.

China's substantial economic achievements during the past 40 years have underscored that 22 percent of the world's population has been supported by only 7 percent of the world's farmland. Sustainable economic and social development, however, is facing greater challenges than in any other part of the world. Water is an acute problem, with water shortages the result of:

1. *overpopulation*. Overpopulation is a key constraint to sustainable development. In 1989, China's population topped 1.1 billion. It is estimated that by the year 2000, it will reach 1.3 billion. If population growth can be controlled efficiently, total population in the year 2050 may peak at 1.5 billion; then, the birthrate is expected to decline. Although family planning has reduced the annual population growth rate to 1.33 percent (from 1980 to 1989), the problem is still serious. Limited water resources for agriculture and industry need to provide sufficient food, energy, and other materials to meet the basic requirements of 1.5 billion people in the 21st century;

2. *compulsory development of irrigated agriculture*. There is a large gap between food demand and cultivated land available for growing food. Agriculture is the largest consumer of water. In 1980, water consumption for agricultural use was 391 billion m^3, of which 33.1 billion m^3 was used for forestry, pastures, off-farm activities, livestock, and rural households. Between 1949 and 1980, the total irrigated area rose from 16 million to 48.6 million ha, and the ratio of irrigated to total cultivated land rose from 16 to 48 percent. About 74 percent of the total grain output came from irrigated areas. Irrigation plays a crucial role in maintaining and promoting agricultural yields to achieve food self-sufficiency objectives. As the potential availability of reclaimable cultivated land becomes increasingly limited, the development of irrigated agriculture becomes more important in relation to food self-sufficiency. According to China's Ministry of Water Resources, the maximum potential irrigated area is 64 million ha, under which the proportion of irrigated area to total cultivated land will need to increase from 48 to 60 percent;

3. *rapid increase in municipal and industrial water demand.* Although industrial development is still in its initial stages, with the gross value of production at 1,822.4 billion yuan (US$352 billion) in 1988, water use in industry has topped approximately 3,127 million m^3 (50,347 million tons). Currently, water needed for industrial development is allocated mainly from the diversion of agricultural water supplies. Many reservoirs, originally designed for agriculture, are now being used to serve industrial and urban activities. This has further affected the development of grain production. The growth of the urban population, improvements in their livelihood, and the rising access of urban areas to water supply facilities will rapidly increase domestic water demand. Total domestic water use in 1988 was about 99 million m^3 (1,590 million tons), despite severe limitations on the availability of municipal water supply outlets and the traditionally low level of water use by Chinese households. Furthermore, despite low access and low individual household demands, over half of China's cities and towns currently face water shortages;

4. *environmental degradation.* Water pollution, massive destruction of natural vegetation, water and soil losses, shortage of water resources, and groundwater overexploitation have been aggravated, with adverse consequences with regard to estuary siltation, salinization, alkalization, and desertification. All these water-related problems impede sustainable development;

5. *deficient funds.* China's per capita income is 1,200 yuan (about US$230) per year. To meet water demands from agriculture, industry, and domestic use, the ratio of water resources utilization has to be increased from the current 18 percent to 40 percent in the next century. Water projects require enormous investments. The projected increment of 5.3 million ha of irrigated lands alone would need a total investment of 88 billion yuan (US$17 billion).

Water Pricing Policy

Urban water supply in China has been characterized by low prices because of its role as a public welfare function. Recently, however, with the development of the commercial economy, the gap between water supply and demand in urban areas has been increasing. The profits of water companies have been decreasing annually, with some companies experiencing deficits. Thus, formulation of rational water prices has become urgent to ensure urban water supply and promote water saving. Components of this policy should include:

1. basing the price on the cost of water, other relevant costs, and a reasonable profit margin; a water resources fee should be charged for user self-supply to prevent groundwater depletion;

2. designing prices according to different industrial classifications, encouraging low water consumption;

3. ensuring planned and reasonable water allocation; this entails regular inspection of water use and a system of rewards and penalties for water use below or in excess of that planned.

Rational pricing policy will not only effect water saving, but also influence the development and utilization of water resources.

Water resources projects encompass both public welfare and commodity production and are controlled by the subsidy, price, and social policies of the state. The water charge standard, as stipulated by the state, should be checked and ratified for all water uses on the basis of the water supply cost, in accordance with the state's economic policies and the conditions of local water resources. The principles underlying water charges for specific uses are:

1. *agricultural.* The charge for grain crops is determined by the water supply cost, and the charge for cash crops should be slightly higher than the water supply cost;

2. *industrial.* For consumptive water use, the charge is calculated based on the total investment in water supply, plus generally 4 to 6 percent profit. The charge for water-short areas may be slightly higher than the original standard. For recycled water, the standard charge should generally be calculated assuming that the induced economic benefit is shared by the water supplier and the water user;

3. *municipal.* The charge is determined according to the water supply cost or the cost plus a slight profit and may be lower than the industrial water charge;

4. *environmental and public sanitation.* The charge may be determined with reference to the agricultural water charge standard.

Reforms in water pricing, still in their initial stages, have ended the long-held belief that water is divinely bestowed and should be supplied freely. It has also promoted implementation of water saving, helped raise partial funds for renewal of water resources projects, and advanced the development of the water supply industry. Problems still exist, however, and require further investigation; these include the standardization of water supply cost accounting, ratification of the subsidy policy for water supply, the variation of water prices over regions, and the low calculation of water supply costs.

Water Management Institutions

Up until the 1970s, the concept of water management in China was narrow, referring usually to flood prevention and irrigation and drainage works, without viewing water as an important resource and environmental element. During the 1980s, water resources agencies at all levels gradually broadened water resources management. In 1988, the Water Law of the People's Republic of China was officially issued, representing a new stage for water management and the formal establishment of a new water management institution in China.

After the water law was issued, the State Council defined the Ministry of Water Resources as the department of water administration responsible for unified water management. The State Council also stipulated the responsibilities of relevant ministries for water resources management; for example, the Ministry of Geology and Mineral Resources manages groundwater resources, and the State Environmental Protection Bureau is responsible for protection of water resources. Water resources departments at provincial levels are the governmental organs for water administration.

The National Leading Group for Water Resources and Water and Soil Conservation was established with the vice premier as its head; the deputy heads are the minister of water resources and the deputy minister in charge of the State Planning Committee. The leaders of 11 relevant ministries and committees (including bureaus and institutes) form the group's membership. The group's responsibilities are to:

1. examine and verify comprehensive basin planning of large rivers;

2. determine key principles and national policies regarding water and soil conservation;

3. deal with major issues in the comprehensive utilization of water resources involving different departments;

4. handle water-related conflicts among provinces.

After the founding of the National Leading Group, local governments established corresponding agencies. In many provinces, local water resources management law and regulations have been formulated; regional water resources assessment conducted; institutions for the collection of water charges and fees built and put into effect; and planned water use and conservation implemented legislatively, administratively, and economically. Such actions have been instrumental in abating water shortages in these areas.

In 1989, targets for unified management of water resources were set for departments of water resources at all levels and include:

1. unified management of (a) surface and groundwater and rivers, lakes, reservoirs, coastal areas, and other water bodies; and (b) water quantity and quality issues;

2. unified water legislation, investigation, and assessment; planning; allocation; formulation of long-term water plans; implementation of a water-withdrawal system; and other important water-related matters;

3. promotion of comprehensive development and utilization of water resources according to the law; unified supervision and management of the development, utilization, and protection of water resources;

4. organization of water-related activities across regions and sectors; mediation of water-related disputes;

5. supervision and management of water conservation;

6. advancement of the basin-based management system, combined with regionally based management.

Environmental Issues

Environmental pollution is escalating in China, the result of the enormous population and corresponding large-scale production activities. In 1988, the national total discharge of wastewater and sewage was 36.8 billion tons, with industrial wastewater constituting 26.8 billion tons (usually untreated). Among 532 monitored rivers, 436 have been polluted to different degrees. Among 15 reaches (located near 15 major cities) of the country's seven largest rivers, 13 have been seriously polluted. Because of overextraction of groundwater, ground subsidence of varying degrees has occurred at more than 20 cities, forming regional depression cone areas. Groundwater pollution is one of the major contributors to urban water shortages; in some areas, groundwater has been almost totally depleted.

To slow environmental pollution and ecological deterioration, China has established a strategy of coordinating economic development and environmental protection, incorporating prevention as a priority and the "polluter pay" principle. A set of corresponding management institutions, laws, regulations, and standards has also been established. The central task of water-related environmental protection is to strengthen pollution prevention in accordance with these laws and regulations.

Policies for Sustainable Development

By the end of this century, total water demand from agriculture, industry, and domestic use will increase over 1988 demand by an estimated 100 to 150 km^3. Water shortages in the Yellow, Huai, Hai, and Liao river basins will intensify. In the 21st century, water resources development in China will face a major challenge.

To narrow the water imbalance, especially in the arid areas in the north and in the coastal cities, comprehensive measures have to be taken, such as water conservation, water resources development in combination with resource protection and utilization, development of new water sources, increased water use efficiency, and acceleration of the transition from a water-consuming to a water-saving economy. Some of the necessary water policies are summarized below.

Enforcement of Water-Saving Strategy

Various economic, administrative, and legislative measures, such as water charges and planned allocation, were implemented between 1980 and 1984, through information dissemination education. From 1978 to 1984, the total industrial output of Beijing increased by 80 percent; corresponding water consumption, however, declined slightly because of the promotion of water reuse. The reuse rate rose from 46 to 50 percent. In agriculture, effective measures have been employed, including adjustments in cropping patterns; planned water use; improvement of irrigation management; appropriate water pricing policy; canal lining; and the development of pipe, sprinkler, and drip irrigation systems. The concept of water saving needs to be gradually instilled into the general population's consciousness. China's State Council is stipulating planned water allocation, strict water conservation, water withdrawal permits, water charges, and water resources fees.

Coordination between Economic and Water Resources Development

The northern part of China—the political, economic, and cultural center of the country with many urban centers (including Beijing and Tianjin)—has the most serious water deficiency. The ratio of water utilization was as high as 87.3 percent in 1987 during a period of consecutive droughts. Currently, water demand has already exceeded the capacity of local resources. Therefore, the establishment of new industrial enterprises that are highly water-consumptive and highly polluting should be restricted, and agricultural infrastructure should be adjusted to reduce water demand.

Reallocation of Water

During 1980-84, two projects concerned with temporary water transfer from the Yellow River to Tianjin were implemented to mitigate water shortage crises in Tianjin. In 1981, the State Council accelerated diversion projects from the Luan River to Tianjin and Tangshan, and from the Biliu River to Dalian. In 1984, it began the Yellow River-Qingdao diversion project. Other long-term arrangements are also under consideration, such as the east, middle, and west route schemes of south-north water transfer from the Yangtze River to northern China, and the water transfer projects from the Yellow River to water-deficient areas. Integrated planning will be necessary for successful interbasin water transfer. Adverse impacts on the environment must also be studied and mitigated.

Water Resources Protection

Water and soil conservation activities must be reinforced, such as protection of water sources, pollution control, wastewater and sewage treatment, and legal penalties for polluting. The Ministry of Water Resources will concentrate on three tasks in the near future: (1) pollution control of drinking water sources and eutrophication of lakes and reservoirs in scenic spots; (2) water quality control of main rivers (especially near large and medium-size cities), lakes, reservoirs, and delivery channels to meet national standards; and (3) groundwater quality control in urban areas to meet national drinking water standards.

Control of Population Growth

The imbalance between population and natural resources, especially water and land, is a key constraint to sustainable development in China; family planning, therefore, is the basic policy of China's strategy to control population growth.

CHINA'S YELLOW RIVER BASIN: WATER RESOURCES MANAGEMENT POLICIES

Shiyang Gong

The Yellow River basin plays an important role in China's agricultural production. Major characteristics of the basin are uneven distribution of runoff, high sediment concentration in the runoff, and limited exploitable groundwater resources. Key issues in the basin's management are control of soil erosion, environmental degradation of the upper basin's loess plateau, and control of the accelerating sediment deposition in the riverbed and the subsequent flood threat. This paper discusses major water resources policies for the Yellow River basin, as well as principal guidelines for water resources allocation. The basin's environmental status is examined: pollution has not had a major impact on water quality because of the purifying behavior of sediment and because of the relatively small amounts of pesticides and fertilizers used. The paper finally presents future development plans for four multipurpose projects on the Yellow River. An integrated water resources allocation plan for the river basin has also been formulated, based on consideration of national economic development targets; water demand studies; and projects proposed by provinces, regions, and sectors.

Yellow River Basin Development

Background

The Yellow River flows through nine provinces and joins the Bohai Sea on the east coast of China. Its total length is 5,464 km, with a drainage area of about 752,000 km^2. The mean annual runoff is 58 billion m^3. The three divisions of the river are shown in table 1.

Table 1. *Yellow River Division*

Section	*Length of main river (km)*	*Drainage area (km^2)*	*Drop (m)*
Upper	3,471.6	385,966	3,496.0
Middle	1,206.4	343,751	890.4
Lower	785.6	22,726	93.6
Total	5,463.6	752,443	4,480.0

The basin plays a major role in the country's production of grain, cotton, and edible oil, supporting 14, 40, and 15 percent of the national output, respectively. Rich coal deposits in the basin account for 46 percent of the country's total. Proper utilization and management of the basin's water resources are significant to the country's economic growth and social development.

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The river has historically brought disastrous flood damage to its lower reaches. Since 1949, many water storage, diversion, and pumping structures have been built by the central and local governments along the lower reaches of the river. Remarkable progress has been achieved thus far: (a) no dikes have been breached in the past 40 years; (b) the irrigation area has increased sevenfold; (c) water demands from urban and rural areas and from industry have been met; and (d) sediment delivery into the Yellow River has been reduced by 16 percent. The utilization ratio of water resources has reached 46.7 percent, and the total installed hydropower capacity is 3,622 megawatts.

Major Characteristics and Key Issues

The Yellow River's earliest hydrometric stations were established in 1919. Studies have been completed using data observed over 70 years and historical documents covering more than 200 years. The main characteristics of the Yellow River are:

- The amount of runoff is relatively small in relation to the drainage area (20.3 m^3 per ha of arable land and 650 m^3 per capita);
- The distribution of runoff is uneven over time and space. About 60 percent of runoff is produced during the flood season, between July and October;
- The sediment concentration in the runoff is high, and sediment deposition in the riverbed is accelerating. For instance, the sediment load passing through the Huayuankou station reaches as much as 1.6 billion tons yearly, or 34.1 kg/m^3 in concentration. It occurs between July and September, forming 80 percent and more of the annual total;
- The exploitable groundwater resources in the basin are limited. The net exploitable volume is 8.2 billion m^3, 6.4 billion m^3 of which have already been utilized since 1980.

Water losses are common and serious because of limited investment, inefficient management, and incomplete infrastructure in the irrigation areas. For example, only 16 percent of infrastructure has been completed in the Hetao irrigated area of Inner Mongolia. The so-called flooding irrigation system leads to average water consumption as high as 15,000 m^3/ha, and grain productivity is only 0.1 kg per m^3 of irrigation water. Consequently, more than three-quarters of the irrigated land has become saline. The municipal water reuse ratio is, on average, 56 percent in large urban areas and nearly zero in medium and small cities. Industrial water consumption is 80 to 150 m^3 per 1,000 yuan (about US$250) of output (or 6 to 12 yuan of industrial output per m^3 of water).

Water quality monitoring has revealed that, for the main river and its tributaries (total length = 13,384 km), severe water pollution has occurred in 1,275 km (9.5 percent of the evaluated stretch length), with all cases near large urban areas. In addition, soil erosion and environmental degradation on the loess plateau need to be effectively controlled.

