Report No. 22040-CHA

China
Agenda for Water Sector Strategy for North China
Summary Report

May 9, 2002

Rural Development and Natural Resources Unit
East Asia and Pacific Region

Document of the World Bank

CURRENCY EQUIVALENTS
(As of January 1, 2002)

Currency Unit = Yuan (Y)
US$1.00 = Y 8.3
Y 1.00 = US$0.12

FISCAL YEAR

January 1 - December 31

WEIGHTS AND MEASURES

Metric System

ACRONYMS AND ABBREVIATIONS

3-H	Hai, Huai and Yellow River Basins
3-HMS	3-H Modeling System
AAD	Accumulated Annual Damage
ARI	Average Recurrence Interval
AusAID	Australian Agency for International Development
Bcm	Billion Cubic Meters
BOD	Biological Oxygen Demand
BOT	Build-Operate-Transfer
BWUs	Beneficial Water Uses
CAD	Comprehensive Agricultural Development
Class (I-V)	Water quality class
COD	Combined Oxygen Demand
CRAES	Chinese Research Academy for Environmental Science
DC	Developing Country
EPB	Environmental Protection Bureau
FPF	Fisheries, Pasture, Forestry
GDB	Groundwater Database
GDP	Gross Domestic Product
GIWP	General Institute of Water Resources and Hydropower Planning and Design
GMA	Groundwater Management Area
GMP	Groundwater Management Plan
GMU	Groundwater Management Unit
GW	Groundwater
ha	Hectare
IC	Industrialized Country
ID	Irrigation District
IPPDI	Irrigation and Power Planning Design Institute
IWHR	Institute of Water and Hydropower Research
km	Kilometer
l	liter
LIS	Large Irrigation Scheme
m	meter
m^3	Cubic Meter
Mcm	Million Cubic Meters
mg	milligram
MR	Main Report (Volume 2)
mu	Chinese unit for area (1 ha = 15 mu)
MWR	Ministry of Water Resources
NIHWR	Nanjing Institute of Hydrology and Water Resources
O&M	Operation and Maintenance
P25	25 percent probability of flow
P50	50 percent probability of flow
P75	75 percent probability of flow
P95	95 percent probability of flow
PPI	Private Sector Participation in Infrastructure
RBCM	River Basin Commission
RBCN	River Basin Council
RSFS	Rapid Sand Filtration System
SDPC	State Development Planning Commission
SEPA	State Environmental Protection Administration
SIDD	Self-Financing Irrigation and Drainage District
S-N	South-North Transfer, Eastern and Middle Route
S-N-E	South-North Transfer, Eastern Route
SOCAD	State Office of Comprehensive Agricultural Development
SOE	State-Owned Enterprise
SY	Sustainable Yield
TDS	Total Dissolved Solids
TVE	Township and Village Enterprise
WB	World Bank
WLS	Working Level Standard
WPM-DSS	Water Pollution Management Decision Support System
WRB	Water Resources Bureau
WSC	Water Supply Company
WTO	World Trade Organization
WUA	Water User Association
WWTP	Wastewater Treatment Plant

Vice President	:	Jemal-ud-din Kassum, EAP
Country Director	:	Yukon Huang, EACCF
Sector Director	:	Mark D. Wilson, EASRD
Task Manager	:	Daniel J. Gunaratnam, Consultant

CONTENTS

TABLES

FIGURES

Disclaimer

The maps in this report have been prepared exclusively for the convenience of the reader and the denominations used and the boundaries shown on the maps do not imply any judgment on the legal status of any territory or any endorsement or acceptance of such boundaries.

PREFACE

In the recent National People's Conference meeting (February 2000), Premier Zhu Rongji indicated that the lack of water resources is a serious limitation to economic and social development in China. The Premier noted that demand management including water conservation and rational pricing system should be high on the government's agenda. This statement is highly relevant to the situation in north China. In fact, nowhere in China are water shortages more evident than in the Hai, Huai, and Yellow (3-H) river basins.

Two out of five people in China live in the 3-H basins. The 3-H basins have 45 percent of China's population, 40 percent of China's cultivated area, and 31 percent of China's gross industrial output value, but only about 10 percent of China's water resources and 1/20th the world average annual per capita water availability.

Since the 1980s water shortages have been growing in magnitude and frequency of occurrence. Shortages and losses amounted to Y 30 billion in 2000. Increasing reliance on groundwater to compensate for surface water scarcity and pollution has compromised sustainable use of the resource for future generations. Flood damage has also been significant in the 3-H basins. Between 1990 and 1997, flood damage amounted to Y 30.7 billion per year and is growing. Surface and groundwater pollution now represent a growing threat not only to the environment but also to public health. Given the degree of scarcity, pollution also diminishes the resource available for essential beneficial uses. Current institutional arrangements do not permit a coherent integrated approach to solving these urgent and complex problems because of the fragmented nature of institutional mandates, overlapping jurisdictions and the status of decentralization of government.

The action plan developed in this Study proposes a set of integrated measures to be adopted by riparian provinces in the 3-H basins and the Ministry of Water Resources. The recommendations include structural changes, policy and nonstructural changes, and institutional changes. If these are applied in the proposed timeframe and with sufficient political and financial commitment, they would ensure that water resources no longer impede the continuing development of north China but rather play an increasingly vital and supportive role in the region's continuing economic and social development.

The reports produced for this Agenda for Water Sector Strategy for North China include (a) the executive summary and summary report (Volume 1), (b) the main report (Volume 2), and (c) the statistical and GIS maps annexes (Volumes 3 and 4). The present summary report (Volume 1) presents data on an aggregated basis for the 3-H basins while the main report (Volume 2) disaggregates data to each individual level I basin (Hai, Huai, Yellow), and the statistical annexes report (Volume 3) presents the data at the level II and III subbasin level. Volume 4 contains a series of GIS maps produced for this study. Volume 1 is the present printed report and Volumes 2, 3 and 4 are on file and will be made available upon request.

