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Introduction

The heavily industrialized region of north China is experiencing rapid economic growth resulting in increasing demands and competition for water and other resources. Local water supplies in this relatively arid region are inadequate to satisfy projected demand with current patterns of water use. In addition, ground water depletions and pollution from economic development have already resulted in land subsidence in some areas and wide-spread water quality problems further reducing the availability of existing water resources.

The Chinese government is considering the construction of several very large and expensive projects to increase and improve the water supply of the north China Plain. Projects being considered include the construction of new reservoirs and as many as three separate interbasin diversions transferring water from the Yantze River, over and under the Yellow River more than 600 km north, to the cities of Beijing and Tianjin. Other, more management oriented alternatives are also being considered, such as improvements in water use efficiency, price incentives and treatment to allow reuse of industrial water.

Reflecting the transition to a market oriented economy and given the scarcity of investment funds and other resources, the economic performance or monetary benefits of government projects is becoming an increasingly important criteria in planning and management decisions. To estimate the economic performance of water projects, information is needed about current and forecast economic conditions

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(e.g. industry production, value, structure, interrelationships, and growth), water use rates (efficiency), hydrologic conditions (supply availability and uncertainty), and institutional requirements (planned allocation of resources and other socio-economic objectives such as population growth, water quality and agricultural production targets). However, the availability of this information for north China is quite limited.

We developed a method and, using available data, constructed the necessary models to estimate the economic performance of water projects while simultaneously considering the resource requirements and constraints and impacts of other policy and management objectives. These models can be used to evaluate the economic performance of a single project or, as applied here, to evaluate the economic performance of a combination of potential water projects and management alternatives in an effort to achieve desired economic performance and other policy objectives through integrated resource management.

Macroeconomic Model Developed to Measure Economic Performance

A macroeconomic model (MEM) was developed to evaluate the economic performance of proposed water projects and impacts of resource management alternatives for north China. The MEM is composed of regional macroeconomic production (industry output and inter-industry requirements) models; water use rate (efficiency) submodels; financial (capital requirements) submodels; agricultural production submodels; employment submodels; and environmental impact (pollutant emission) submodels.

The central component of the MEM is the industry production model based on regional Input-Output (I-O) production values. The I-O production value tables provide critical information about industry output values, industry structure, and inter-industry relationships and requirements. The production value tables are also used to generate coefficients that define the direct and indirect resource requirements for each industry. This is important because as the production of one industry changes, the resources required (such as water demanded) by the other industries will also change. These indirect or secondary effects can have significant impacts on the total quantity of resources required, on the allocation of those resources and, thus, on a water project's economic performance.

I-O tables have traditionally been used to model economies with just one or a few resource constraints and a single objective, usually to maximize economic output (performance). The approach used in this study extends traditional Input-Output analysis in the evaluation of economic performance by integrating a number of resource requirements, constraints, impacts and alternatives and, by explicitly considering other policy objectives as well as economic performance.

Several submodels are used to provide essential information for the Macroeconomic Model. The Water Use submodel provides the MEM with current and forecast water use rates for each type (sector) of industry. Improvements in water use efficiency, including the financial requirements, are incorporated as a potential management alternative. The Financial submodel provides information to the MEM about the capital investment requirements for each sector. Investments in large water projects compete with the finances available for industry growth, affecting economic performance. The Employment submodel provides information to the MEM about employment in relation to output value for each industry sector. Since high employment is another management objective, population and employment will have an impact on the economic performance and structure of industry. The Agricultural submodel provides information about agricultural output (physical quantities of crops, livestock, forestry and fisheries produced), production requirements (land and water use rates), and forecast changes in production (crop yields and water efficiency improvements). To provide consistency, physical output from the Agricultural submodel is linked to the value of agricultural production and associated resource inter-industry requirements of the I-O model. Maintaining per capita agricultural production is another management objective which has a direct impact on resource allocation and economic performance. The Environmental submodel provides information about industry and urban population impacts on water quality. Water quality impacts are measured by the quantity (in tons) of Biological Oxygen Demand (BOD) produced. Another management objective is to maintain or improve water quality. This can be achieved by constructing water treatment plants (a management alternative), altering patterns of industry production (change in output) or reducing pollutant emissions (a management alternative) to permit economic growth. Thus, consideration of the environment also has a direct effect on resource allocation and economic performance.

Project Area

The focus of the north China project was on the Beijing-Tianjin-Tangshan (JJT) area consisting of five subregions: the Municipalities of Beijing and Tianjin, and the cities of Tangshan, Qinhuangdao and Langfang in Hebei province. The JJT region encompasses an area of 55,390 square km. More than half of the population of 34 million (1990) are in urban areas. The region is characterized by rapid economic growth, heavy industry, high density population, increasing water demand, and growing environmental problems. Precipitation in the region averages 400 mm per year but is highly variable with the monsoonal climate, ranging from 200 mm to over 1000 mm. The region has also experienced extended periods of drought lasting for 10 years or more. Rivers in the region are almost nonexistent. Available water is diverted into a complex criss-cross network of conveyance canals. Water use is closely tied to historical allocations and management policies. Local agricultural production is emphasized in national and regional resource management policies with the result that approximately 75 percent of the water used in the region is consumed by agriculture. Given current use patterns and projected increases in industrial growth, local surface and ground water resources will not be adequate to meet the forecast demands for water. Water supply and management alternatives are needed that can sustain economic growth and help achieve other regional and national economic, environmental and social policy objectives.

Model Characteristics and Results

The Macroeconomic model for the JJT region is characterized in spatial, temporal, economic and demographic terms by: five administrative areas; three ten year planning periods (1990 base year, 2000, 2010 and 2020); eight industrial production sectors and agricultural production functions for each of the five subregions; and flexibility in subregional urban/rural population and employment outcomes. The eight industrial sectors in the MEM are: agriculture; mining; light industry; heavy industry; electricity; construction; transportation; communications; and services. The final demand vector includes: private consumption, government consumption, gross fixed capital formation, and imports and exports.

Water supply availability is derived from the Water Simulation Model (WSM) based on historical climatic, hydrologic, and institutional conditions. An iterative process is used to calibrate water allocations (demand) in the Water Simulation Model to the historical (1990) and economically efficient water allocations of the MEM. Water supply projects and management alternatives are selected by the MEM (and then included in the WSM) based on their contribution to economic performance and other policy objectives.

The economic performance of one or a group of water projects will depend on the particular policy objectives selected and associated resource allocations and constraints. For a given set of objective and resource conditions, the Macroeconomic Model can provide an economically efficient (optimal) solution, including information about the projected economic output, investment, employment, pollutant emissions, agricultural production, and selection and timing of water supply projects and management alternatives needed to satisfy this level of economic production.

For example, if economic output is selected as the single management objective, results of the MEM indicate that: economic output would grow at 7 to 9 percent (in real terms); BOD discharges would be 2.5 times greater than desired to maintain water quality; food production would be 35 percent lower than per capita consumption requirements (water is reallocated to industry); water investment would be almost one third higher than in "balanced" objective scenario's; and most of the proposed water supply projects would need to be constructed in the first planning period.

The MEM by itself (and supporting submodels) can only be used to derive optimal solutions for a single policy objective. However, the Macroeconomic Model presented in this paper has been incorporated into, and forms the core of, a multiple objective analysis model (MOA-ME) decision support system. In this system, the MOA-ME model can more fully evaluate the economic performance of water projects by finding optimal resource allocation solutions (including water supply projects and management alternatives) for various combinations of multiple policy objectives, objective priorities and management constraints.