The threat from dangerous floods, including ice floods, remains. The flood-prone area in the entire basin is 120,000 km^2, of which 7.3 million ha are arable. The affected population is 70 million. Preliminary flood prevention engineering systems, including dikes, protection of vulnerable areas, river training, the Dongping Lake, and Beijinti detention basins, have been established, along with three major reservoirs. The preventive capability of the system, however, can only protect against a flood with a 60-year return period at an estimated peak discharge of 22,000 m^3/s. The successive heightening of the main dikes at a rate of 1 m every 10 years, to protect against the riverbed rising because of heavy sediment deposition, involves not only an enormous investment, but also increasingly high risks to flood protection (see "Technological Aspects" below).

The river's runoff cannot be effectively regulated because the total effective storage capacity of the existing reservoirs is only 25 million m^3, primarily located in the upper reaches. The result has been both water abandonment and water depletion in the lower Yellow River during the nonflood season (November to June). Data show that since 1974, the average annual runoff in the nonflood season at Lijin station has been 11 billion m^3; even in the dry years of 1986 and 1987, there were 4.9 billion m^3 of runoff passing through the station and flowing needlessly into the sea.

Water Resources Utilization

The total amount of water resources consumed is 33.5 billion m^3 (27.1 billion m^3 of surface runoff and 6.4 billion m^3 of groundwater). The consumption of water by sector is shown in table 2. In agriculture, the irrigated area reached 5.9 million ha in 1980, of which 3.9 million ha were irrigated by surface runoff and 2 million ha by groundwater.

Long-Term Water Allocation

The long-term runoff allocations for the year 2000 have been estimated (table 3), based on hydrometric data series from 1919 to 1975 and the present regulation of Longyangxia, Liujiaxia, Sanmenxia, and Xiaolangdi reservoirs.

Current allocation schemes represent adjustments made to the initial requests from provinces, regions, and sectors, considering the overall needs of basin development. Components of these schemes are:

1. Total water consumption in the year 2000 is estimated at 37 billion m^3 (from a mean annual runoff of 58 billion m^3); the remaining 21 billion m^3 will be used for flushing sediment into the sea;

2. The area irrigated by surface runoff will reach 5 million ha and require 29 billion m^3 of runoff, i.e., 78.8 percent of the total amount of runoff consumed in 2000;

3. The allocation of surface runoff to nonagricultural sectors will increase from 1 billion m^3 in 1980 to 7.84 billion m^3 in 2000, constituting 21.2 percent of the total amount consumed (compared to 3.9 percent in 1980). This is mainly the result of energy, industry, and urban development use as well as population increase.

Table 2. *Water Resources Consumption by Sector, 1980 (million m^3)*

	Total basin area			*Area above Huayuankou*		
Sector	*Total*	*Surface runoff*	*Ground-water*	*Total*	*Surface runoff*	*Ground-water*
Irrigation	31,599	26,000	5,599	21,765	17,770	3,995
Industry	1,376	881	495	743	295	488
Municipal	178	78	100	172	77	95
Rural area	302	105	197	267	104	163
Total	33,445	27,064	6,391	22,947	18,246	4,701

Table 3. *Runoff Utilization by Region and Sector*

	1980		2000	
	Irrigated area ('000 ha)	*Water consumed (million m³)*	*Irrigated area ('000 ha)*	*Water consumed (million m³)*
Region				
Upper reach	1,088	11,860	1,317	11,880
Middle reach	1,702	5,910	1,948	9,190
Lower reach	1,068	8,230	1,743	8,090
Entire river	3,858	26,000	5,008	29,160
Sector				
Industrial	n.a.	881	n.a.	4,136[a]
Municipal	n.a.	78	n.a.	821[b]
Rural	n.a.	105	n.a.	2,881[c]
Total	n.a.	1,064	n.a.	7,838

a. Includes energy generation water use (1.58 billion m^3).
b. Includes Qingdao city water use (500 million m^3).
c. Includes Hebei and Tianjin province/city water use (2 billion m^3).

Institutional Arrangements

Water-related legislation was enacted in the 1980s, including the Water Law and laws regarding water resources and environmental protection. The Yellow River Conservancy Commission (YRCC) is the administrative agency for water resources management of the entire Yellow River basin. It is responsible for integrated planning, coordination, and management, in conjunction with provincial and regional agencies. It has two basic functions: (1) flood control of the main river course downstream of the Sanmenxia reservoir (local agencies are responsible for other sections of the river and its tributaries); and (2) management, utilization, and regulation of the basin's water resources.

Flood prevention in the lower Yellow River is handled by the governors of Henan, Shandong, and Shanxi provinces, and by the director of the YRCC. As the executing agency, the YRCC is responsible for the planning, design, construction, protection, maintenance, and management of engineering works for flood prevention. These works include reservoirs, dikes, protection of vulnerable areas, river training, culverts, and detention basins, as well as flood forecasting and regulations. Other agencies were also established under the YRCC, including the River Engineering Bureau of Shandong and Henan provinces, the Sanmenxia Reservoir Management Bureau, the Guxian Reservoir Management Bureau, and the Institute of Reconnaissance.

As a guideline, the YRCC uses the water resources allocation plan of the Yellow River basin approved by the State Council. The YRCC supervises the water use of each province and region by hydrometric survey at stations along the river near the provincial boundaries. The construction of water intake engineering works on the main branches of the river and interprovincial tributaries requires YRCC approval. The provincial administrative agencies work within the parameters defined by the allocation plan. Water quality management is conducted similarly.

Present hydrometeorological forecasting techniques cannot handle all the needs inherent in the huge basin area and the long distances between upper and lower reaches. The daily management of water runoff is therefore conducted separately for two sections. For the section above Hekouzhen, a water regulation committee of the upper Yellow River was established in 1968, chaired by the YRCC and consisting of the heads of the water administrative bureaus of Qinghai, Gansu, Ningxia, and Inner Mongolia provinces and regions, as well as the head of the Power Administration Bureau of Northwest China. An office within the committee was set up as the executive agency for examining and supervising the implementation of the water supply plan. For the section below the Sanmenxia reservoir, management and regulation are carried out directly by the YRCC and its subagencies.

The institutional framework is still incomplete. For example, there is no agency overseeing the middle reaches of the Yellow River. The regulation system and number of managers and staff are inadequate for the tasks assigned.

Water Resources Investment and Pricing Policies

The main water policies established for the Yellow River are:

- Flood protection works are viewed as part of social welfare. Construction investments and the maintenance costs of flood control projects will be funded by the central and local governments, without reimbursement. The affected population living along the river will participate in activities on a voluntary base;

- For water resources utilization, the costs of construction and maintenance of the key water supply projects had been covered jointly by the central and local governments, without reimbursement. Subsequently, there has been an attempt to launch a policy of providing low-interest government loans and recovering partial costs from benefiting sectors;

- Since 1988, several regulations, such as issuance of water use licenses, collection of water charges, etc., have been formulated and implemented. Subsidies to agriculture, however, render irrigation water charges low and inadequate to recover the costs of maintenance and reconstruction of irrigation supply systems. Charges for municipal and industrial water use are also low. Policies on water charges that more closely examine the costs of water supply are expected to be formulated and implemented, initially in the municipal and industrial water sectors. Charges for the utilization of basin water resources, including groundwater exploitation, are also under consideration;

- To promote water saving, progressive and floating water charges are being considered;

- Alleviation of water pollution has been promoted through collection of pollution charges and fines. Current policy is based on requiring the actual polluters to provide treatment. Because of inadequate regulations and management, however, this policy's impact has been limited.

The role of pricing mechanisms in intersectoral water allocation in the Yellow River basin is a new issue. As yet, there is no unified policy. In some provinces, during the dry season, enterprises have negotiated with farmers and paid them for the right to surface water use, and in some regions the charge for power used in high-lift pumping irrigation is subsidized to ensure the grain harvest.

Technological Aspects

Heightening the dike system of the lower reaches of the river has been proposed. This project seeks to enhance the system's preventive capability against a flood with a 300-year return period, thus reducing the opportunity and scope of inundation of the Beijinti detention basin where the Zhongyuan oil field is located. Four hundred km of main dikes need to be heightened by an average 2 m, and a new intake structure with a diversion capacity of 10,000 m^3/s installed. A large amount of earthfill and riprap works would be required, and the water levels of stretches (600-km length) would be 1.5 m higher than at present, causing increasingly high risks to flood prevention work. Moreover, because there would be no benefits achieved regarding silt reduction, ice flood prevention, water supply, and power generation, the cost-benefit ratio of this scenario is only 0.73, and the cost recovery ratio is less than 6 percent.

Artificial avulsion of the lower river course has been suggested by some Chinese and foreign scholars. A new river course with a total length of 550 km would be formed by construction of a new dike system to enclose the depression terrains on the north bank of the existing river channel. A storage capacity of 276 million m^3 would trap sediment deposition for nearly 60 years. This plan, however, requires an enormous amount of earthfill works (340 million m^3) for the institution of a new dike system, and it will seriously deteriorate existing irrigation, drainage, and communications systems. In addition, more than 350,000 ha of arable land will be inundated, and 2.5 million inhabitants will need to be resettled. Therefore, this plan's acceptability is unlikely.

Forty years of experience show that soil conservation works on the loess plateau are effective for reduction of sediment delivery into the Yellow River, but require a long period to obtain noticeable results. The problems of the lower river channel can be effectively alleviated or resolved, therefore, only through integrated measures. Some of the measures undertaken include reducing sediment yield by soil conservation, trapping sediment, regulating sediment discharge by reservoirs, diverting and utilizing sediment by warping, and transporting sediment into the sea by river training. For instance, about 3.5 billion m^3 of runoff will be needed to transport 100 million tons of sediment in the lower Yellow River into the sea. The check-dam system built in the concentrated sediment yield area (about 100,000 km^2) on the loess plateau could reduce the sediment delivered into the river, with a reduction in runoff of only 700 million m^3. This is beneficial not only for flood control, but also for the utilization of the river's water resources. Further study is needed.

Ice floods are another source of damage threatening the lower reaches of the river, particularly around February. The magnitude of ice floods essentially depends on the volume of water stored in the river channel after a period of freezing and the amount of inflow during thawing. In the last 20 years, the threat of ice floods has been alleviated by regulation of the water discharge regime in the lower reaches by the Sanmenxia reservoir. Since the Longyangxia reservoir, located on the upper reaches of the river, has also begun operating, the inflow in the lower reaches during the dry season has increased. Although this benefits water resources utilization, it also requires a much larger amount of water to be stored during the ice run, greatly exceeding the storage capacity of the Sanmenxia reservoir. Additional measures, therefore, should be considered to ensure ice flood prevention.

Environmental Issues

Generally, the water quality of the Yellow River basin is good. The waters are slightly alkaline, with a pH value of 8 and above. Of the total length (13,384 km) of examined stretches of main rivers and tributaries, 71 percent is suitable for drinking and fisheries, and 19 percent is suitable for irrigation. Severe pollution makes 9.5 percent unsuitable for any use. (These results were obtained from analysis of the "muddy water" of the river.) These stretches are all situated in tributaries near large urban areas. For example, in the stretches of more than 500 km of Fen River downstream of Taiyuan City, river runoff has a high concentration of phenol and therefore is of no use.

Sediment, particularly if it is fine, has strong absorption abilities regarding most of the toxic elements in water, such as phenol, arsenic, mercury, cadmium, and lead. Once these toxic elements have been absorbed, they will not be released to the water bodies, which are slightly alkaline. Analysis has also revealed that the amount of arsenic and other heavy-metallic elements in pure water (free from sediment) has not exceeded the critical values defined for drinking water. Therefore, Yellow River sediment functions not only as a pollution absorber but also as a pollution purifier.

Thus far, there have been no adverse health impacts as a result of man-made water pollution. Local diseases have only been found in some areas where the quality of local groundwater is inappropriate because of geochemical reactions.

Non-point pollution does not have a predominant impact on the water quality of the river basin for two reasons: (1) relatively small amounts of pesticides and fertilizers are used, and (2) the particular behavior of sediment (discussed above) might play an important role in self-purification of river runoff.

The wastewater released by urban areas and industries is the main source of water pollution. Based on the "polluter pay" principle, policies of collecting charges and fines related to polluted water released have been implemented. In addition, it has been mandated that pollution treatment measures be designed, constructed, and operated simultaneously with newly built projects. To maintain the river's self-purification abilities, minimum water discharges are defined for different sections of the main river.

Future Development Plans

China plans to build four multipurpose projects on the Yellow River in the coming years: Xiaolangdi, Longmen, Daliushu, and Qikou.

Xiaolangdi

The Xiaolangdi project has recently been approved by the National People's Congress, and construction is expected to begin during the eighth five-year plan. Situated in a critical position whereby it is able to control most flood and runoff portions and almost the entire amount of the river's sediment load, the Xiaolangdi project will play a key role in resolving the major problems of the lower Yellow River, thus yielding significant benefits. A sound flood prevention engineering system will be established through implementation of the project, protecting against floods with a return period of 1,000 years. Threats from ice floods will be essentially eliminated, a condition favorable to the development of the estuary area and Shengli oil fields. In addition, enormous inundation losses will be avoided, and the flood resistance of a vast area ensured. There will be no channel aggradation in the lower Yellow River for 20 years after implementation of the project; the enormous investments and labor needed for dike raising can therefore be bypassed and the risk of dike breaches reduced. Water exhausted in nonflood seasons will also be recovered. The reliability of water supply for irrigation, municipal, and industrial uses will be increased. Annual hydropower output will be 5 billion kilowatt-hours. The project's cost recovery ratio is estimated at 14.6 percent.

An environmental appraisal made by the State Planning Commission and the State Bureau of Environmental Protection stated that construction of the Xiaolangdi project will provide many more benefits than it will damage to the ecology and environment of the area, except regarding resettlement. Other conclusions from the appraisal are that there will be little damage to crop cultivation and that the irrigation area and water supply reliability will be increased. The major negative impact of the project is the need for resettlement. The reservoir will inundate about 11,000 arable ha, necessitating the resettlement of 140,000 people. The guiding principle for resettlement is that the productive and living standards of those resettled should be the same as or higher than their original conditions, leaving some leeway for continuous economic development of the resettled areas.

Longmen

A 216-m-high, earth-rock-filled dam is planned at Longmen, situated 130 km upstream of the Sanmenxia dam project. A reservoir with a total storage capacity of 11.4 billion m^3 will be constructed and will effectively regulate floods and runoff originating from the area above the dam site. The primary benefit will be the reduction of inundation losses and of sediment deposition in the Sanmenxia reservoir area. Water demand from highland irrigation areas will be met. Power generated by the project will be 2,100 megawatts. Although the volume of engineering works and the cost of the project are almost the same as those of the Xiaolangdi project, the Longmen project can control only one of the three major flood sources of the lower river, thus providing fewer benefits for flood protection. In addition, the Longmen dam site is 250 km upstream of the Xiaolangdi project, and some sediment load will be recovered from this long stream path, resulting in the Longmen project's being less effective (about 40 percent of the Xiaolangdi project's effectiveness) vis-à-vis silt reduction of the lower Yellow River. The cost recovery ratio of the Longmen project is 11.46 percent.

Daliushu and Qikou

Two other multipurpose projects, Daliushu and Qikou, will be built on the main river. The former aims to perfect regulation of runoff of the river's upper reaches and to mitigate the region's conflicts among flood protection, irrigation, and power generation. The latter project will regulate runoff for local uses and effect the successive reduction of silt deposition in the lower river.

Comprehensive Water Resources Plan

An integrated water resources allocation plan for the river basin has been formulated. A draft was developed by the YRCC based on consideration of national economic development targets and studies of water demands, as well as projects proposed by provinces, regions, and sectors. Revisions were then made after discussion and coordination with related agencies. The plan was finalized after evaluation by China's Ministry of Water Resources (MWR) and the State Planing Commission, and was approved by the State Council in 1984.