Please note that this is the final version of the Volume 1 and incorporates inputs from the workshop held with the Ministry of Water Resources April 16-17, 2001 in Beijing.

ACKNOWLEDGMENTS

This report was undertaken as a collaborative effort by the Australian Agency for International Development (AusAID); the Ministry of Water Resources (MWR), China; and the World Bank. AusAID provided A$2.5 million for joint-venture consultants Sinclair Knight Mertz and Egis Consulting Australia to work with local consultants, the General Institute of Water Resources and Hydropower Planning and Design (GIWP), the Institute of Water and Hydropower Research—Beijing (IWHR), the Nanjing Institute of Hydrology and Water Resources (NIHWR) and the Chinese Research Academy for Environmental Sciences (CRAES) to undertake a series of specialized studies in key aspects of the water sector.

We are grateful to Ministry of Water Resources (Messrs. Dong Zheren, Yu Xingjun and Liu Jianming) for their assistance in reviewing the Terms of References and finalizing the contract. In addition, we are also grateful to many MWR and other specialists, including retired specialists, who participated in many informal meetings to review the study.

These consultants provided many different specialized studies for the report in the areas of (a) water pricing (for example, Economics of Price and Demand Management for Efficient Urban Water Resource Use; Review of the Current Water Price System in China; Econometric Analysis); (b) water demand (for example, Irrigation Water Demands; Industrial and Domestic Water Demand Forecasts); (c) water pollution (for example, Water Pollution Management; Water Pollution Control Plan and Ninth Five-Year Plan for the Huai River Basin; Hai River Pollution Control Plan; Industrial Wastewater; Hai and Huai River Basins); (d) groundwater management (for example, Groundwater); (e) flood control (for example, Flood Control and Floodplain Management in China; Hai, Huai and Huang River Basins; Research Report on Flood Control and Loss Reduction); (f) river basin management (for example, River Basin Management and Institutional Reform); (g) investment planning (for example, Investment Planning; Hai, Huai and Huang River Basins).

The World Bank provided specialist consultants and staff to undertake the detailed economic modeling (Dr. Garry Kutcher), and hydrologic analysis (Dr. Daniel Gunaratnam). The World Bank team, consisting of Al Nyberg, Wang Lan, Li Zhi, Yu Xiangyong, Zheng Shaoqing, Shi Haifeng, Li Yuanyuan, Daniel Gunaratnam, John Foerster and Harvey Ludwig, also undertook additional detailed analysis of different aspects of the water sector including agriculture, floods, wastewater reuse and water pollution. GIWP staff who also participated include Zhou Jinsong, Li Jianqiang, Hou Jie, Shi Xiaoxin, Yangqing, Guan Chunman, Zhang Jichang. In addition, IWHR staff, including Gan Hong, Wang Dangxian, Pei Yuansheng, Zhang Xiangming, and Tang Kewang, prepared special reports on irrigation, hydrology, water demand and input for the 3-H modeling system. The report was written by John Foerster, Daniel Gunaratnam and Harvey Ludwig and was formatted and edited by Meredith Dearborn, Rebecca Kary and Wang Lan. The task manager for the Study was Daniel Gunaratnam (Lead Water Resources Specialist—now retired).

EXECUTIVE SUMMARY

In a meeting of the National People's Conference on February 2001 Premier Zhu Rongji indicated that the lack of water resources is a serious limitation to economic and social development in China. The Premier noted that demand management, including water conservation and a rational pricing system should be high on the government's agenda. This statement is particularly relevant to the water situation in North China—the geographic focus of this study. Nowhere in China are water shortages more prevalent than in the Yellow (Huang), Hai and Huai (3-H) river basins. About one-third of China's population lives in the 3-H basins. Also, 31 percent of China's gross industrial output value originates in the 3-H basins, but they contain only about 10 percent of China's water resources. Forty percent of China's cultivated land area is in the 3-H basins and forms China's breadbasket, producing two-thirds of China's wheat, 44 percent of its corn and 72 percent of its millet—plus a large portion of its oilseeds and cotton.

Continued population growth and accelerating industrial expansion over the past half-century have resulted in increasingly severe freshwater shortages, especially in subregions where growth has been greatest. This issue, developing over recent decades, is reaching crisis proportions and is now vividly apparent—it is also recognized that traditional water management methods will not support continued sustainable growth in the 21st century. The acute water shortage and pollution problems in North China will soon become unmanageable, with catastrophic consequences for future generations, unless much more significant, comprehensive and sustained commitments are made to rapidly implement strategies and initiatives to bring water resource utilization back into a sustainable balance. While supply augmentation, including South-North (S-N) transfers, appears to be a necessary part of the solution to water shortage problems; preconditions for its success are the combined requirements of complementary pricing, management, and regulatory reforms in all areas of water resources—including groundwater, water pollution and wastewater reuse.

Study Methodology

The above water management issues were studied and evaluated to develop more knowledge of: (a) the past and present situation, and (b) the future impacts of various social and economic growth scenarios and management measures, utilizing the following analytical approaches:

(a) A constrained optimization model for water resource allocation to maximize economic benefits in the system—subject to a variety of hydrological, physical and agronomic constraints. The basic economic inputs were derived from forecasts of economic parameters over time and regions;

(b) A "knowledge-based" model was designed for the water pollution component in recognition of the degree of spatial and temporal uncertainties associated with pollution load data generated by identified pollution sources; and

(c) Institutional issues related to each component of the study (groundwater, irrigation, pollution management, etc.) were investigated separately and complemented with a review of broad basinwide issues based on local expert knowledge and existing Chinese and international literature. The study results were discussed and agreed with Chinese experts; quantitative estimates of shortages and economic losses; related matters were verified with data in the field. Major findings of the study are contained in the following paragraphs.

Findings

Water Shortages. Since the 1980s water shortages have grown in severity and frequency of occurrence for urban industry, urban domestic consumption, and for irrigated agriculture, creating serious economic losses. Many rivers in the 3-H basins have no flow for five to eight months of the year. This has serious implications for river regimes and estuarial siltation.

Shortages would occur despite the government's current programs (modeled as the base case) to: (a) improve irrigation efficiency by 7 to 8 percent, (b) reduce unaccounted-for water in urban and rural industrial and household supplies to 10 to 15 percent, (c) increase water prices by 10 percent per year in real terms till 2050, and (d) treat wastewater in urban areas to enable a minimal 5 percent reuse of urban water supplies. Baseline (2000) demand for water in the 3-H basins [169 billion cubic meters (Bcm) per year] exceeds supply (132 Bcm per year) by 37 Bcm. Water shortages are projected to be 56.5 Bcm by 2050 (equivalent to the total Yellow River flow) unless measures are taken to reduce demands and to augment supplies.

Demand management proposed in the action plan, consisting of further increasing water prices and further improving irrigation efficiency would reduce the overall shortages by only 22 percent. Supply augmentation consisting of reusing treated water would further reduce shortages by 4 percent. Reuse of treated wastewater would be directed to priority uses where it has high marginal value; thus irrigation would no longer have this source of supply. However, increased return flows from greater supplies to priority uses would indirectly benefit agriculture. But, the combination of demand management and supply augmentation would reduce overall shortages by only 26 percent. These statistics vividly illustrate the extremely constrained water supplies in the 3-H basins.

After applying these demand management and reuse measures, total water shortages of 42 Bcm would accrue (by 2050), causing economic losses of Y 59 billion. Water losses of this extent would create severe economic consequences in the 3-H basins because industries close several afternoons each week and municipal supplies to key cities would be limited to a few hours each day.

In addition to the demand management measures and reuse of water noted above, the Study demonstrates that the S-N transfer would be economically justified and would ensure that priority water shortages were reduced by 88 percent (2 Bcm per year) and total water shortages were reduced to 30 Bcm. Additional water supplied from the proposed S-N transfer is not intended for irrigated agriculture consumption but rather for priority uses including urban industry and domestic consumption. The Study does not purport to evaluate the social or environmental feasibility of specific S-N transfer alternatives, but only to demonstrate that S-N transfer schemes could be economically justified within a mix of actions to improve water resource management.

It is clear that a complex of measures—irrigation efficiency improvement, wastewater reuse, price increases, and the S-N transfer—are needed to ensure a significant reduction in water shortages. With these measures, serious social and economic distress, due to water shortages, would be averted in the 3-H basins.

Agriculture. The 3-H basins produce over 50 percent of the major grains in China—having a value of over Y 120 billion annually. Irrigated agriculture, using residual water from priority users, accounts for two-thirds of agricultural production in the 3-H basins. Out of 415 million mu of land lying within irrigation command areas, only 33 percent is fully irrigated, 52 percent is partially irrigated and 15 percent is unirrigated. North of the Yellow River the irrigated areas are mostly partially irrigated or rainfed.

In 1997 the irrigation water shortfall was about 32 Bcm and was estimated to increase to 41.1 Bcm in 2050. Measures to improve irrigation system efficiency for on-farm and main canal systems include: (a) water-saving measures; (b) low-yield land improvement; and (c) large-scale systems rehabilitation. Rehabilitation would reduce the 2050 water shortage to 33 Bcm. The full package of measures, price increases, efficiency improvement, reuse of water, and S-N transfer, would reduce this shortage to 28 Bcm.

A 28 Bcm irrigation water shortage would reduce grain production by about 9 million tons (7 percent) by 2050. The value of agricultural production would decline by about Y 2.7 billion (2 percent) because farmers would shift rapidly from low-value grains to higher-value cash crops. However, the proportion of farmer income in coastal provinces (e.g. Hebei) derived from farm activities would decline from 39 percent of total income (in 1999) to 25 percent in 2020. Maintaining and improving household food security would depend substantially upon household income and whether farmers are net producers or consumers of grain. Irrigation management and water pricing reforms would play a very important role in ensuring farmers could sustainably optimize crop production per unit of water supplied.

Water Pollution. Surface and groundwater pollution are very serious environmental and public health problems. Given the degree of water scarcity, pollution also diminishes the resources available for essential beneficial uses. Pollution also represents a growing constraint to achieving national development objectives. Currently, over 80 percent of river lengths in the Hai and Huai basins are classified as very highly polluted and cannot meet any designated beneficial use. The annual opportunity cost of forgone water reuse benefits incurred by not treating wastewater were estimated at Y 4.0 billion in 2000, increasing to Y 23 billion in 2050.

Major groups of polluters include urban industry, urban municipal, rural industry, livestock operations, and rural municipal. Total combined oxygen demand (COD) generation in the Hai and Huai basins was estimated to be 12.2 million tons in 2000. Over 50 percent of this load comes from rural sources, sources that escape regulation and remain essentially uncontrolled. Some 25 percent is generated solely by the urban-based paper industry. Other highly polluting industries include: (a) chemical, (b) brewing and distillation, (c) food, (d) pharmaceutical, and (e) textile. About 3 million tons are generated in 10 cities in the Hai and Huai basins. The current government program that promotes modernization of production technology and wastewater reuse by urban industry is expected to reduce loads to 9.3 million tons by 2020.