The major guidelines for water resources allocation are:

- keeping annual runoff at Lijin station no lower than 20 to 24 billion m^3 for flushing sediment into the sea;
- giving priority to water supply for industries, mines, energy sources, and cities approved by the state;
- improving the irrigation infrastructure to promote water saving in irrigated areas;
- establishing new irrigation areas in grain-deficient regions;
- under drought conditions, minimizing conflict between industrial and agricultural water uses by providing only 75 percent of the quota to irrigation areas (except to those in grain-deficient regions and to rural inhabitants);
- ensuring minimum flow discharge along the main river to protect water quality and the environment.

In the long term, the Yellow River basin's water resources are insufficient in view of the enormous amount of land and mineral resources involved. Surveys carried out by the YRCC to study the possibility of diverting water from the source of the Yangtze River and its tributaries to the upper reaches of the Yellow River (the so-called West Route plan) suggest that an annual diversion of 15 to 20 billion m^3 may be possible, but further study is needed.

INTERNATIONAL BASIN MANAGEMENT OF THE DANUBE RIVER

Helmut H. Hauck and Bernhard H. Schmid

The Danube is an international river whose characteristics and uses differ considerably among riparian countries. There are, however, areas of common concern. With the abolition of the Iron Curtain, the division of the basin along political and ideological lines has shifted to underscore socioeconomic distinctions, bringing a new dimension to the basin's dynamics.

Characteristics of the Danube River Basin

With a total length of 2,850 km, the Danube is the second-longest river in Europe. On its course from the Black Forest to the Black Sea, the Danube is joined by several tributaries, some important ones being the Inn, Enns, and Tisza. The river flows through eight countries: Germany, Austria, Czechoslovakia, Hungary, Yugoslavia, Bulgaria, Romania, and the former Soviet Union.

The Danube basin can be divided into three main sections:

1. The *upper* basin covers the area from the source (Germany) to the Devin Gate, east of Vienna. The lower end of this section is characterized by a distinct decline in average slope;

2. The *middle* basin is the largest of the three sections, starting from the Devin Gate (in Czechoslovakia) down to the fault section between the southern Carpathians and the Balkan Mountains near the Iron Gate on the Yugoslav-Romanian border;

3. The *lower* basin comprises the Romanian-Bulgarian lowlands and the Siret and Prut basins (partly in Romania and partly in the former Soviet Union).

Climatic conditions in the basin vary significantly. The mean annual precipitation ranges from 3,000 mm in mountainous zones to 400 mm in the delta. The mean flow varies from 300 m^3/s at Ingolstadt in Germany to approximately 1,900 m^3/s at Vienna, and to 6,550 m^3/s near the mouth of the river.

Framework for Water Use

Socioeconomic conditions in the riparian states diverge, influencing water use in the Danube basin. Although Germany and Austria are among the developed industrial nations, others in the basin are still struggling with the heritage of previous regimes. (Table 1 lists the riparians' GNP per capita.) In addition, climatic and topographical differences affect water use in the basin, which varies considerably

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Table 1. *GNP Per Capita in the Riparian Countries, 1985, 1989 (US$)*

Country	*GNP Per Capita* *1985*	*1989*
Austria	10,210	17,300
Bulgaria	4,150	2,320
Czechoslovakia	5,820	3,450
FRG (former)	13,450	20,440
Hungary	4,180	2,590
Soviet Union (former)	4,550	n.a.
Romania	2,540	n.a.
Yugoslavia	2,790	2,920

Source: For 1985 figures, Rado, *Great World Atlas*, Budapest, 1985; for 1989 figures, World Bank, *World Development Report 1991*.

among countries. In the upper part of the basin, the river water is used primarily for industrial and municipal supplies, as well as for hydropower generation. In the middle and lower reaches, irrigation dominates water use. Transportation on the river is important to the majority of riparian states. A sharp increase in the amount of cargo shipped on the Danube is expected after the completion of the Rhine-Main-Danube Canal connecting the Black and North seas.

Institutional Arrangements

The first official authority for river planning and its implementation was founded in 1773 to improve inland navigation. Several agreements have been reached over the years, the most important of which is the Danube Convention (or Danube Declaration) of 1948. This agreement promotes and coordinates navigation on the Danube River and recommends improvements and design with respect to, for example, navigable depth, width, curvature, slope, and lock size.

Hydropower Development

The relative importance of hydroelectric power varies among the riparian countries. In Austria, hydropower supplies more than two-thirds of the total electricity supply. In Czechoslovakia, Hungary, Bulgaria, and Romania, the percentage is considerably lower. Some countries depend largely on fossil fuels, particularly Czechoslovakia, a dependence that may create severe environmental problems. For example, because many Czechoslovakian thermal power plants do not meet modern standards, air pollution and acid rain have become serious concerns.

Regarding the Danube River's hydropower potential, there are two distinct areas that are particularly suited for hydropower development: the stretch between the German/Austrian border and Gönyü in Hungary, and a stretch downstream of Belgrade in Yugoslavia. The Austrian reach has been the subject of considerable planning and construction activity. In addition to Jochenstein, which is managed jointly by Germany and Austria, there are eight run-of-river plants operating. A ninth will soon be constructed at Vienna. All Austrian plants on the Danube are multipurpose, covering river navigation, flood control, improvement of environmental conditions, irrigation and drainage, and power generation.

Downstream of the Austrian reach, a conflict regarding Danube River development has arisen between Czechoslovakia and Hungary. The countries had entered into an agreement on the construction of the Gabcikovo-Nagymaros hydropower project to generate electrical power and to solve the severe inland navigation problems imposed by the river's morphology on the Czechoslovakian/Hungarian stretch. The project consisted of a large reservoir downstream of Bratislava, a weir structure at Dunakiliti, an approach canal, a power plant at Gabcikovo, an outlet canal discharging into the Danube River, and a reservoir and power plant at Nagymaros. The Gabcikovo plant at the upper reach was intended to perform peaking operations, with the Nagymaros plant providing the necessary compensation reservoir to prevent surge waves from traveling further down the river. Construction on the project at Nagymaros began, but was stalled in 1989 as a result of objections raised by environmentalists, thus creating conflict between Czechoslovakia and Hungary. The issue remains unresolved.

Further downstream, Yugoslav-Romanian projects include the Djerdap project (Portile de Fier I), constructed during 1964-72 and with a 32-m dam, and the Gruia plant (Portile de Fier II), which began operating in 1984. Both projects are linked, with the Gruia backwater acting as a compensation reservoir for peaking operations at Djerdap.

Flood Control

Flood control is an important issue in the basin. Flood protection dikes and levees along the Danube were built by the Germans beginning in the mid-19th century. The disastrous floods of 1830 and 1864 in Austria prompted decisions to provide Vienna with adequate flood protection. Comprehensive river training, regulation, and construction of flood protection dikes were undertaken. The flood protection system in Vienna is now being improved to protect against floods with a maximum peak runoff of 14,000 m^3/s. In large parts of the Austrian Danube reach, flood control measures were taken together with general planning for hydropower development. In Czechoslovakia, flood control embankments have been built or strengthened since the second half of the 19th century. In the first half of this century, the Hungarian flood protection system, which includes dikes and river training, reached a stage that allows safety control over floods with 60-year return periods. Similar flood abatement measures have also been taken in Yugoslavia, Bulgaria, and Romania, where extensive systems of dikes have been built. Flooding by ice jams, which has caused considerable damage, has also been reduced by river training and regulation.

Environmental Issues

Although water quality standards on either side of the former Iron Curtain differ, the water quality of the Danube River is presently much better than that of the Rhine. Measured on a scale of four grades (grade I—almost unpolluted; grade IV—very heavily polluted), Danube river water falls primarily in grade II (moderately polluted). Grade III is applied only to stretches downstream of major settlements and industrial areas. Considerable efforts are under way to improve the pollution situation in these areas, and many wastewater treatment plants have begun operating.

Environmental problems occur in some unimpounded reaches of the river because of riverbed degradation and corresponding decreases in groundwater levels, thus threatening riverine biotopes. In Austria, this problem has been solved through low-head hydropower development. Impoundment stops degradation of the riverbed and permits riverine lowlands to be irrigated in a way similar to natural conditions.

Conclusion

Since the change in political regimes in Eastern Europe, the division of the Danube basin is more along socioeconomic lines than political ones. Although the use of Danube waters differs among riparian states, river navigation, hydropower development, and the construction of wastewater treatment plants are common concerns. Consequently, considerable investment will continue to be needed, particularly in the newly democratic countries.

WATER RESOURCES PLANNING AND MANAGEMENT OF THAILAND'S CHAO PHRAYA RIVER BASIN

Boonyok Vadhanaphuti, Thanom Klaikayai, Suwit Thanopanuwat, and Natha Hungspreug

The Chao Phraya River basin is Thailand's largest geographical unit in terms of land and water resources development. Hydropower in the basin is a major source of the country's electrical energy. For centuries, small-scale irrigation projects have been operated in the basin. The Chao Phraya delta is known as the country's rice bowl, and high priority is currently given to agricultural water allocation; however, as industrial development is promoted in the basin, new allocation criteria will be required. Legislation on irrigation water charges has been passed, but has not yet been effectively implemented, mainly because of frequent changes in government and lack of political will. The government is expected to consider shortly a new policy on water charges. Although environmental legislation is in place, a gradual tightening of law enforcement is required. This paper discusses water allocation priorities, administrative bodies responsible for basin and project management, and the basin's environmental status. In the near future, improvement of basin planning and development will be emphasized, stressing enhanced water management and encompassing rehabilitation, refinement of information systems, and modernization of existing irrigation facilities.

Water Resources Development

Background

The Chao Phraya River basin is Thailand's largest and most important geographical unit in terms of land and water resources development. It is located in the north and central regions of the country and occupies about 35 percent of the country's total area. About 20 million people (30 percent of the population) reside in the basin, nearly 80 percent of whom are farmers. Rice is the main crop in both irrigated and rainfed areas of the basin.

Average annual rainfall in the basin ranges between 1,000 and 1,400 mm. The climate is dominated by the southwest monsoon, which occurs between May and October. About 90 percent of annual rainfall occurs during this period, causing heavy floods. The scarcity of rain between November and April makes agricultural conditions unfavorable. On average, the total volume of water available has been estimated at 31,300 million m^3 per year.

Characteristics of the Basin's Upper and Lower Reaches

The river basin can be characterized geographically into upper and lower basins. The upper basin is mountainous, with 40 percent forest cover and 41 percent cultivated land. Traditionally, agriculture has been practiced in the river valleys. Shifting cultivation has caused soil degradation and erosion in

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some areas and has changed the hydrological regime. The lower basin (the river's delta) is the floodplain and is well suited to rice cultivation. After irrigation water became available in the 1970s, farmers in the lower basin switched from growing floating rice to cultivating higher-yielding varieties.

For centuries, small-scale irrigation projects have been operated in the upper part of the basin. These projects, organized by small farmer groups, are constructed, operated, and maintained by local farmers. Water rights are strictly observed, not only among farmers who share water in the same project, but also among upstream and downstream projects in the same subbasin.

In the lower part of the basin, the farm holding size is normally larger. Farmers often experience losses as a result of water shortages at the beginning of and excessive water at the end of the growing season. Supplementary irrigation and flood protection projects have therefore been implemented in this area. Many of these projects are relatively large, and the construction of works is beyond the capability of small farmer groups. In addition, because water is generally abundant in the wet season, these farmers have no strong incentive to form water user groups for allocation and management.

Basin Infrastructure

SURFACE WATER DEVELOPMENT. Among the basin's major infrastructure, the Chao Phraya barrage irrigates an area of about 1.2 million ha in the lower part of the river basin to increase wet season rice production. The multipurpose Bhumibol and Sirikit dams are upstream of the barrage. Their construction enabled provision of water to 400,000 ha of dry-season cropping in the lower part of the river basin. Hydropower from these dams has become a major source of electrical energy for Thailand.

On-farm improvement works have also been developed, including land consolidation and the introduction of ditches and dikes. Consequently, the area of dry-season paddy increased tenfold in eight years, resulting in a shortage of water in the dry season and increasing conflicts among water users and various farmer groups.

In the 1980s, the government began a development program to improve living conditions in rural areas that had not benefited from large-scale water resources development projects. This program emphasized small- and medium-scale projects, including the improvement and rebuilding of temporary weirs and control structures in irrigation projects. Small-scale projects were limited by total costs and were mandated to be completed within one financial year. Since 1980, over 1,300 small-scale projects have been constructed in the Chao Phraya basin. About 65 percent of these are located in the upper part of the basin, which has favorable topographical conditions and active farmer participation. The average capacity of small reservoirs is about 340,000 m^3. Medium-scale projects are classified as those with a reservoir capacity of less than 100 million m^3 or an irrigable area less than 12,800 ha. There are more than 200 medium-scale projects, located primarily in the upper and central parts of the basin. About 70 percent of them have an irrigable area of less than 1,000 ha and storage capacity less than 5 million m^3. These projects are approved on the basis of sociopolitical objectives, but their economic rate of return is also considered. Environmental impact assessment is not required.

Flood protection is important in the lower part of the river basin because of the risk of large-scale damage to public and private property. Dikes were constructed downstream of the Chao Phraya barrage to prevent the inundation of cultivated land and also on the eastern side of Bangkok to protect residential areas.

The Chao Phraya River is the principal source of water for domestic and industrial uses in the basin. The major user is the Bangkok Metropolitan Water Works Authority (MWWA), with an annual requirement of about 1,100 million m^3. This amount has been supplemented with groundwater. The MWWA intends to terminate the use of groundwater and replace it with transfers from the Meklong basin. Presently, less than 10 percent of water use in Bangkok comes from groundwater.

GROUNDWATER DEVELOPMENT. Large pumping projects are normally implemented, operated, and maintained by the Royal Irrigation Department (RID). Such projects presently cover 57,000 ha in the basin. So far, farmers have not been required to pay pumping costs or any other charges. In two projects financed by the Asian Development Bank, farmers had agreed to pay partial pumping costs. After the projects were completed, however, the payments were deferred for unclear reasons.

There are over 200 small-scale pumping projects in the Chao Phraya basin, primarily located along the rivers upstream of the Chao Phraya barrage and serving a total of 48,000 ha. Each project consists of a small pumping unit and a system of concrete-lined canals to irrigate an area of about 80 to 480 ha. Farmers in each project area are required to form a cooperative for the operation and maintenance (O&M) of the system. They are also required to pay part of the pumping costs, currently about US$12.5/ha in the wet season and about US$25/ha in the dry season. So far, these projects have received a fair response from farmers.

There are also several private pumping units in the basin owned by farmers, operators, or cooperatives. Private pumping is not regulated, and this situation could eventually lead to conflicts among users when river flows are low. The total quantity of water being pumped privately, however, is relatively small. The use of groundwater by industries, which have their own pumping facilities, will be slowly replaced by water supply provided by either the MWWA or the Provincial Water Works Authority (PWWA).

In the lower part of the Chao Phraya basin, there is good potential for groundwater development. The use of groundwater for industry is popular because it is cheaper than the piped water supplied by the PWWA. Increasing extraction of groundwater, however, has resulted in land subsidence, salinity intrusion, and flooding. In 1985 the Groundwater Act was passed, stipulating a reduction in groundwater extraction.

Water Allocation and Pricing

Water Allocation Criteria

Water allocation guidelines for the operation of the major reservoirs in the Chao Phraya basin have been adopted on a priority basis and include:

- *domestic consumption*. Top priority is given to domestic consumption, which accounts for about 7 to 8 percent of total demand;

- *irrigation*. Water for irrigation, which amounts to 90 percent of total water demand, is available during droughts in the early wet season to avoid damage to newly planted crops;

- *inland navigation*. When water levels are low, extra releases are made available for short periods to facilitate inland navigation. Barge operators are also requested to lower their carrying capacity to reduce the depth of water required to support navigation;

- *saline water intrusion*. To maintain a certain salinity level near the river mouth and thereby protect fruit trees, orchards, and potable water, water is released to prevent saline water intrusion;

- *hydropower generation*. Hydropower plants operate at peak power generation in the evening to supplement power generation from other power plants connected to the national grid.

Water Charges

The State Irrigation Act of 1942 and subsequent amendments stated that landowners receiving benefits from irrigation works shall be subject to payment of irrigation service fees to the local project offices of not more than US$0.125/ha. The act also applied volumetric water charges to industrial and other uses at not more than US$0.02/m^3. A 1975 amendment stipulated that the collected fees be deposited in a special revolving fund that could be used for future O&M. The irrigation act also stipulated that the minister of agriculture and cooperatives designate areas as irrigation waterways subject to irrigation service fees. Thus far, only small areas have been designated as irrigation waterways. The charge for industrial and other uses was prescribed in a 1975 ministerial regulation, but no charge for irrigation service has yet been specified.

There are many reasons why collection of irrigation fees has not been effectively implemented. The main reason may be that there has been no real political will to implement water charges. It is generally accepted that farmers are the lowest-income group and therefore it is not appropriate or politically expedient to impose any additional burden upon them. In addition, frequent changes in government have also delayed the issuance of regulations. Regulatory changes normally take a year to be endorsed by the cabinet before becoming effective. Attempts have recently been made to review the water rates for industrial use as well as the areas designated as irrigation waterways. Fees should at least reflect investment costs as well as O&M costs of projects.

The 1974 Agricultural Land Consolidation Act required farmers in the land consolidation areas to pay O&M costs and part of the capital costs of land improvements. The collection of these cost recovery charges has been carried out since 1984. The act stated that the subsidy to farmers shall not be less than 10 percent of the cost of land consolidation. In practice, the amount of subsidy varies by project depending on the farmer's ability to pay. Recently, farmers—through their political representatives—have often requested that such payments be deferred and the amount of government subsidy be increased. Farmers have reported yield reductions resulting from poor water delivery. This fact, combined with low product prices, has made it difficult for farmers to pay the required fees to recover project costs.

Institutional Arrangements

Water Management

There are 24 departmental-level agencies, under eight ministries, involved in water resources planning, development, and management. At the national level, there are two committees attached to the office of the prime minister: the National Water Resource Committee and the National Rural Development Committee. These committees are responsible for devising development guidelines and for coordinating the activities of all agencies concerned.

At the ministerial level, several committees set policy guidelines and oversee the overall management of projects. The most important are the Committee on Agricultural Policy and the Committee on Irrigated Agricultural Development, both chaired by the minister of agriculture and cooperatives. Subcommittees, which work closely with water user groups and farmers, are established at the project level where appropriate.

In the Chao Phraya River basin, the principal agencies in charge of water resources development are the Electricity Generating Authority of Thailand (EGAT), the Royal Irrigation Department (RID), and the National Energy Administration (NEA). The EGAT is responsible for the construction, operation, and maintenance of hydropower plants. The RID is responsible for the management of the irrigation system and for water allocation for other uses, such as municipal supply and navigation. The NEA is in charge of the country's overall energy development policy and is also involved in water resources development in the operation of small pumping projects for irrigation. The main agencies involved in the nonagricultural use of water are the Bangkok Metropolitan Water Works Authority and the Provincial Water Works Authority.

Basin Management

To avoid conflicts among water users, since 1980 the EGAT and the RID have coordinated their activities and adopted the following operational guidelines for improved management of the basin's reservoirs:

1. The RID estimates the weekly demand for irrigation and other downstream uses and informs the EGAT in advance;

2. Estimated weekly demand constitutes the target reservoir release for the coming week. If downstream requirements are not fulfilled, the shortfall is made up in the following period;

3. At the end of October, target areas of the basin for dry-season cropping are set by a committee that reports to the minister of agriculture and cooperatives. Farmers and relevant agencies are informed of these decisions. First priority is given to areas where wet-season crops could not be cultivated in the previous season.

Project Management

The agencies responsible for different-size projects vary, as do management philosophies. For small-scale projects, O&M are the responsibility of water user groups, considering the water rights of nearby downstream users. For medium-scale projects, which are located mainly in the upstream watershed and are irrigation-oriented, the RID is responsible for O&M, carried out by project personnel in close cooperation with the water user groups. For large-scale projects, management is essentially a joint responsibility of the executing agencies. For example, the reservoirs at Bhumibol and Sirikit are managed jointly by the EGAT and the RID.

Environmental Issues

Since 1981, water quality monitoring has been conducted by the Office of the National Environmental Board on a 380-km stretch of river in the lower Chao Phraya basin. Sampling is carried out on a monthly basis during the month's lowest ebb and highest tide.

The critical period for poor water quality was found to be between January and April of each year. Values for dissolved oxygen (DO) ranged from 0 mg/l near the river mouth to 7 mg/l upstream. These findings correspond to the concentration of over 2,300 industrial sites in the river mouth region. The values for biochemical oxygen demand (BOD) have risen over the past 10 years because of the increased waste load from the expansion of the Bangkok metropolitan area. Total coliform bacteria and fecal bacteria counts have also increased substantially around Bangkok. Levels of heavy metals, which were insignificant in 1981 (with a range of 0 to 0.06 mg/l), were higher in 1990 at 0.15 mg/l. Pesticides have rarely been detected, but dieldrin has been above the allowable standard at three locations corresponding to major irrigation areas. Salinity levels have been declining, perhaps because of increased volumes of wastewater pushing the salinity wedge downstream.

Comparison of the measured values of water quality with standard values resulted in the classification of the lower Chao Phraya River into three zones: 60 km of river—fairly clean, but requiring special treatment before consumption; 80 km—moderately clean, but requiring ordinary treatment prior to consumption; and 240 km—very clean, but requiring ordinary treatment prior to consumption.

The species density of plankton in the Ping and Wang rivers, tributaries of the Chao Phraya River, has been relatively high, indicating that the water is still a productive source of nutrients for aquatic life. A 1955 survey of the fish population in the lower Chao Phraya indicated the presence of 127 different species. A survey of the Ping and Nan rivers (Chao Phraya tributaries) in 1987 reported 34 and 31 species, respectively. The decline may be caused by increased water pollution and increasing use of fish for consumption. Although environmental legislation is in place, a gradual tightening of law enforcement in this area is required.

National Water Policies

In Thailand's early stages of development, the chief national policies involved flood mitigation, inland navigation, and supplementary irrigation. These policies were retained until the 1940s. In the 1950s, when rice exports were the country's major foreign currency earning, water policy emphasized large-scale project development, with project justification based on the overall economic rate of return. On-farm development and land consolidation works were justified only when the price of rice was favorable. In the late 1970s, development policy switched to small-scale rural development projects because of the poor conditions of small farmers with insufficient infrastructure and public utilities. Recently, the country's economy has been stable, creating opportunities for new development in industries, resorts, real estate, infrastructure, and public utilities.

In the next decade, water management improvement will require special attention, including improvement of management information, rehabilitation, and modernization of existing irrigation facilities. In the seventh national development plan, improvement of basin planning and development is a high priority. The government is expected to consider shortly a new policy on water charges.

Recently, unpredictable rates of development in sectors such as industry, infrastructure, and tourism have led to the use of irrigable land for other purposes. Because there is presently no law prohibiting land use changes, unplanned and uncoordinated development is likely to create conflicts over future water use. High priority is currently given to agricultural water allocation. As industrial development is promoted in the Chao Phraya basin, new allocation criteria will be required.

EXAMINING SENEGAL'S DEVELOPMENT OBJECTIVES AND STRATEGIES FOR THE SENEGAL RIVER BASIN

Mamadou Sylla

The Senegal River basin is international, and its development is one of the most important factors in achieving both Senegal's national objectives and regional cooperation among riparians. Several efforts have been made to reclaim the river valley, but the results have not been satisfactory, mainly because of the lack of a central institution at the regional level and excessive, uncoordinated government intervention at the national level. This paper provides an overview of the basin and examines the objectives and strategies of the basin's regional development program, focusing on the left bank master plan.

Background

Senegal's economy is based on the cultivation of millet and groundnut. To combat severe economic crisis, the government adopted a structural adjustment program in 1982, supported by the IMF and the World Bank. In line with the program, Senegal's new agricultural policy aims to liberalize markets and to reduce government intervention.

The development of the Senegal River valley is one of the most important factors in achieving national objectives, such as reaching 80 percent food self-sufficiency by the year 2000, establishing regional equilibrium, controlling desertification, and increasing rural income to slow rural-to-urban migration. The development of the Senegal River basin is also strategically important because of its great land potential, estimated at 500,000 ha, with 240,000 ha irrigable. There are 1.7 million inhabitants in the basin, of whom 800,000 live on the left bank.

The Senegal River Basin's Regional Development Program

The Senegal River is 1,800 km long. It begins in the north of Guinea, flows through the western part of Mali, and constitutes the border between Mauritania and Senegal. The area of the Senegal River basin is approximately 289,000 km^2. The upper basin, located upstream of Bakel, is mountainous. The lower basin is mainly flat. Different production activities are undertaken in the basin, such as rainfed crops and animal husbandry in the upper valley; recession crops, rainfed crops, and animal husbandry in the upstream middle valley; recession crops, animal husbandry, and fishing in the downstream middle valley; and livestock and fishing in the lower valley and delta.

Because of climatic changes and rapid demographic growth, traditional activities have become insufficient to satisfy the food demand of the local population. To improve the region's economic outlook, the riparian countries have undertaken a vast regional development program. The components of this program are agricultural development, power generation, and navigation management.

Two major dams have been constructed as part of the program: the Diama Dam in Senegal, which was completed in 1986, and the Manantali Dam in Mali, completed in 1988. The Diama Dam raises the

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water level upstream, thus permitting the irrigation of approximately 42,000 ha of delta land throughout the year, with low pumping lifts. It also replenishes Lake de Guiers, which supplies water to Dakar. The Manantali Dam supports irrigated agricultural land totaling approximately 375,000 ha during all seasons, of which 240,000 ha are located on the left bank. It also maintains an artificial flood for recession crops. Although the dam was designed to generate hydropower as well, water is used currently only for irrigation.

The current major problems that slow the development program are:

- a fixed producer pricing system, making relative production costs higher than the world average;
- lack of maintenance capacity, which has caused rapid degradation of the production system, rendering rehabilitation impossible;
- small land plots without strict management rules;
- lack of responsibility and management capability in farmers' maintenance and rehabilitation skills.

Moreover, although the implementation of the development program will benefit greatly from a dynamic private sector, the economic, institutional, and legal environment does not favor private investment.

The Senegal River's Left Bank Master Plan

The left bank master plan is designed to implement the left bank development program, whose objectives are to achieve food self-sufficiency and to improve the living conditions of the local population, ensuring sustainable development. Four sets of guidelines for each left bank section—Bakel, Matam, Podor, and Dagana—were established in March 1990, as the first phase of the master plan. These guidelines emphasize rehabilitation of existing schemes, selection of new development sites to suit agricultural development, and maintenance of a minimal artificial flood level to protect the environment.

The plan's main strategies are:

1. Food production should be increased and diversified, and it should satisfy the domestic market;
2. Government intervention should be limited to public service activities, such as infrastructure, research, and training;
3. Private sector development should be promoted.

As part of the plan's development, five scenarios were proposed (see table 1), examining different combinations of concurrent water users: food crops, cash crops, and hydropower. The analysis of the scenarios is based on economic criteria (actualized net value, rate of return, and cost-benefit ratio); financial criteria (impact on public finance and on foreign currency balance); and social criteria (food balance and impact on agricultural employment). The cropping intensity ratio is assumed to be 1.6.

Table 1. *Scenarios for Left Bank Water Use*

Scenario	*Guaranteed areas (ha)*			*Guaranteed hydropower*	
	Walo (flood-plain)	*Irrigated crops*			
		Cash	*Food*	*Capacity (MW)*	*Power (GWh)*
1	0	10,500	154,500	84	853
2	33,135	10,500	88,000	59	766
3	50,137	8,300	53,000	42	741
4	57,000	7,600	40,096	37	728
5	67,515	7,600	14,500	17	703

In the first scenario, irrigated farming is highly developed, leaving no water resources for artificial flooding. Recession crops, forest regeneration, and grazing land development depend exclusively on natural flooding. Capacity and power are at maximum levels. In the second scenario, irrigated farming is combined with 33,135 ha of possible artificial floodplain and with almost double that amount for forests and grazing. About 70 percent of hydropower capacity and 90 percent of power generation are guaranteed. In scenario 3, irrigated farming of food crops covers 53,000 ha, and the guaranteed floodplain constitutes 50,137 ha. Hydropower capacity is 50 percent, and that of power generation is 87 percent. In the fourth scenario, the status quo is maintained, i.e., 40,096 ha are irrigated for food crops. Artificial flooding would allow the reclamation of 57,000 ha. In the last scenario, the irrigated area for food crops is 14,500 ha, and the floodplain covers 67,515 ha. Hydropower capacity is 20 percent.

Economic analysis shows that none of the scenarios presents a significant return. Considering that the larger the irrigation scheme, the lower the return, it would be advisable to maintain the status quo, i.e., scenario 4. The impact on foreign currency, notwithstanding the savings in rice imports, is negative in all scenarios. Food and employment increase with the size of the irrigation schemes. In the first scenario, despite its negative economic and financial results, food self-sufficiency is almost reached by the year 2015. Compromising among economic, social, and environmental requirements, the government chose the second scenario, anticipating reclamation of 88,000 ha for irrigated food crops by the year 2015. In this scenario, the rate of return varies between 2.6 and 8 percent and the cost-benefit ratio between 0.7 and 1.0.

Total cost of the left bank development program will be approximately 900 billion Senegalese francs (CFAF), with an annual average cost of CFAF 12.3 billion. Comparative evaluation of the project reveals a net benefit of CFAF 76 billion. Total public expenditure for implementing the project will be CFAF 667 billion. The implementation of the project is based on the integrated development of three components: infrastructure, economic activities, and complementary activities. For example, the reclamation of 88,000 ha will require installation of hydroagricultural infrastructure. The government and program beneficiaries will share the responsibility for financing, implementing, and operating these installations.

Institutional Arrangements in Basin Management

Regional Level

Although early regional cooperation regarding Senegal River basin development began during the colonial period, the most significant event occurred in 1972, when Mali, Mauritania, and Senegal signed an agreement on sharing the Senegal River and on creating the Organization for Development of the Senegal River (OMVS). This agreement is based on the principles of free navigation and equal treatment of riparians.

The OMVS consists of the Committee of State and Government, which defines OMVS policies of cooperation and development; the Council of Ministers, which elaborates policy, planning, and coordination; and the High Commission, which implements policy. Advisory bodies include the Permanent Water Committee and the Regional Planning Committee (the latter is not yet operational). The OMVS has proved to be efficient and flexible in adapting to change and resolving conflicts among riparians.

National Level

In Senegal, several ministries at the national level are in charge of managing water resources. The Ministry for Agricultural Development and Hydraulics controls the River Valley Development Company (SAED), the National Power Company, and the National Water Company. The development of the left bank is the responsibility of the National Planning Committee for the Development of the Left Bank, which is directly under the Secretariat of the Presidency of the Republic.

In 1981, the SAED took charge of the integrated development of the river valley. This disengaged the SAED from its production-related activities and directed it toward public service activities, such as research, extension and training, management, and implementation of governmental structural changes.

Water use for irrigation, domestic needs, power generation, and navigation is subject to charge. Use in flood recession crops is excluded. Charges cover operating and maintenance costs of installation and facilities. The level of charges depends not only on the quantity of water, but also on the users' capacity to pay. In reality, however, only irrigated farming and Dakar's water supply from Lake de Guiers are subject to charges, though at preferential rates.

Legal Aspects

At the regional level, the OMVS imposes regulations concerning water management, utilization, and financing of common investments. Two 1981 regulations determined the modalities for the sharing of costs and operating expenses.