Government monitoring and enforcement programs are having limited impact because of selective regulatory application, weak enforcement at the local levels, the absence of mass-based standards, and inappropriately high standards that are incapable of being met—given existing technology levels, affordability, and minor cost of infraction penalties. Rural pollution sources such as livestock operations, rural industry and towns remain essentially uncontrolled but represent over 50 percent of the total load. The toxic pollution load is undocumented but estimated to be about 1.7 percent of the total COD loads, representing a significant threat to public health and aquatic systems. Although loads from urban and rural industry are projected to decrease, contributions from other sources would continue to grow, and water quality would continue to decline—unless remedial measures are adopted. These high pollution loads would continue to increase the cost of treatment for water supply, lower public health standards, diminish the existing water resource base and impose higher costs on future generations.

Structural remediation measures focus on industrial wastewater pretreatment and internal reuse of process water, pollution prevention programs [including cleaner production, municipal wastewater treatment plants (WWTPs) and combined industrial and municipal WWTPs], wastewater reclamation for urban uses, irrigation, and artificial groundwater recharge with wastewater and floodwaters.

The proposed efficiency improvements, reuse, higher water prices and the S-N transfer would; (a) make more water available, and (b) reduce demand. Thus, in 2020 more water should be available under the base-case scenario. This additional water would dilute pollutants discharged to the sea; however, unless the quantities of COD generated can be reduced, the loads may increase.

The current Study calculated COD load generation for 2000 and 2020 under the base case (current policy structure) and the action plan case (treatment, pollution prevention and reuse in urban areas; treatment and pollution prevention for rural industry; reuse and latrines for rural domestic sources; and settling ponds for livestock operation). The effect of implementing the antipollution program was to reduce loads generated within the Hai and Huai basins—this was estimated to improve quality by one class, for example from Class V+ to IV by 2020, which implies that COD would decline from more than 30 milligrams per liter (mg/l) to 20 mg/l.

Floods. The magnitude of peak flows in the main rivers and tributaries remain larger than flood storage capacity afforded by reservoirs and floodplains. In addition, extensive human settlement and erection of infrastructure in the floodplains have significantly increased the cost of flood damage, especially in Anhui, Beijing, Jiangsu, and Hebei. Key cities and major industries remain inadequately protected from floods—between 1990 and 1997 flood damages averaged Y 30.7 billion annually.

The current flood management strategy focuses on: (a) protecting regions at risk of flooding (including lowlands between levees, tributaries and estuaries; flood areas; and detention basins); (b) rehabilitating reservoirs and levees requiring major repair works; (c) increasing the discharge capacity of rivers; and (d) improving flood control standards. But, despite these efforts, flood damages are increasing in the 3-H basins. Flood protection is a substantial drain on public finance, given the extent of floods in North China. There is need to develop a methodology to minimize flood damage to key assets by assigning higher protection levels to these areas and lower protection levels to areas with lower-valued assets.

Occupation of the floodplain areas between levees remains a serious problem, but given the dearth of arable land and intensive population pressure, only partial remedies such as implementing damage mitigation strategies can be applied. These measures include the construction of polders, river training works, flood zoning and regulations on land use, and resettlement assistance. The use of detention basins is equally problematic as they are widely inhabited for similar reasons—removing inhabitants from these areas is not a viable option. Flood forecasting and warning systems are already in use in the 3-H basins, however, improvements based on experiences with the present methodology are proposed.

Groundwater. Increasing reliance on groundwater to compensate for surface water scarcity and pollution has compromised sustainable use of the resource for future generations. Current water supplies are so dependent on groundwater resources that limiting extraction would dramatically increase water shortages. In addition, groundwater is insurance for dry years when surface water is scarce, but this insurance has almost disappeared because of excessive abstractions.

In the Hai basin sustainable groundwater supplies are estimated to be 17.3 Bcm, while 1998 withdrawals were 26.1 Bcm, indicating annual over extraction is as high as 8.8 Bcm. As a result, deep and shallow groundwater tables in the Hai plains have dropped by as much as 90 and 50 meters, respectively. Anecdotal evidence indicates that deep wells around Beijing are now drilled to 1,000 meters to tap fresh water, adding substantially to the cost of supply. At the level of the entire Huai and Yellow basins, groundwater extraction may be lower than resource availability, but many localized areas show signs of unsustainable extraction. But, in the Hai basin aquifers throughout the basin are severely overpumped. Other side effects of unsustainable exploitation include salinity intrusion in 72 areas of coastal provinces covering an area of 142 square kilometers, and ground subsidence of several meters in Beijing, Tianjin, Taiyuan, Shijiazhuang, and Shanghai—causing Y 1.4 billion in damage to structures during the last decade, lowering flood protection and exacerbating waterlogging in urban areas by lowering drainage.

Although the government has a groundwater monitoring and control program, current efforts are insufficient to reduce abstractions to a sustainable level. Restoring groundwater aquifers to levels of the recent past is largely impossible, and the best efforts will only halt further declines in water levels and pressures—although localized restoration may be possible. Restoration of groundwater levels at specific locales may have beneficial environmental impacts such as reducing or preventing salinity intrusion or preventing ground subsidence.

Institutions. There are many dimensions to China's water problems, including quantity, quality, temporal and spatial distribution, the condition of the water storage and distribution infrastructure, and the management of that infrastructure. The issues are complex and interrelated and include floodplain management, resource allocation and protection, pollution control, demand management, conflict resolution, and institutional arrangements to ensure sustainable economic and environmental development.

Current institutional arrangements inhibits a coherent integrated approach to solving these urgent and complex problems because of the fragmented nature of ministerial mandates and uncertain relations between the central and provincial governments. Existing river basin commissions operate under the aegis of the Ministry of Water Resources and lack the authority to impose river basin management over other ministries and provinces. Current water allocation principles are based on periodic negotiations between riparian provinces using real time monitoring and river forecasting modeling—this process essentially *reacts* to past climatic events rather than anticipating future eventualities. The major issues arising with current groundwater management include: (a) possible interference in the planning process by the realities of economic development and the urgent need to find water, (b) multiple and overlapping responsibilities by different government departments and (c) insufficient monitoring of both groundwater extraction and groundwater quality.

The institutional aspects of water resource management that require further strengthening include water resource allocation (both surface and groundwater) between and within river basins and sectors; regulation and enforcement; water resource protection including pollution control, environmental and floodplain management; demand management; financing and incentives; and service delivery organization.

To optimize economic efficiency, water allocation should be based on market principles—rather than on administrative planning principles. Concepts of social and environmental equity can be introduced into a market-based system. Resources and service charges for all sectors are currently set at levels that inappropriately reflect the degree of scarcity or cost of service delivery promoting excessive consumptive use and imposing uneconomic prices on water supply companies. This means that prices to industrial and household consumers who have priority use should be increased, because the water use in these subsectors has a higher marginal value.

Agriculture uses almost 75 percent of the water in the 3-H basins, and future trends indicate that this sector will receive declining supplies. Improving management of irrigation schemes and irrigation efficiency through improved technology would ensure that water savings could be distributed within agriculture to extend irrigated areas. Rehabilitating and completing surface irrigation and drainage systems, including the installation of control structures and water measuring devices to improve efficiency, would produce local benefits.

Action Plan Recommendations

Institutional Management. It is crucially important to manage and operate water resources on a basin basis and eliminate overlapping and conflicting management authority. Consequently, it is recommended that River Basin Coordinating Councils (RBCNs) be created in each of the 3-H basins, controlled by boards with balanced representation from central and provincial governments and local agencies. (Given the perilous state of Hai basin resources, introducing the new institutional structure might be initiated in that basin on a priority basis.) These Councils would be supra agencies with the authority to manage surface and groundwater in a comprehensive integrated manner—interministerially, across administrative boundaries, and between sectors. Such authority suggests a strong "top down" approach to basin coordination, but this would be balanced by a "bottom up" element through the coordination and participation of lower jurisdiction bureaus, water user associations, etc.

These RBCNs would have the authority for determining water resource allocations and developing water resource policies for optimal basinwide water use. The existing River Basin Commissions (RBCMs) might serve as the working arms for the RBCNs, including review of water charges—for all sectors. Other elements of institutional management reform would include: (a) ensuring that a single agency was responsible for issuing permits for water extraction; (b) enlarging the scope of municipal permits, that receive imported water, to ensure cost coverage of all "water handlers," including water supply, water uses, and wastewater treatment, to ensure optimal water use; and (c) transferring management of irrigation districts to local institutions following appropriate consultations. Additionally, provincial water resource coordinating committees would be established to manage water resources at the local levels.

Water Scarcity and Water Resource Development. The proposed action plan recommends two key demand management measures to reduce water demands to minimum feasible levels: (a) water price increases for all sectors to appropriately reflect the cost of supply and scarcity; and (b) a series of measures for increasing water use efficiency in all sectors. However, demand management measures alone would be insufficient to match available basin supply with demand. Hence two supply augmentation measures are proposed, namely: (i) systematic increase in reuse of treated wastewaters; and (ii) interbasin S-N water transfers.

Wastewater Reuse. Treated municipal wastewaters in industrial countries represent a very valuable source of supplemental water for industrial water supply and for irrigation of urban area green zones and agriculture generally. Hence provisions for planning municipal sewerage systems to facilitate reuse is proposed. Planned reuse would be subject to regulatory control through permits to ensure public heath protection. The action plan proposes investments of Y 119 billion and Y 149 billion in the Hai and Huai basins, respectively, for municipal treatment, sewerage, cleaner production and pretreatment. The following factors (in order of importance) were considered in identifying cities for treatment plant upgrading; (a) toxic waste and COD discharge, (b) location upstream of water supply intakes, (c) water shortages, (d) location upstream of irrigation intakes, (e) unsustainable groundwater pumping, and (f) potential for artificial recharge.

Interbasin Transfers. Because interbasin transfers are very expensive all other demand management and supply augmentation measures should first be implemented to minimize transfer volumes. Supply augmentation, via transfers, requires improvement, rehabilitation, and expansion of all city supply, wastewater treatment and drainage systems on the S-N transfer routes to ensure more efficient water distribution and drainage. Specific feasibility studies and environmental/ social assessments would need to be carried out separately in the context of planning for S-N transfer projects.

The scarcity and resource development actions proposed are summarized as follows:

1. Increasing the efficiency of irrigation systems by a further 10 percent;
2. Increasing wastewater reuse from 5 to 15 percent for priority supplies;
3. Increasing prices by a further 10 percent per year over existing prices (real terms);
4. Increasing water supplies by about 19.7 Bcm/year via S-N East and Middle transfer routes;
5. Rehabilitation and expansion of city water supplies;
6. Intrabasin water allocation; and
7. Intersectoral water allocation.

Groundwater. Massive overabstraction of groundwater in recent years is clearly not sustainable in the long run and immediate action to redress the imbalance between recharge and abstraction is required to prevent complete loss of this resource. The key actions include: (a) definition of groundwater management units with determination of sustainable yields; (b) preparation and implementation of groundwater management plans; (c) allocation licensing, by a single department, linked to sustainable yield and coupled with rigorous monitoring and enforcement of abstraction and pollution limits; (d) licensing of well construction drillers; (e) development of a national groundwater database; and (f) preparation and implementation of a groundwater pollution control strategy, including provision in selected cities for groundwater recharging by spreading treated wastewater effluents and/or floodwaters on permeable areas, and for injection of treated effluents to establish groundwater mounds to inhibit salinity intrusion into freshwater aquifers.

Agriculture. Agriculture is currently and will remain, the largest user of water in China; however, its share of water use will decline as municipal and industrial water demands increase. There are important social and political (including food security) implications of maintaining adequate water supplies to rural areas for agriculture. At the same time, the cost to government of supplying large volumes of water to low value-added agricultural activity is not sustainable.