At the national level, the most important law is the Water Code of 1981. This law affirms that water resources are state property and that their use is subject to the state's authorization, control, and charges. The task of applying the Water Code, however, is difficult and costly; therefore, it has been ineffective until recently. In addition, agricultural extension officers' lack of experience in land management has led to a chaotic distribution of irrigated land.

WATER RESOURCES MANAGEMENT POLICIES IN PAKISTAN

Shamsul Mulk and Khalid Mohtadullah

The largest irrigation system in the world has evolved in the Indus basin, Pakistan's dominant water resource. Irrigated agriculture provides 90 percent of food and fiber production, and irrigation water use will continue to assert priority over other competing demands. Many water sector problems are institutional, such as insufficient attention to maintenance, lack of planning, and inadequate coordination with other institutions. This paper uses the relationship between the country's irrigation and agriculture departments to illustrate that coordination among sectors at the operational level is vital to achieving maximum efficiency in water use. Pakistan's extensive irrigation system is responsible for some of its major environmental problems, such as waterlogging, salinity, and sedimentation, and the health of the general population is affected mainly by polluted drinking water. Technological issues include conjunctive use of surface and groundwater, crop zoning, and improved water use efficiency. In view of these major concerns, future policies should involve both curative and preventive strategies within an integrated management framework.

Water Resources Development

Background

Pakistan has an area of approximately 813,900 km². Its population, which has been growing at 3.1 percent annually since 1961, stands at an estimated 114 million (1990) and is concentrated in the canal-irrigated areas of the northeast Indus Plain and in the south of the country around Karachi. The climate is tropical in plains and subtropical in mountainous regions. Most rainfall occurs during the monsoon season.

Surface and Groundwater Infrastructure

Pakistan has made great progress in developing surface water infrastructure. The Indus River is Pakistan's dominant surface water resource. Under the 1960 Indus Waters Treaty, the flows of three eastern rivers (Sutlej, Beas, and Ravi) were allocated to India, while the flows of three western rivers (Indus, Jhelum, and Chenab) were available to Pakistan, totaling 169 billion m³. To meet the irrigation requirements dependent on the waters of the three eastern rivers, Pakistan developed several engineering works. Its current irrigation system consists of 3 storage reservoirs (at Tarbela, Mangla, and Chashma); 16 barrages; 12 link canals; 2 syphons; and 43 main canals. The system has 89,000 watercourses. The total length of farm channels and watercourses is about 1 million miles. Surface water development has increased the amount of land under irrigation and brought greater control of water supplies and diversions. These achievements have increased agricultural production, but have also contributed to severe waterlogging.

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Before the introduction of tubewells, the use of groundwater as an irrigation supplement was not significant. Large-scale development of groundwater began in the public sector, but was soon overtaken by the private sector, both inside and outside the canal command areas. Groundwater withdrawals are now mainly controlled by the private sector through tubewells, and about 70 percent of private tubewells are located in the canal command areas to supplement supplies from the canals. The Indus Plain aquifer has favorable physical characteristics, and the good-quality groundwater can be pumped economically because of shallow water tables.

Intersectoral Water Use

AGRICULTURAL POTENTIAL AND IRRIGATION WATER USE. During the last 100 years, the largest and one of the most complex irrigation systems in the world has evolved in the Indus basin. Comprehensive studies of the basin's potential have concluded that it has one of the world's most favorable environments for large-scale, intensive, and highly productive irrigated agriculture. Field surveys by Pakistan's Water and Power Development Authority (WAPDA) and the International Food Policy Research Institute indicate that Pakistan and Thailand are the two Asian countries capable of exporting food on a sustainable basis in the 21st century.

Pakistan's agriculture is classified as irrigated. It has a canal command area of 16.2 million ha, out of a total cultivated area of about 21 million ha. Irrigated agriculture provides 90 percent of food and fiber production, the remaining output coming from rainfed agriculture. Although the share of agriculture in GDP has declined substantially, from 55 percent in 1959-60 to 23 percent in 1988-89, agriculture is still the dominant source of income and employment for the majority of the population. A 5 percent annual rate of agricultural growth is needed to meet targets for export and national consumption of agricultural products between 1988 and 2000. A new agricultural policy has been announced that provides the farm sector with incentives oriented toward achievement of self-reliance, social equity, export orientation, sustainable agriculture, and enhanced productivity.

Irrigation is the largest water user in the Indus basin and will continue to assert priority over other competing demands. Out of a total 169 billion m^3 of flows into the Indus River system, an average of 128 billion m^3 is being diverted for irrigation. A substantial quantity of the diverted water, however, is lost through seepage and other leakage before reaching crops. Groundwater irrigation requires about 54 billion m^3. The total area under irrigation increased to 16.6 million ha during 1989-90. According to Pakistan's National Commission on Agriculture, a sustained growth of 5 percent in the agricultural sector requires an annual water availability growth rate of 1.6 percent, which aggregates to approximately 156 billion m^3 in the year 2000. This underscores the need in the next decade to furnish an additional 25 billion m^3 of water at the farmgate.

OTHER POTENTIAL WATER USERS. Hydropower is one of Pakistan's prime energy sources. The country has an active program of developing its hydroelectric resources. It has already installed 2,900 megawatts, and extension of existing facilities will add another large energy component. Three major projects at an advanced planning stage—Ghazi Gariala, Kalabagh, and Basha on the Indus—are expected to provide up to 8,325 megawatts.

The municipal sector accounts for 3 percent of total surface water consumption, while industry claims about 1 percent. Despite this small demand, these sectors are important in the planning and management of water resources, especially water quality conservation.

Fisheries are an unexploited resource in Pakistan, given the coastal potential and opportunities created by large irrigation systems. The country has over 4.5 million ha of surface area of running and still waters, comprising canals, reservoirs, rivers, waterlogged areas, watercourses, lakes, and ponds. Water development project planning has not paid adequate attention to developing fisheries potential from either ecological or commercial perspectives.

Increasing Urbanization

Urbanization is accelerating, with many small farmers and landless people in rural areas migrating to cities because (a) subsistence agriculture provides limited job opportunities in rural areas; (b) there is an absence of civic amenities in rural areas; and (c) retail markets and construction activities are expanding in urban areas. The urban population is growing twice as fast as the rural population. Cities are becoming overcrowded, and slums engulf good agricultural land. This increasing urbanization will affect the future development of the water sector.

Interprovincial Water Allocations

Water sharing has been one of the most complex and sensitive issues in interprovincial relations. Several committees were established to resolve water conflicts among provinces, but few succeeded in achieving their objectives. The interprovincial accord on Indus water distribution has the potential to significantly enhance Pakistan's economy. It will help the provinces to initiate their own irrigation projects to optimize the use of the apportioned supplies within the provincial framework. The accord's implementation will be monitored by the newly created Indus River System Authority (IRSA). The actual work of distributing water among provinces will begin once the IRSA becomes fully functional. Needed funds for the current fiscal year, totaling 10 million rupees (Rs), have been transferred to the IRSA (on an ad hoc basis).

Institutional Arrangements

Pakistan's legislative structure regarding water use is still based mainly on the acts introduced by the British during the 19th century for governing the implementation and use of irrigation canals. The most important legislation in the postindependence era is the West Pakistan Water and Power Development Authority Act of 1958. Another significant legal document is the 1960 Indus Waters Treaty between Pakistan and India.

The Ministry of Water and Power (MWP) is responsible for water resources management at the national level. It is assisted by the Central Engineering Authority, the Ministry of Food and Agriculture, the Meteorological Department, the Federal Flood Commission, and the Geological Survey of Pakistan. The Water and Power Development Authority is the principal agency under the MWP for water resources development. Its mandated functions are investigation, planning, and execution of schemes in irrigation, water supply, and drainage; flood control; inland navigation; and prevention of waterlogging and reclamation of waterlogged and saline land.

Provincial irrigation and power departments also participate in water sector development. They are primarily responsible for ensuring efficient and equitable distribution of water within provinces. So far, they have not been able to provide efficient water supplies in accord with crop requirements, partly because of inefficient management and poor operation and maintenance (O&M) standards.

Many water sector problems are institutional, such as insufficient attention to maintenance; little interest in planning, design, and research; inadequate project preparation; and deficient coordination with other institutions. For instance, the links between the irrigation and agriculture departments involve two levels, the district coordination committee and the provincial government. Both are remote to farmers. The techniques and advice provided by the departments are independent of one other: this lack of coordination stems essentially from the departments' different administrative patterns. The management structure of the irrigation department is based on the canal commands, which usually extend beyond the civil administration units of districts. The agriculture department, however, is confined to the districts. The two departments are thus not uniform as counterparts. To achieve maximum water use efficiency, coordination among sectors at the operational level is vital. The following measures are proposed to achieve workable coordination:

- The two departments should be represented jointly in policy formulation, program design, and approval procedures for projects/programs that have a substantial productivity enhancement impact;

- Water scheduling cells should be established in the provincial irrigation departments for distribution of irrigation supplies more in line with the crop water requirements of different canal commands. At all levels of water distribution, the agriculture and irrigation departments should confer. Joint committees could be formulated for institutional inflow of information and decisionmaking;

- The operation of both canals and tubewells should be entrusted to the same irrigation department official, who should ensure that tubewells and canals be operated so that both drainage and crop water requirements are adequately met;

- A unit for water use and soil reclamation should be established in each provincial agriculture department's extension service to advise farmers on appropriate irrigation methods, including land leveling; watercourse improvement; water use practices with tubewell water of different quality; and methods for reclaiming salt-affected soils;

- Coordination efforts should be extended down to the farm level to ensure productivity improvement;

- Traditional sectoral planning is inadequate for understanding the needs of other sectors. Greater interagency cooperation is necessary.

Environmental and Health Issues

Major Environmental Problems

Pakistan's extensive irrigation system is responsible for some of its major environmental problems, such as waterlogging, salinity, and sedimentation. The continual recharge of groundwater aquifers through seepage from watercourses, canals, rivers, and irrigated lands without adequate drainage has resulted in the steady rise of water tables, which in some areas have even reached the surface. The total area with water tables less than 5 ft amounts to 2.4 million ha. Salinity and sodicity, which usually follow waterlogging in regions with high temperatures and evaporation rates, are claiming significant tracts of fertile land in irrigated areas. Almost 25 percent of the surveyed area in Sind and about 15 percent in Punjab are salted. Almost 10 percent of the best agricultural land is affected by salinity. The sediment load in the Indus River is the fifth highest in the world. Sedimentation has resulted in losses of storage capacity in the Tarbela reservoir at a rate of 14 percent every 10 years.

Measures for salinity control include construction of drainage facilities to lower the water table, safe disposal of saline drainage effluent, and proper land-leveling preparations. In view of the serious drainage problems in the saline groundwater areas, policies should involve both curative and preventive strategies for waterlogging and salinity/sodicity control. So far, measures have been curative, and preventive measures have been almost totally ignored. Tubewells offer a satisfactory solution to drain the saline water and lower the water table, particularly in areas with water tables less than 5 ft from the surface. Watershed management merits serious attention, and some successful experiments in catchments such as Mangla are worth emulating. Farmers should be encouraged to adopt appropriate water management skills to carry out these measures.

Health Issues

The health of the general population is affected mainly by polluted drinking water. About 60 percent of infant mortality and 40 percent of all urban deaths are related directly or indirectly to waterborne diseases. All surface waters are generally contaminated and unsuitable for direct human consumption. Sources of pollution include sewage, industrial wastes, agrochemicals, and saline drainage disposal. There are few controls over waste disposal. Even relatively clean and safe water from underground sources is contaminated during transmission, storage, and distribution. Fifty-three percent of the population has access to safe water (80 percent in urban areas and 40 percent in rural areas), and about half of the urban population has access to sewerage and drainage.

Environmental protection agencies have been set up in all provinces to implement existing environmental laws. The seventh five-year plan (1988/93) aims to increase the coverage of potable water supply and sanitation. By 1992/93, clean water availability will increase from 80 to 95 percent in urban areas, and from 40 to 75 percent in rural areas. Similarly, the provision of sewerage facilities will increase from 52 to 70 percent in urban areas, and from 10 to 30 percent in rural areas. The quality of water for various uses needs to be analyzed and standardized.

Economic Aspects of Water Allocation and Management

Although production decisions are made by farmers rather than by public sector functionaries, these decisions can be influenced by policies designed by the public sector, such as subsidies and taxes, water charges, reliability of water supply, and the price of products and raw materials.

Cost Recovery and Water Rates

Generally, the capital costs of irrigation works are recovered through the sale of land in canal colonies. Water charges are used to cover O&M costs. Currently, costs recoveries are too meager to take care of even the usual O&M expenses. This has resulted in a progressive deterioration of supply systems. The government should develop appropriate cost recovery policies to ensure recovery of not only O&M costs but also part of public investment.

Water rates were intended to encourage farmers to use canal water and thus have not been designed scientifically. Between 1959 and 1969, water rates were raised several times in Punjab and the Northwest Frontier Province to meet O&M requirements, mainly because farm earnings had risen as a result of increases in the prices of agricultural products. In 1978, the government raised water rates by 25 percent for all crops. In Sind, the flat rate system—under which the assessment of water charges is based on the irrigated area regardless of crop—was applied until 1980, after which crop-based water rates, similar to those applied in Punjab and the Northwest Frontier Province, were introduced. To streamline the system of recovering O&M costs from farmers, the government has completed a detailed study on the improvement of assessing and collecting water and drainage charges. An action plan constituting short- and long-term measures has been prepared for full recovery of the O&M costs of surface irrigation, surface saline drainage, and flood control/protection works. It will be carried out through increased water charges and/or other appropriate measures and will be phased in by June 1996.

Subsidy and Taxation Policies

Subsidies have been an increasingly heavy burden on the national budget. In the water sector, the government's policy has continued to encourage private tubewell installations through subsidies, despite the remarkable growth in the number of private tubewells and their excellent performance. In some areas, for example, farmers are offered Rs 32,000 to 48,000 per tubewell as a subsidy on fractional tubewells. This subsidy's impact has been low water productivity per unit of water consumed, partly because of inadequacies in farmers' knowledge about effective water use and partly because of their control over water supply through tubewells. Also, because water supply through private tubewells is financially attractive, the use of public resources in either groundwater development or in support of such development through a public sector subsidy policy seems unwarranted.

The national inadequacy of savings is reflected in provincial resource allocations. Because of the limited tax base, the provinces are allowed to share part of federally collected taxes. This dependence discourages the provinces from making serious efforts to broaden such provincial revenue sources as water charges and taxes on agricultural incomes, land, and property.

Role of the Private Sector

Because public sector resources are limited, there is a need to activate the private sector to the maximum extent possible to complement public investment resources. The areas in which the private sector can play an important role are (a) groundwater development; (b) on-farm improvements such as water conservation, land leveling, and improved water distribution; and (c) construction of field drains. For instance, a policy decision was made that no public tubewells would be installed in fresh groundwater areas. The resultant financial savings can be directed toward more pressing and remunerative investments in the public sector.

Technological Issues

Conjunctive Water Use

Presently, there is little concern about the scheduled supplies of surface and groundwater or about institutionally planned usage. Public tubewells are usually operated as drainage facilities to maintain water tables at the required level. In some areas, good-quality groundwater is an additional source of irrigation supplies. Private wells are operated only to supplement surface irrigation supplies during the peak period of crop requirements. To increase the efficiency of irrigation and drainage systems, pilot projects could be initiated to test and develop institutions and methodologies for conjunctive use of surface and groundwater to achieve optimum production per unit of water. Consideration could be given to methods of compensating farmers for additional pumping costs resulting from conjunctive use policies.