The need to increase participatory mechanisms and to continue management reforms and develop innovative models for irrigation district management, including joint stockholder cooperatives, water supply companies, water user associations and self-financed irrigation and drainage districts is well understood and they will continue to be promoted. Proposed improvements parallel existing government programs, particularly the comprehensive agricultural development (CAD) program, the large irrigation district (LIS) program, and the water-saving program. These programs are focused on demand management, increased efficiency of water use, and appropriate pricing without any supply augmentation. Increased commitments to these objectives are important.

A key aspect that needs strengthening, in conjunction with the participatory institutional and water pricing measures, is water measurement and volumetric water charging. Irrigation water charges are stated in terms of cubic meters of water use, but in reality adequate water measurement at the lower end of the irrigation systems is lacking and the actual calculation of the water charge is based on the irrigated area and an average water usage rate, rather than on a measured delivery amount. Although there are no accurate data for generalization, anecdotes suggest that when transparent water measurement and volumetric charging are introduced in specific areas there are no major distortions due to water shortages. The Government and the World Bank have strongly focused (and will continue to do so) on "Self-Managing Irrigation and Drainage Districts" (SIDDs), which have fostered the development of farmer "Water User Associations" (WUAs) and the creation of financially autonomous Water Supply Organizations, which sell bulk water to the WUAs. Water measurement and volumetric charging in conjunction with WUAs must remain a high-priority initiative.

The 50 percent of China's arable land that is irrigated produces about 75 percent of the national agricultural output, but urban and industrial encroachment continually reduces the land available for agriculture. With China's very low "arable land/population" ratio it is crucial that efficiency be optimized on irrigated land—where yield potential is highest. However, most irrigation and drainage systems were constructed in the 1960s, often with substandard design and quality and some were left incomplete, and are in need of rehabilitation and upgrading including improvements in water conveyance and field efficiencies. These facilities must be rehabilitated/ renovated as financing becomes available—but it is important to identify investments, which benefit individuals and which benefit the public at large to ensure repayment is appropriately allocated.

An integrated holistic approach to effect real water saving in the agricultural sector is recommended. The integrated approach does not rely solely on engineering measures, unlike the present National Irrigated Agricultural Water Saving Program, but instead focuses on: (a) physical improvements to canal and on-farm irrigation and drainage systems; (b) agronomic measures; and (c) irrigation management measures. In addition, it would be appropriate to support agricultural research that focuses on optimizing output per unit of water consumed—instead of the traditional focus on output per unit of land.

Flood Protection. A series of strategic projects for improving flood protection are proposed, including: (a) additional dam and reservoir construction; (b) road construction to serve as auxiliary dikes and as flooded area escape routes, and other safety measures; and (c) upgrading of flood forecasting and warning systems, including the development of hydrodynamic and decision support models with flood progression mapping and other nonstructural flood control warning and protection measures. A methodology is needed to prioritize flood protection areas with priority attention accorded the protection of densely built-up residential and industrial areas where the benefit-cost ratios would be maximized—although, in general, flood protection should be consistent with overall basin needs to ensure a reasonably equitable distribution of flood hazards. But, it is economically profitable to protect areas with higher potential damage, such as cities like Tianjin, with a higher safety level than areas with lower potential damage such as rural areas, hence the concept of zones. Some 31 protection areas, or zones, were identified in the Hai basin.

The guiding principles for planning nonstructural measures for seriously affected lowland areas include: (a) using modern technology in flood forecasting and flood warning; (b) using measures to reduce the frequency and intensity of lowland use; (c) assigning priority to achieving a high standard of safety for residents with respect to buildings, refuges, and evacuation routes; (d) assuring that emergency response plans are effective and regularly tested; (e) using community education to raise and maintain awareness of the flood risk and ensure that the populations at risk are prepared and would respond during flood emergencies; and (f) exploring options for compensation, flood insurance and related matters.

Water Pollution. Over the past decade water quality has improved in some of the larger rivers, but the remainder have continued to deteriorate—as have freshwater lakes and coastal waters. Some of the problems are technical, but the pivotal constraints are primarily institutional, managerial, and financial. Considerable progress has been made in reducing pollution from state-owned industries, with significant gains coming from the closure of unprofitable and heavily polluting industries in large urban areas. The proportion of industrial wastewater passing through wastewater treatment plants increased during the 1990s, but the effectiveness of the treatment process, defined as the proportion of treated wastewater meeting national standards declined. This suggests that while the regulatory system provides incentives for installing treatment facilities, it provides less incentive to operate them effectively. Structural, nonstructural and institutional investments and programs are recommended to strengthen existing government efforts to improve declining water quality trends.

Urban municipal pollution would be mitigated through the improvement of municipal sewerage systems, including collection sewers and treatment plants with capacities for receiving and treating industrial wastewater. This would result in large savings, both to the municipality and industries, because of scale economies in removing degradable organics (with the provision that participating industries would first remove toxic and other objectionable substances through in-plant treatment before discharging to the municipal system). The treated municipal effluent would be reused, to the extent practicable, as water supply for irrigation and industrial use. In addition, the municipal systems would include provisions for effective use of on-site excreta disposal units for homes and buildings not connected to municipal sewers.

Industries in urban areas would reduce waste production through the use of cleaner technology and would dispose of wastewater, after removal of toxic materials, by discharge to municipal systems, the environment, or by reuse. Rural industries, including livestock operations and township and village enterprises (TVEs), represent a large pollution source that has received minimal attention. Livestock operators would be required to utilize stabilization treatment ponds, and TVEs, that could afford such, would be required to utilize appropriate treatment facilities—TVEs that could not afford to comply would plan a gradual phase-out. The overall pollution control program would also include attention to promoting adequate solid waste management in both urban and rural sectors, to ensure these wastes would not be left unmanaged to infiltrate waterways through surface runoff.

The proposed nonstructural investments include: (a) review and revision of water quality standards, both ambient and emission—with emission standards based on mass rather than concentration units—and assurance that the revised standards are practicable and appropriate for use in the 3-H basins and China; (b) establishment of a permit system whereby municipalities can control waste discharges from industries, including effective monitoring and performance enforcement; (c) use of the environmental impact assessment process for all major waste polluters to reinforce the permit system operations; and (d) coordination of the basin water-quality monitoring programs operated by the State Environmental Protection Administration (SEPA) and MWR to eliminate overlapping and fill important gaps.

Costs. The cost of implementing the proposed action plan is rather substantial, estimated at Y 1,350 billion (real terms) over the next 25 years. However, not investing in the action plan would be even more costly.

Action Plan Implementation Cost (Constant 2000 Y Billion)

	2000-2005	2006-2010	2011-2015	2016-2020	2021-2025	Total
Water Supply New & Rehab.	135	142	19	13	4	313
Water Pollution Control & Reuse	54	81	67	67	17	286
Irrigation Efficiency Improvement	54	58	54	20	19	205
Groundwater Recharge & Rehab.	39	48	41	24	0	152
Flood Control	131	159	59	34	11	394
Total	**412**	**488**	**240**	**158**	**52**	**1,350**

Conclusion

It is clearly feasible for China to alter its water management practices, including structural, nonstructural, and institutional modifications, to improve the water balance in the 3-H basins sufficiently to support all essential beneficial uses—including agriculture, urban water supply, industrial water supply, and protection of ecological resources to support continued sustainable development. Implementing the institutional reforms and achieving the objectives of the new strategy will require strong and immediate government support in implementing new management measures. Implementation will alter prevailing lines of authority and practices and replace many existing practices—strong resistance to these changes will need to be overcome.

1. INTRODUCTION

A. THE PURPOSE OF THE STUDY

Continuing and accelerating growth of population and industry over the past century in China has resulted in increasingly severe problems related to freshwater shortages, especially in China's subregions where growth has been greatest. This is literally a new problem, hardly envisioned even a half-century ago, but it is now being recognized, at the turn of the century, that the traditional and conventional ways of managing the water resources must be markedly modified in order to support continuing sustainable growth in the 21st century. The situation in China is most serious in the country's Hai, Huai, and Yellow (Huang) River basins on the northern east coast of China, called the 3-H basins, which are three of China's most important subcountry areas in terms of economic productivity. The increasing water shortage problem in the 3-H basins has been making continuing growth increasingly difficult, to the extent that the government recognizes the need for prompt critical analysis to formulate an action plan on what to do so that continuing growth would be sustainable.

The specific Terms of Reference for the Study are quoted here as follows:

> "Provide an integrated set of recommendations to the World Bank, MWR [Ministry of Water Resources], and the riparian provinces for addressing (water) problems at the level of the river basin. The recommendations would include, but not be limited to, identification of structural changes in the management and use of water resources, propose recommendations of the policy and regulatory framework for water resources development and management mechanism, procedure and regulatory policy, pricing of water to enhance sustainability of water resources management identification of key projects in the water sector to enhance water supply capability and improve efficiency of water resources utilization" (Concept paper, September 1998).

Table 1.1 shows the area of the 3-H basins that belong to different provinces. Figure 1.1 shows the 3-H basins within China. Figures 1.2, 1.3 and 1.4 show the individual Hai Huai, and Yellow river basins respectively.

B. THE GENERAL STUDY CONCLUSION

The Study's essential conclusion is that it is necessary for China to modify not only its water management practices, including structural, nonstructural, and institutional changes, but also to augment the existing 3-H basins' supply, preferably from another basin. This is so that the water supply in the 3-H basins would be sufficient in quantity and quality and reliable in times of drought to support all essential beneficial uses—including agriculture, urban water supply, industrial water supply, and protection of precious ecological resources—so that continuing development would be sustainable. The present report delineates the recommended Water Sector Strategy and Action Program. Achieving the goals of this new program would require that the government be willing to accept and implement the recommended new management measures and to do this promptly. The government must act with firm determination and the recognition that doing so would disturb many existing practices and would require the establishment of new practices, and that resistance to such changes must be overcome.

TABLE 1.1: PROVINCE AREAS IN THE 3-H BASINS

Province/Municipality Autonomous Region	Total Area (km^2)	Area in 3-H basin catchments (km^2)			% of total area in 3-H basins
		Hai basin	Huai basin	Yellow basin	
Beijing Municipality	16,810	16,810			100
Tianjin Municipality	11,310	11,310			100
Liaoning Province	145,900	1,710			1
Hebei Province	187,400	171.620			92
Neimenggu A.R.	1,183,000	12,580		153,600	14
Shanxi Province	156,300	59,130		97,090	100
Henan Province	167,000	15,300	88,240	36,040	84
Shandong Province	153,300	29,710	111,570	12,020	100
Hubei Province	185,900		400		...
Anhui Province	139,700		67,310		48
Jiangsu Province	102,600		63,190		62
Shaanxi Province	205,600			133,000	65
Ningxia A.R.	66,400			51,820	78
Gansu Province	454,300			144,750	32
Sichuan Province	570,000			11,080	2
Qinghai Province	721,000			152,500	21
Total		318,170	330,710	793,770	

Sources: For province areas: *Encyclopedia Yearbook of China 1988*. For catchment areas: IWHR.