Improving Water Use Efficiency

To meet the food requirements of its growing population, Pakistan will have to improve existing irrigation and cultural practices at the farm level. Current water losses are serious. About 25 percent of the supplies diverted from rivers are lost in the canal system through seepage and evaporation, with only 75 percent delivered to the outlets. Watercourse losses are as much as 20 to 40 percent of the outlet discharge. Thus, only 45 to 60 percent of the supplies diverted from rivers are delivered to the field for irrigation. There are additional losses in the irrigated field itself, depending on the extent of land leveling and irrigation methods. Advanced technologies can be adopted to increase crop production per unit of water consumption; these technologies include sprinkler, drip, lined watercourse, pipe supply, furrow irrigation (instead of flood irrigation), and subdivision of irrigated areas. Efficiency could also be improved by lining the watercourses and canal systems.

Crop Zoning

No scientific crop zoning is practiced in irrigated areas in Pakistan. The primary requirement for increasing agricultural productivity is adequate crop water supplies, so it would be desirable to deliberately introduce crop zoning patterns for different canal commands. This would represent a demand on irrigation waters that is more in line with irrigation supplies, resulting in maximized production per unit of water. To implement this practice, a detailed evaluation of cropping patterns, the cropping calendar, and socioeconomic factors will be necessary.

Sailaba Agriculture

Sailaba agriculture refers to the traditional practice of utilizing moisture and layers of soft silt deposited by floods to grow crops. Generally, floods devastate summer crops in the cultivated areas, but at the same time they leach out salts and store moisture in the soil, which is useful for winter crops. They also deposit a layer of silt that forms a good seedbed. The total area cultivated under *sailaba* agriculture is estimated at over 1.2 million ha.

Policies for Future Development

The construction of surface storage and the replacement of storage lost through sedimentation should be a continuing component of water resources development. Any future exploitation of the underground reservoir should be balanced by considering both groundwater recharge needs and waterlogging. To encourage private tubewell development, the public sector should (a) extend liberal credit facilities on easy terms, (b) ensure periods of uninterrupted power supply, (c) provide technical guidance, (d) develop special development programs in riverine areas for groundwater exploitation, and (e) promote research on the development of technologies for tile drainage and for skimming the shallow layers of fresh groundwater overlying saline groundwater sources to reduce capital costs. For water conservation, cost-effective programs for improving watercourses should be expedited. Priority lining of canals, located in the saline groundwater area and from which seepage losses are high, should be studied. Finally, research programs should be established to investigate the allocation of water rights, the effective timing for release of storage water to achieve increased crop yields, conjunctive water use, the control of waterlogging and salinity, and the potential increased water availability through integrated comprehensive management.

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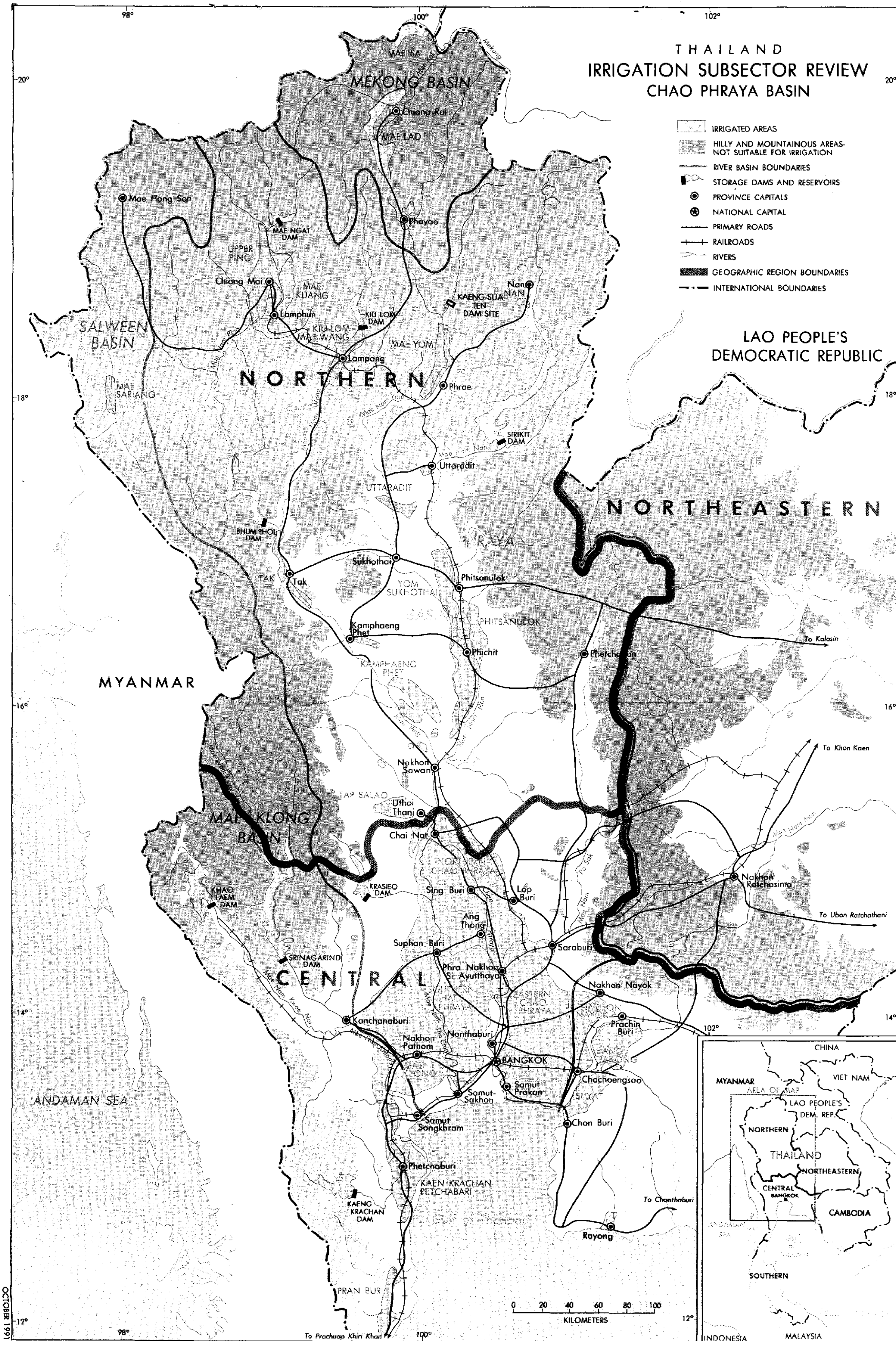
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CHAO PHRAYA BASIN
IRRIGATED AREAS
HILLY AND MOUNTAINOUS AREAS-NOT SUITABLE FOR IRRIGATION
RIVER BASIN BOUNDARIES
STORAGE DAMS AND RESERVOIRS
PROVINCE CAPITALS
NATIONAL CAPITAL
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RAILROADS
RIVERS
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INTERNATIONAL BOUNDARIES
LAO PEOPLE'S DEMOCRATIC REPUBLIC
MYANMAR
NORTHERN
NORTHEASTERN
CENTRAL
MEKONG BASIN
SALWEEN BASIN
MAE KLONG BASIN
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Mae Hong Son
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Chiang Mai
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Lampang
Nan
Phrae
Uttaradit
Sukhothai
Tak
Phitsanulok
Kamphaeng Phet
Phichit
Phetchabun
Nakhon Sawan
Uthai Thani
Chai Nat
Sing Buri
Lop Buri
Ang Thong
Suphan Buri
Saraburi
Phra Nakhon Si Ayutthaya
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BANGKOK
Prachin Buri
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Samut Prakan
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Samut Songkhram
Chon Buri
Phetchaburi
Rayong
Nakhon Ratchasima
MAE NGAT DAM
KIU LOM DAM
KAENG SUA TEN DAM SITE
SIRIKIT DAM
BHUMIPHOL DAM
KRASIEO DAM
KHAO LAEM DAM
SRINAGARIND DAM
KAENG KRACHAN DAM
To Kalasin
To Khon Kaen
To Ubon Ratchathani
To Chonthaburi
To Prachuap Khiri Khan
0 20 40 60 80 100
KILOMETERS
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AREA OF MAP
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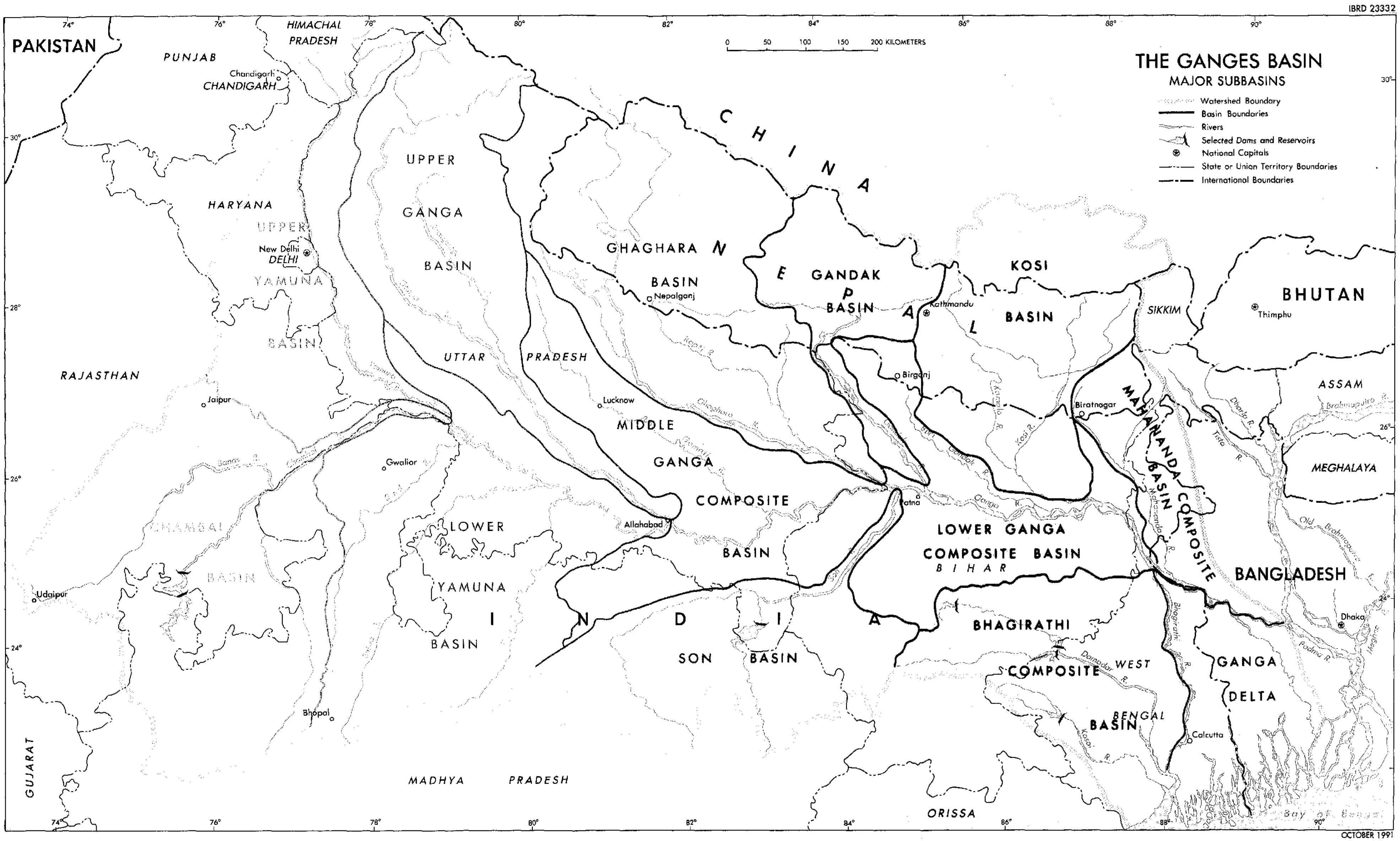
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THE GANGES BASIN
MAJOR SUBBASINS
Watershed Boundary
Basin Boundaries
Rivers
Selected Dams and Reservoirs
National Capitals
State or Union Territory Boundaries
International Boundaries
0 50 100 150 200 KILOMETERS
PAKISTAN
PUNJAB
HIMACHAL PRADESH
Chandigarh
CHANDIGARH
HARYANA
New Delhi
DELHI
UPPER YAMUNA BASIN
RAJASTHAN
Jaipur
Gwalior
CHAMBAL BASIN
Udaipur
LOWER YAMUNA BASIN
Bhopal
GUJARAT
MADHYA PRADESH
UPPER GANGA BASIN
UTTAR PRADESH
Lucknow
MIDDLE GANGA COMPOSITE BASIN
Allahabad
GHAGHARA BASIN
Nepalganj
CHINA
NEPAL
GANDAK BASIN
Kathmandu
Birganj
KOSI BASIN
Biratnagar
SIKKIM
BHUTAN
Thimphu
ASSAM
MEGHALAYA
MAHANANDA COMPOSITE BASIN
Patna
LOWER GANGA COMPOSITE BASIN
BIHAR
INDIA
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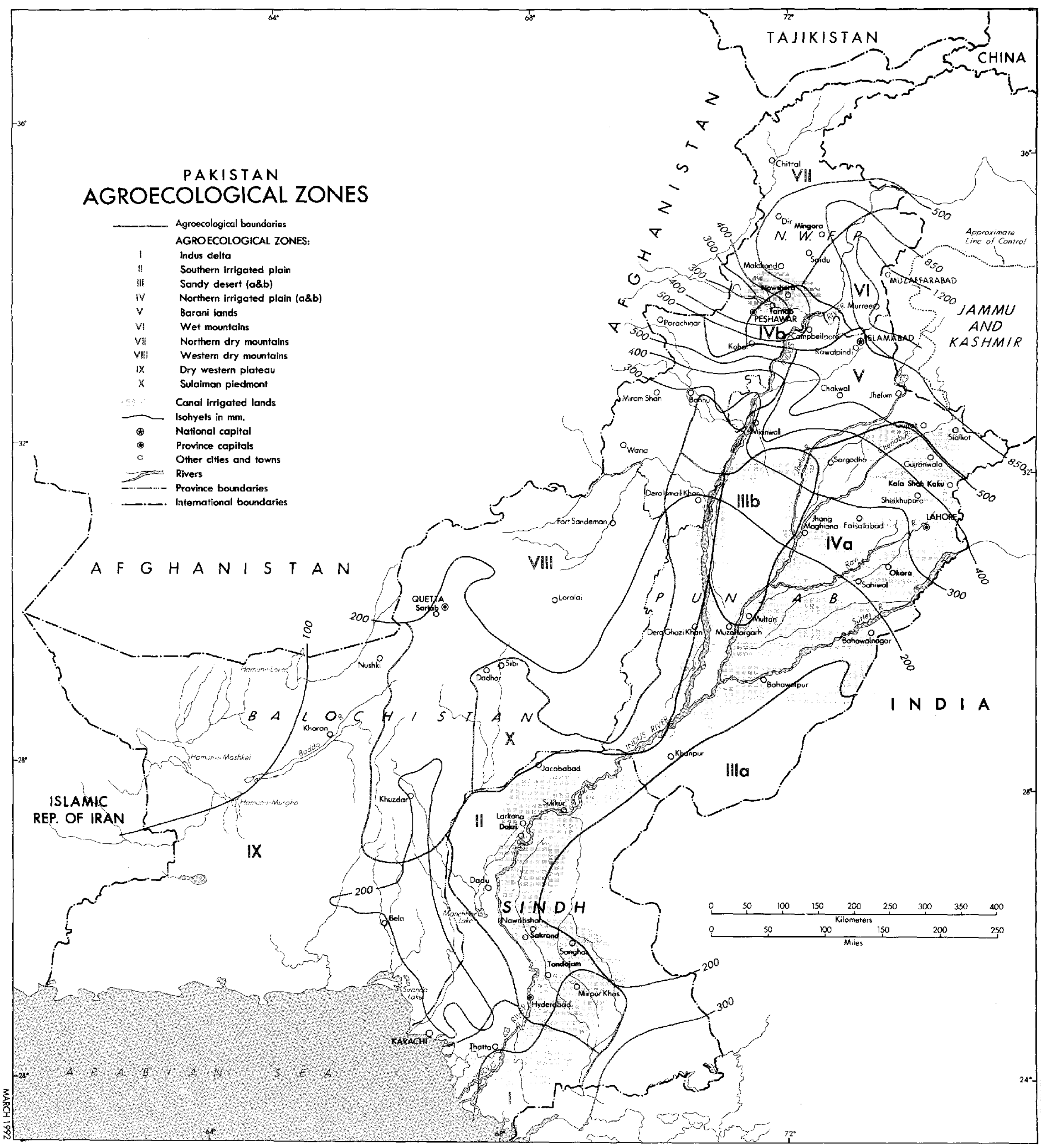

PAKISTAN
AGROECOLOGICAL ZONES
Agroecological boundaries
AGROECOLOGICAL ZONES:
I Indus delta
II Southern irrigated plain
III Sandy desert (a&b)
IV Northern irrigated plain (a&b)
V Barani lands
VI Wet mountains
VII Northern dry mountains
VIII Western dry mountains
IX Dry western plateau
X Sulaiman piedmont
Canal irrigated lands
Isohyets in mm.
National capital
Province capitals
Other cities and towns
Rivers
Province boundaries
International boundaries
TAJIKISTAN
CHINA
AFGHANISTAN
JAMMU AND KASHMIR
Approximate Line of Control
INDIA
ISLAMIC REP. OF IRAN
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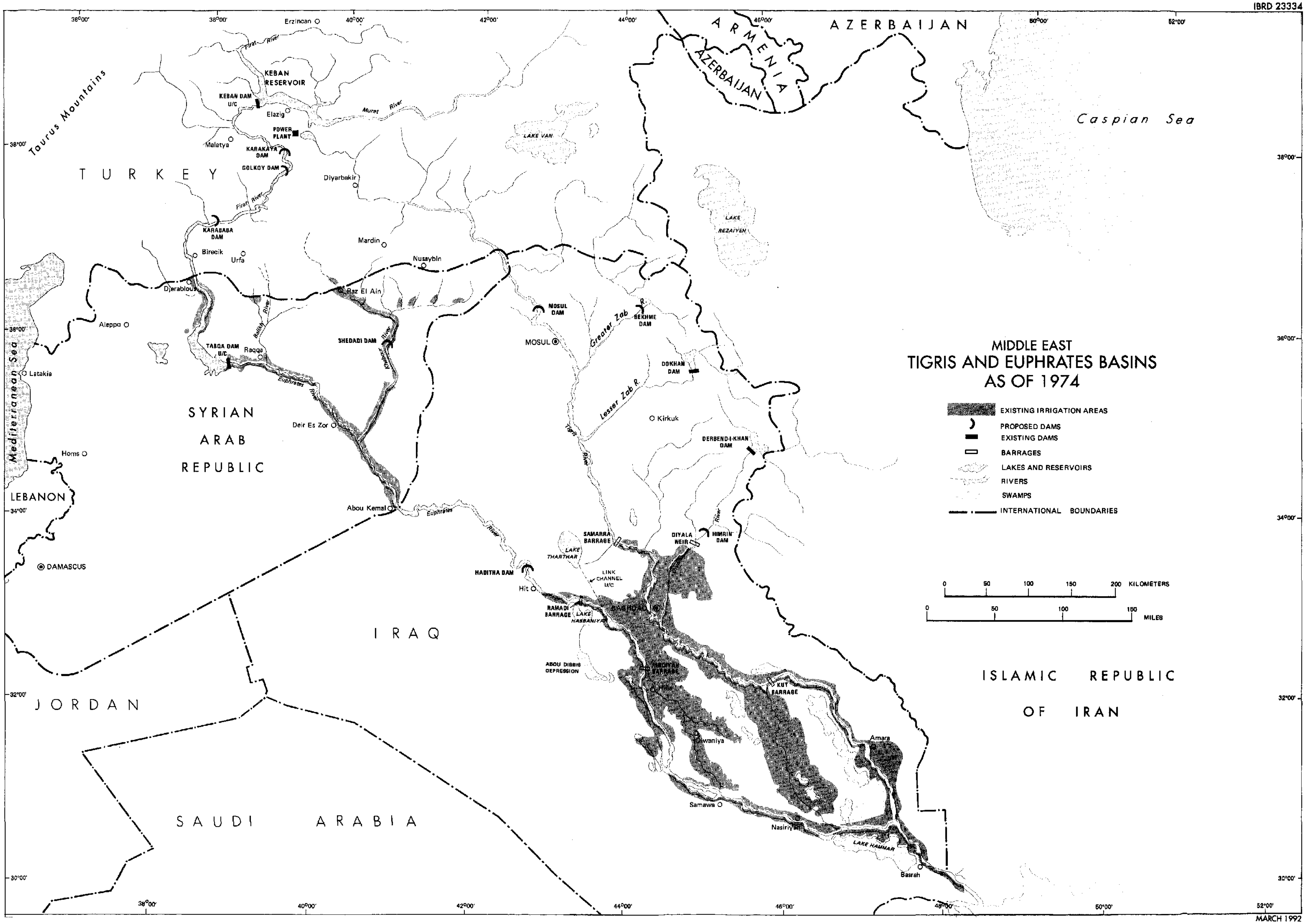
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TIGRIS AND EUPHRATES BASINS
AS OF 1974
EXISTING IRRIGATION AREAS
PROPOSED DAMS
EXISTING DAMS
BARRAGES
LAKES AND RESERVOIRS
RIVERS
SWAMPS
INTERNATIONAL BOUNDARIES
0 50 100 150 200 KILOMETERS
0 50 100 150 MILES
TURKEY
SYRIAN ARAB REPUBLIC
IRAQ
JORDAN
SAUDI ARABIA
LEBANON
ISLAMIC REPUBLIC OF IRAN
ARMENIA
AZERBAIJAN
Caspian Sea
Mediterranean Sea
Taurus Mountains
KEBAN RESERVOIR
KEBAN DAM U/C
POWER PLANT
KARAKAYA DAM
GOLKOY DAM
KARABABA DAM
TABQA DAM U/C
SHEDADI DAM
MOSUL DAM
BEKHME DAM
DOKHAN DAM
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DIYALA WEIR
HIMRIN DAM
HADITHA DAM
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RAMADI BARRAGE
LAKE HABBANIYA
LAKE THARTHAR
ABOU DIBBIS DEPRESSION
KUT BARRAGE
LAKE HAMMAR
LAKE VAN
LAKE REZAIYEH
Erzincan
Elazig
Malatya
Diyarbakir
Mardin
Nusaybin
Birecik
Urfa
Djerablous
Aleppo
Raz El Ain
Raqqa
Latakia
Deir Es Zor
Homs
Abou Kemal
DAMASCUS
MOSUL
Kirkuk
Hit
BAGHDAD
Hilla
Diwaniya
Samawa
Nasiriya
Amara
Basrah
Firat River
Murat River
Balikh River
Khabour River
Euphrates River
Greater Zab
Lesser Zab R.
Tigris River
Diyala River
38°00'
40°00'
42°00'
44°00'
46°00'
48°00'
50°00'
52°00'
36°00'
34°00'
32°00'
30°00'
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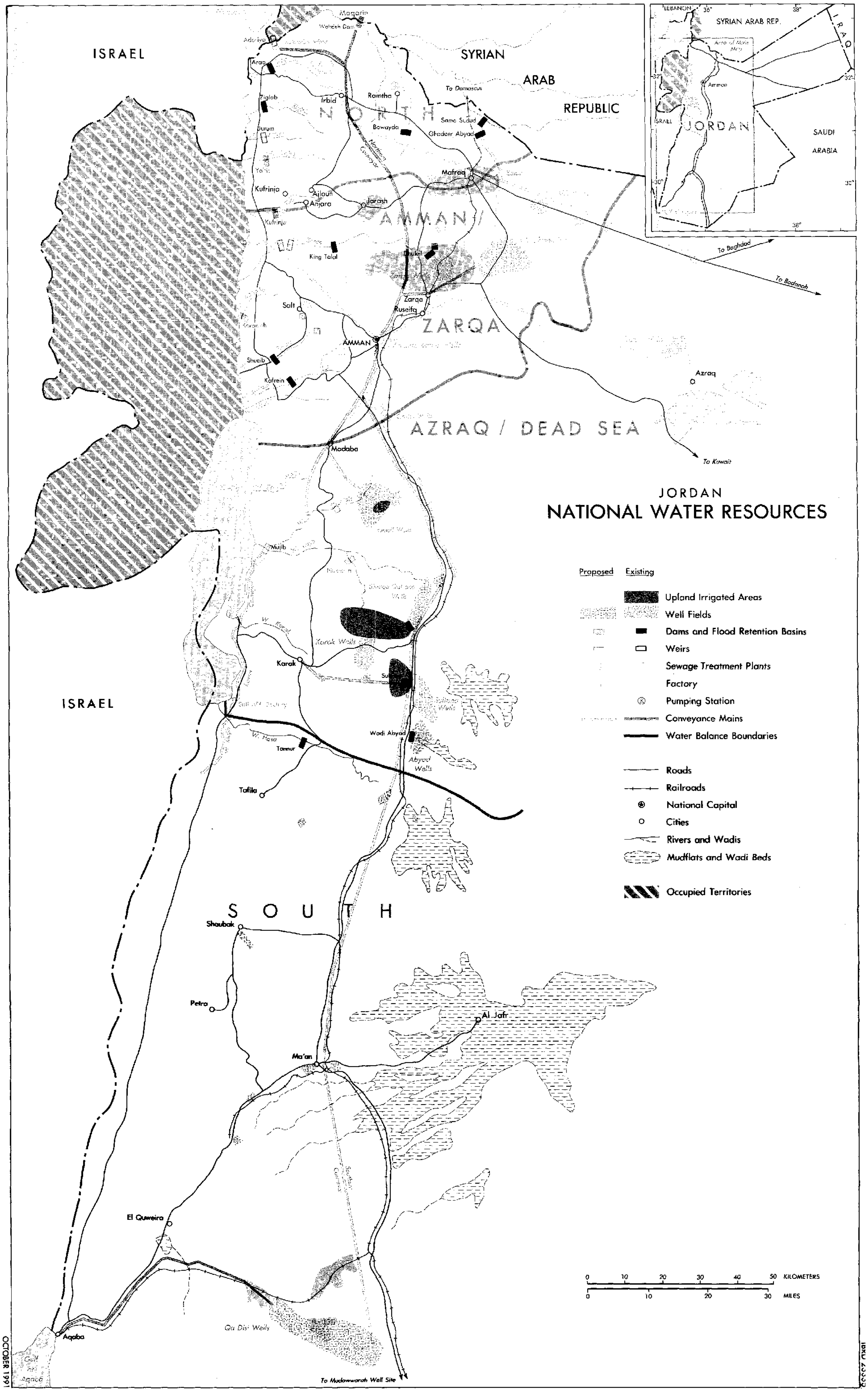
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Dams and Flood Retention Basins
Weirs
Sewage Treatment Plants
Factory
Pumping Station
Conveyance Mains
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Roads
Railroads
National Capital
Cities
Rivers and Wadis
Mudflats and Wadi Beds
Occupied Territories
0 10 20 30 40 50 KILOMETERS
0 10 20 30 MILES
ISRAEL
SYRIAN
ARAB
REPUBLIC
NORTH
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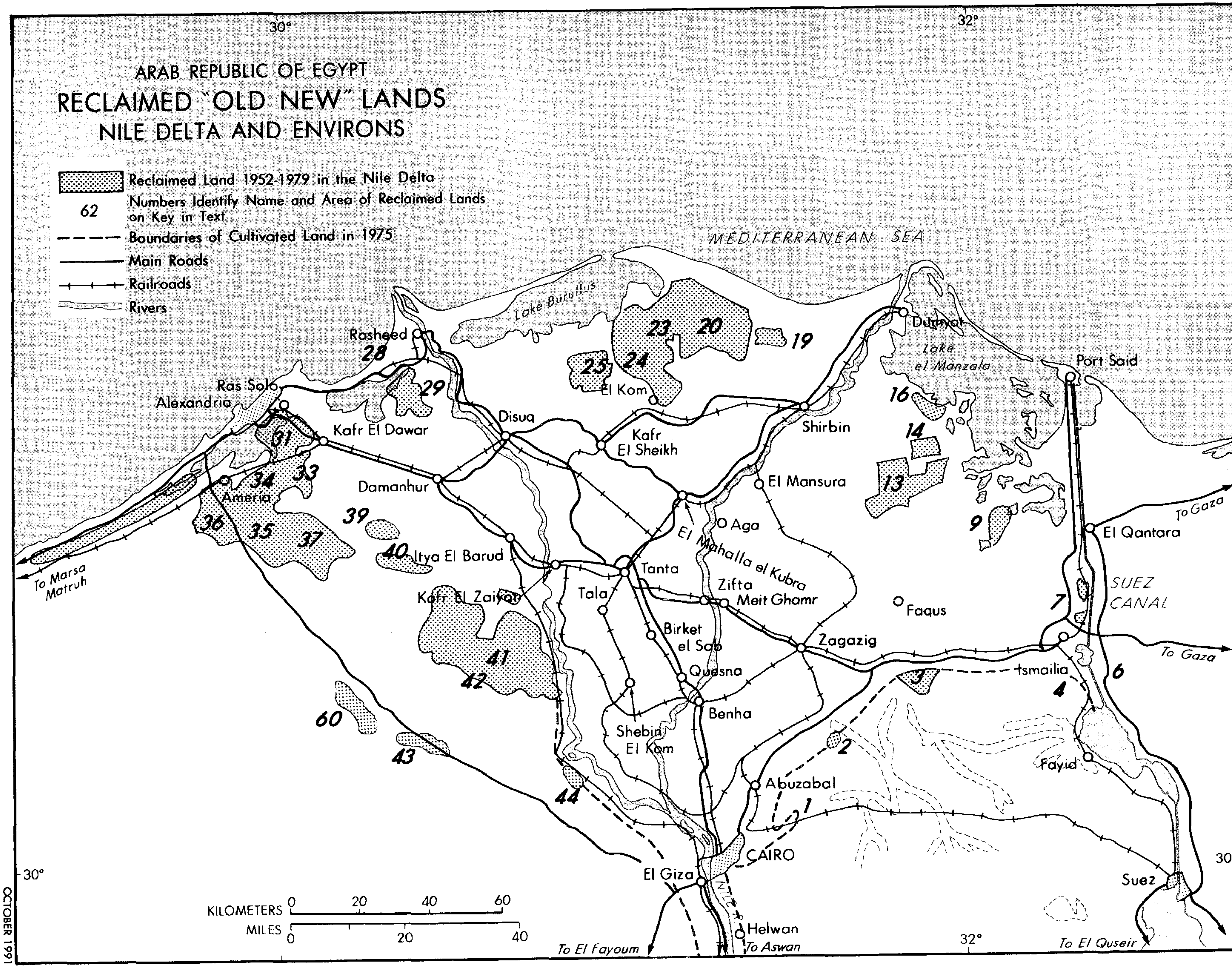
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RECLAIMED "OLD NEW" LANDS
NILE DELTA AND ENVIRONS
Reclaimed Land 1952-1979 in the Nile Delta
62 Numbers Identify Name and Area of Reclaimed Lands on Key in Text
Boundaries of Cultivated Land in 1975
Main Roads
Railroads
Rivers
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Lake Burullus
Lake el Manzala
SUEZ CANAL
Rasheed
Ras Solo
Alexandria
Kafr El Dawar
Disuq
Kafr El Sheikh
El Kom
Shirbin
Dumyat
Port Said
El Mansura
Damanhur
Ameria
Aga
El Mahalla el Kubra
El Qantara
Ityа El Barud
Tanta
Tala
Zifta
Meit Ghamr
Faqus
Kafr El Zaiyat
Birket el Sab
Zagazig
Ismailia
Quesna
Benha
Shebin El Kom
Abuzabal
Fayid
CAIRO
El Giza
Helwan
Suez
To Marsa Matruh
To Gaza
To Gaza
To El Fayoum
To Aswan
To El Quseir
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30°
32°
KILOMETERS 0 20 40 60
MILES 0 20 40
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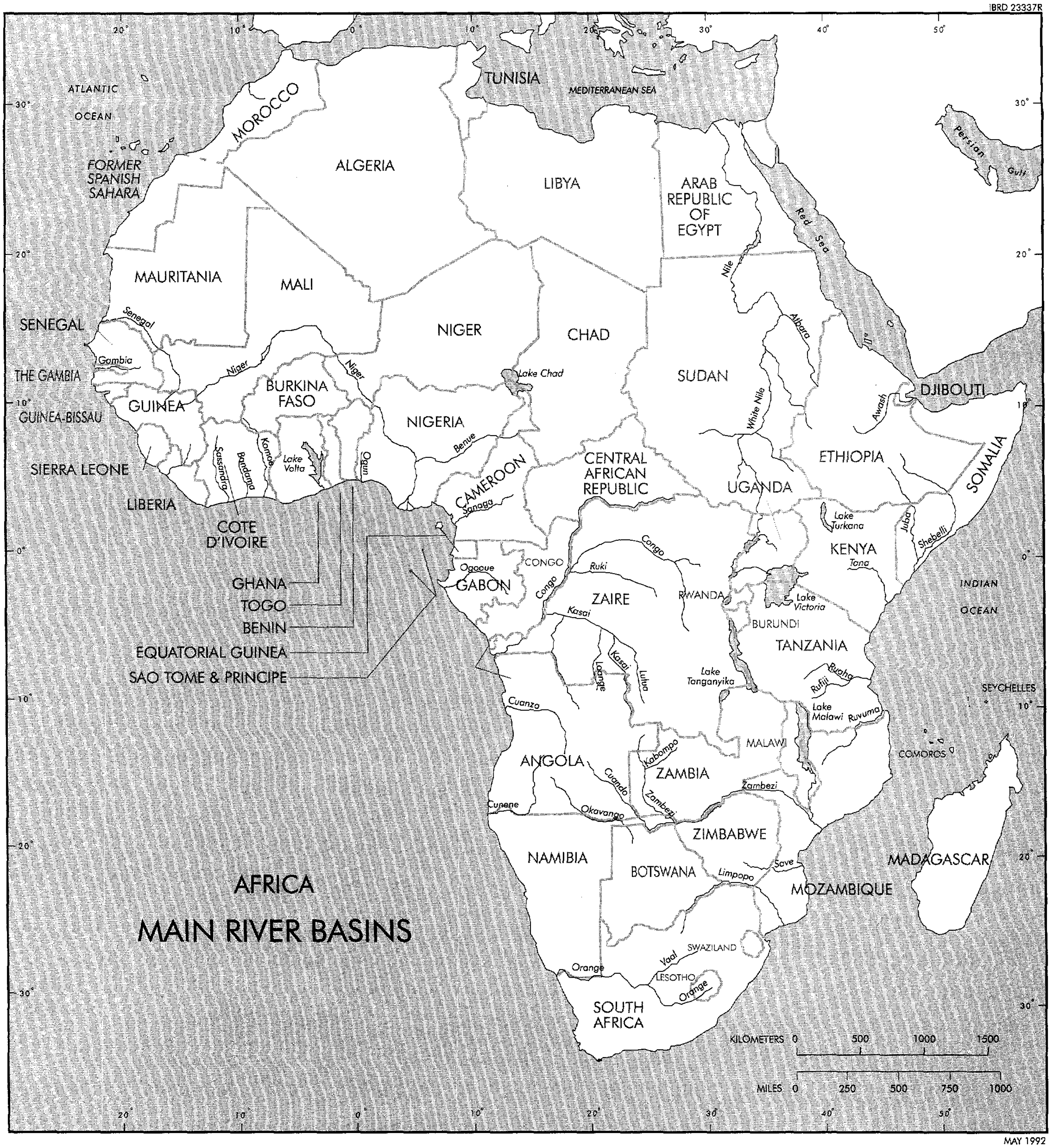

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MAIN RIVER BASINS
ATLANTIC OCEAN
MEDITERRANEAN SEA
INDIAN OCEAN
Red Sea
Persian Gulf
MOROCCO
ALGERIA
TUNISIA
LIBYA
ARAB REPUBLIC OF EGYPT
FORMER SPANISH SAHARA
MAURITANIA
MALI
NIGER
CHAD
SUDAN
SENEGAL
THE GAMBIA
GUINEA-BISSAU
GUINEA
SIERRA LEONE
LIBERIA
COTE D'IVOIRE
BURKINA FASO
GHANA
TOGO
BENIN
NIGERIA
EQUATORIAL GUINEA
SAO TOME & PRINCIPE
CAMEROON
CENTRAL AFRICAN REPUBLIC
GABON
CONGO
ZAIRE
RWANDA
BURUNDI
UGANDA
KENYA
TANZANIA
ETHIOPIA
DJIBOUTI
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SEYCHELLES
COMOROS
ANGOLA
ZAMBIA
MALAWI
MOZAMBIQUE
ZIMBABWE
NAMIBIA
BOTSWANA
SOUTH AFRICA
SWAZILAND
LESOTHO
MADAGASCAR
Senegal
Gambia
Niger
Sassandra
Bandama
Komoe
Lake Volta
Ogun
Benue
Lake Chad
Sanaga
Ogooue
Congo
Ruki
Kasai
Loange
Lulua
Nile
White Nile
Atbara
Awash
Lake Turkana
Juba
Shebelli
Tana
Lake Victoria
Lake Tanganyika
Ruaha
Rufiji
Lake Malawi
Ruvuma
Cuanzo
Kabompo
Cuando
Zambezi
Cunene
Okavango
Save
Limpopo
Vaal
Orange
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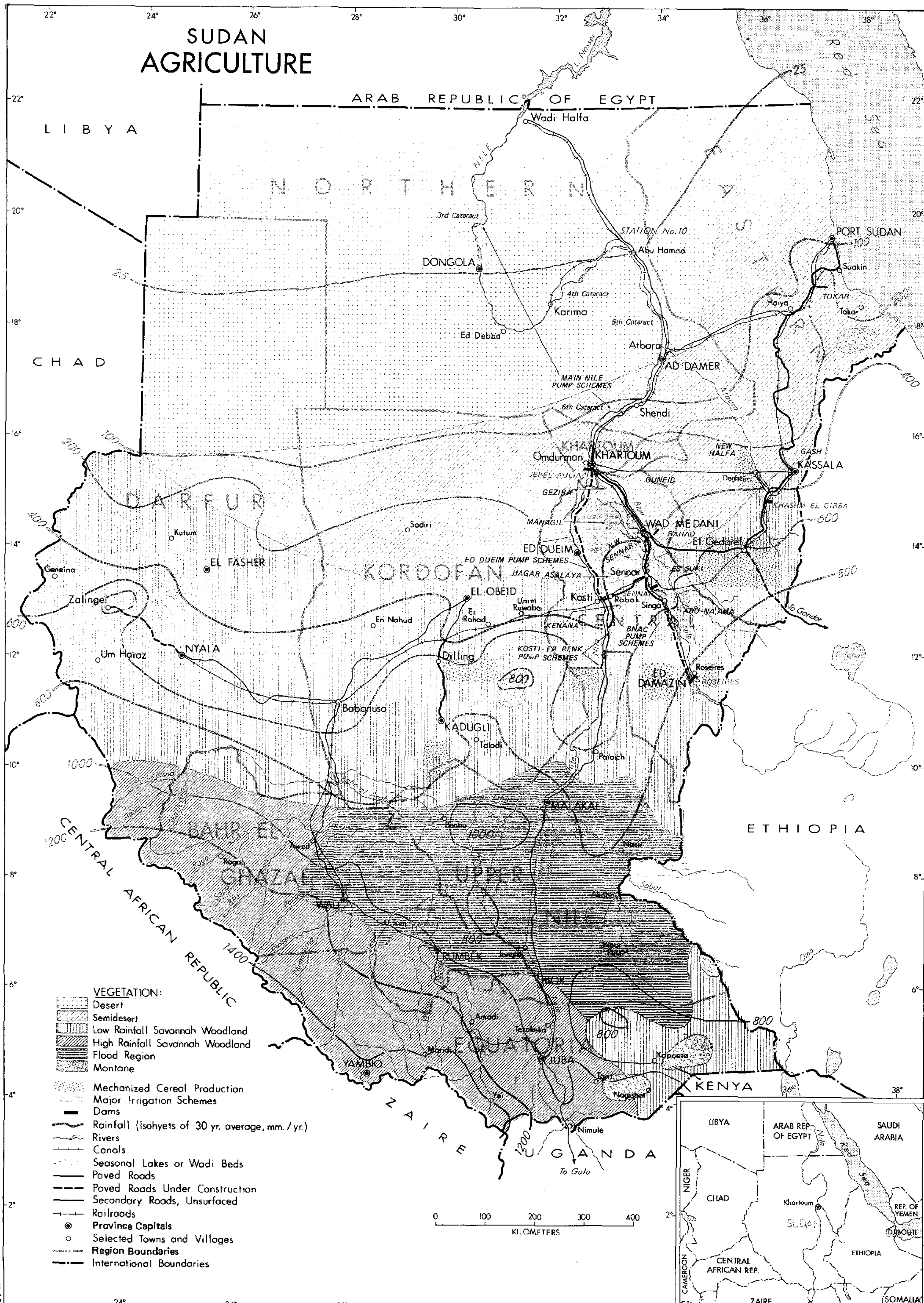
MAY 1992


SUDAN
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LIBYA
ARAB REPUBLIC OF EGYPT
CHAD
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NORTHERN
EASTERN
DARFUR
KORDOFAN
KHARTOUM
CENTRAL
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UPPER NILE
EQUATORIA
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Abu Hamad
PORT SUDAN
Suakin
Tokar
Haiya
Karima
Ed Debba
Atbara
AD DAMER
Shendi
Omdurman
KHARTOUM
KASSALA
WAD MEDANI
El Gedaref
ED DUEIM
Sennar
Kosti
Singa
EL OBEID
EL FASHER
Geneina
Kutum
Zalingei
NYALA
Um Haraz
En Nahud
Sodiri
Dilling
Babanusa
KADUGLI
Talodi
Paloich
ED DAMAZIN
Roseires
MALAKAL
Nasir
Aweil
Raga
WAU
RUMBEK
BOR
Akobo
Amadi
Terakeka
JUBA
Maridi
YAMBIO
Yei
Kapoeta
Torit
Nimule
To Gulu
To Gondar
3rd Cataract
4th Cataract
5th Cataract
6th Cataract
STATION No. 10
MAIN NILE PUMP SCHEMES
JEBEL AULIA
GEZIRA
MANAGIL
GUNEID
NEW HALFA
GASH
KHASHM EL GIRBA
RAHAD
ED DUEIM PUMP SCHEMES
HAGAR ASALAYA
ES SUKI
KENANA
KOSTI - ER RENK PUMP SCHEMES
BNAC PUMP SCHEMES
ABU NA'AMA
ROSEIRES
VEGETATION:
Desert
Semidesert
Low Rainfall Savannah Woodland
High Rainfall Savannah Woodland
Flood Region
Montane
Mechanized Cereal Production
Major Irrigation Schemes
Dams
Rainfall (Isohyets of 30 yr. average, mm./yr.)
Rivers
Canals
Seasonal Lakes or Wadi Beds
Paved Roads
Paved Roads Under Construction
Secondary Roads, Unsurfaced
Railroads
Province Capitals
Selected Towns and Villages
Region Boundaries
International Boundaries
KILOMETERS
0 100 200 300 400
LIBYA
ARAB REP. OF EGYPT
SAUDI ARABIA
CHAD
NIGER
Khartoum
SUDAN
REP. OF YEMEN
DJIBOUTI
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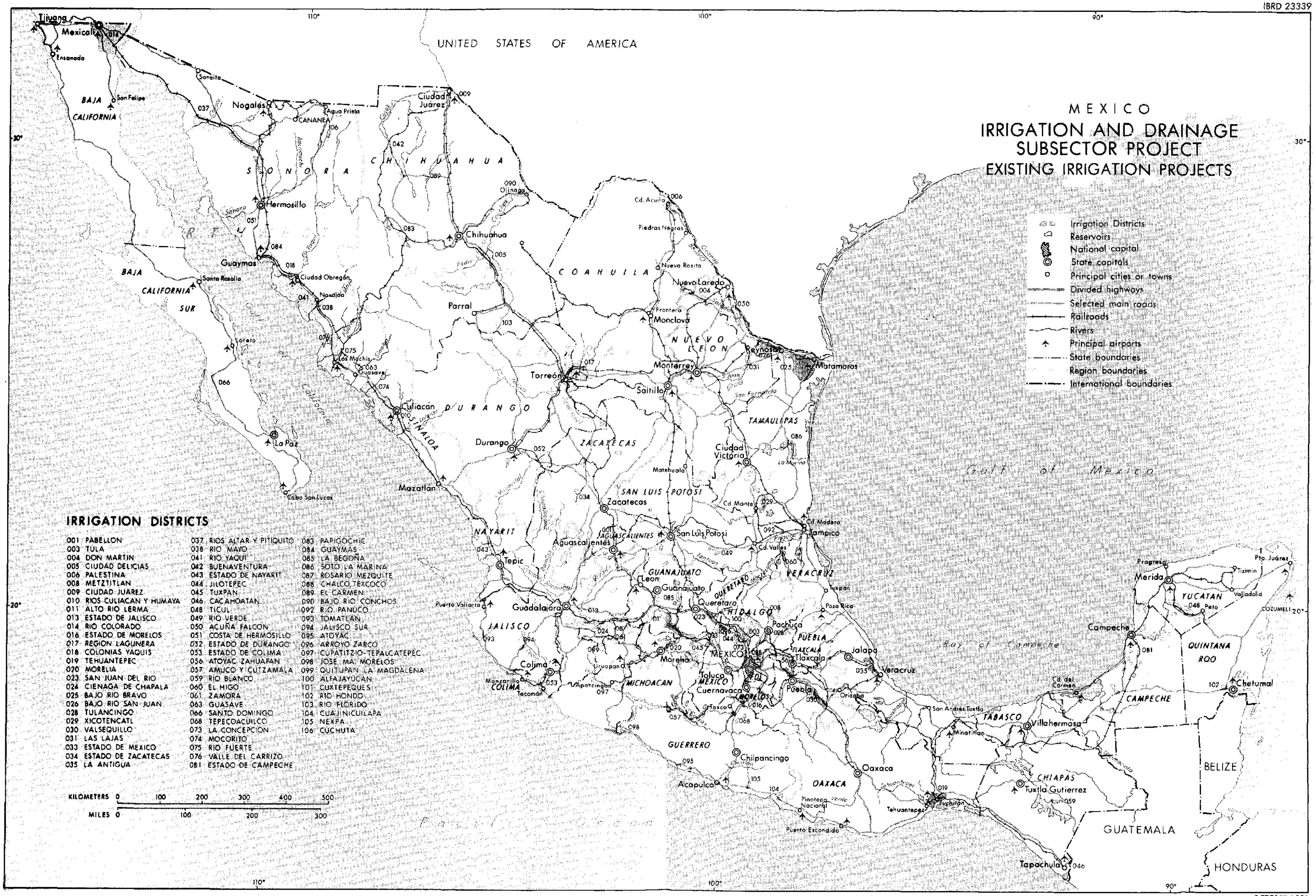

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