C. THE STUDY WORK PROGRAM

The study was jointly sponsored by the World Bank (WB), the Ministry of Water Resources (MWR), and the Australian Agency for International Development (AusAID). The work was carried out by the World Bank and WB consultants working closely with staff of MWR's research institution, the Institute of Water and Hydropower Research (IWHR), the General Institute of Water and Hydropower Planning (GIWP) in Beijing and the Nanjing Institute of Hydrology and Water Resources (NIHWR), with coordination by the WB task manager, Daniel Gunaratnam. Specific substudies for key aspects of the project were carried out by Sinclair Knight Merz, Egis Consulting Australia and Hassell International, who also worked closely during the project period with the Chinese counterpart institutions mentioned above.

D. METHODOLOGY AND STRUCTURE OF THE REPORT

Numerous reports have been prepared on China's water sector as a whole, and on individual subsectors and regions, which have furnished valuable background for the study. Two recent reports in particular, covering all of China, furnished a framework for the present study: the first providing consistent long-term water demand and supply projections (IWHR 1999). Second, the Asian Development Bank's "Strategic Options for the Water Sector" (TA 2817 PRC) report analyzed the context surrounding the water sector (the external environment) and its impacts on the water sector itself (the internal environment). This approach was adopted here to provide a framework for the structure of the present report so as to mesh the separate substudies and their individual recommendations to formulate the integrated action plan.

The present report builds on these earlier reports in respect of the 3-H region in four main ways:

- **Information Base:** By developing an updated and consistent water resources database for the 30 Class II and III regions and provinces that comprise the 3-H region.

- **Analytical Tools:** By developing a set of analytical tools to support the analysis of impacts of China's changing society on water resources in the 3-H basins. In particular: (a) water demand projections are based on a generalized demand model utilizing results of a regional economic growth and development model for the 3-H region that includes parameters for population changes, urbanization, rising incomes and income disparity, higher consumption of goods and services, and changing productivity base from agriculture to industry; (b) alternative management options for river water quality are based on a water and waste estimation model that links water use such as urban, rural, domestic and industrial, and irrigated agriculture to waste generation including domestic and process wastes and return flows; and (c) components of the action plan are ranked based on the refinement of the constrained optimization model for the Yellow River Basin (first constructed in 1992) and its extension to the Hai and Huai basins.

- **Analysis of Issues:** By revising and refining the analysis of the key issues facing the 3-H basins, reflecting the detailed database and utilizing analytical tools developed under the study.

- **Components of the Action Plan:** By suggesting a range of policy and tentative project options, bearing in mind current government programs, that constitute a more detailed plan for action than contained in previous reports, combined with the institutional changes and financial arrangements required to ensure that the plan is effective.

Figure 1.5 shows the structure and information basis of the report.

FIGURE 1.1: LOCATION OF 3-H BASINS IN CHINA

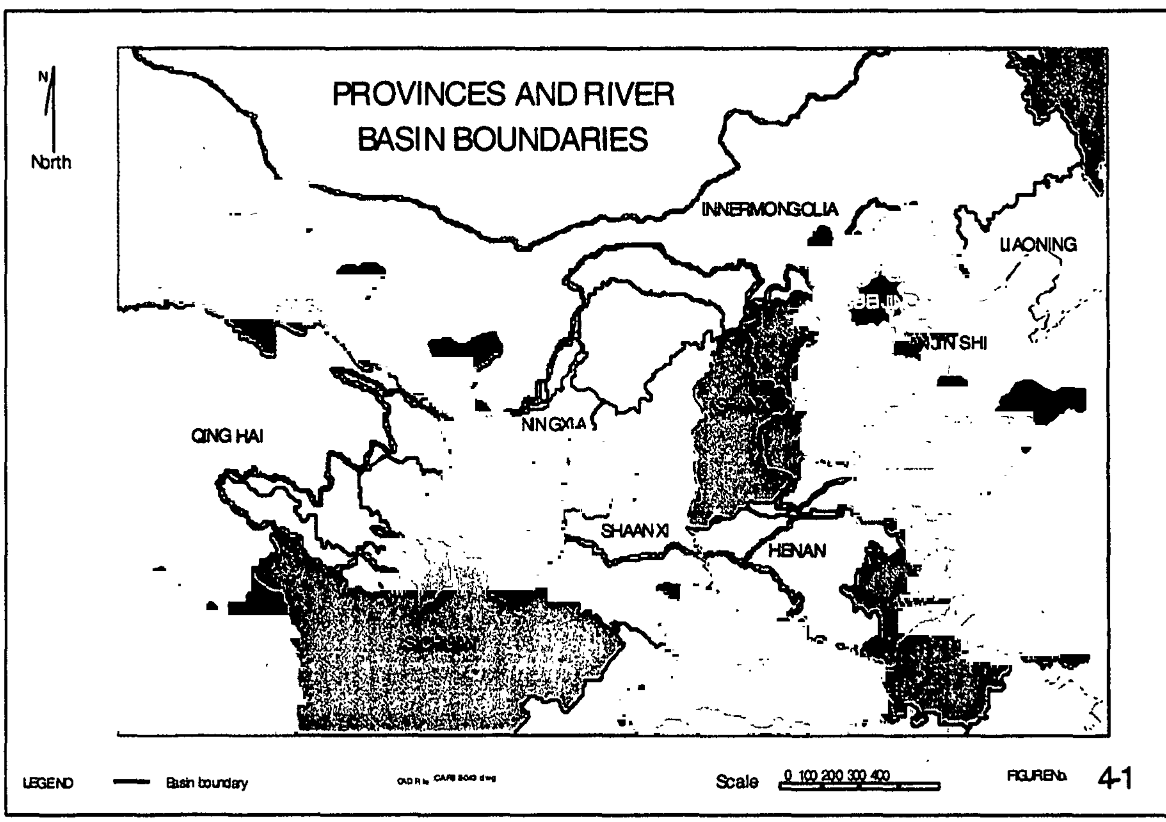


FIGURE 1.2: MAP OF HAI BASIN

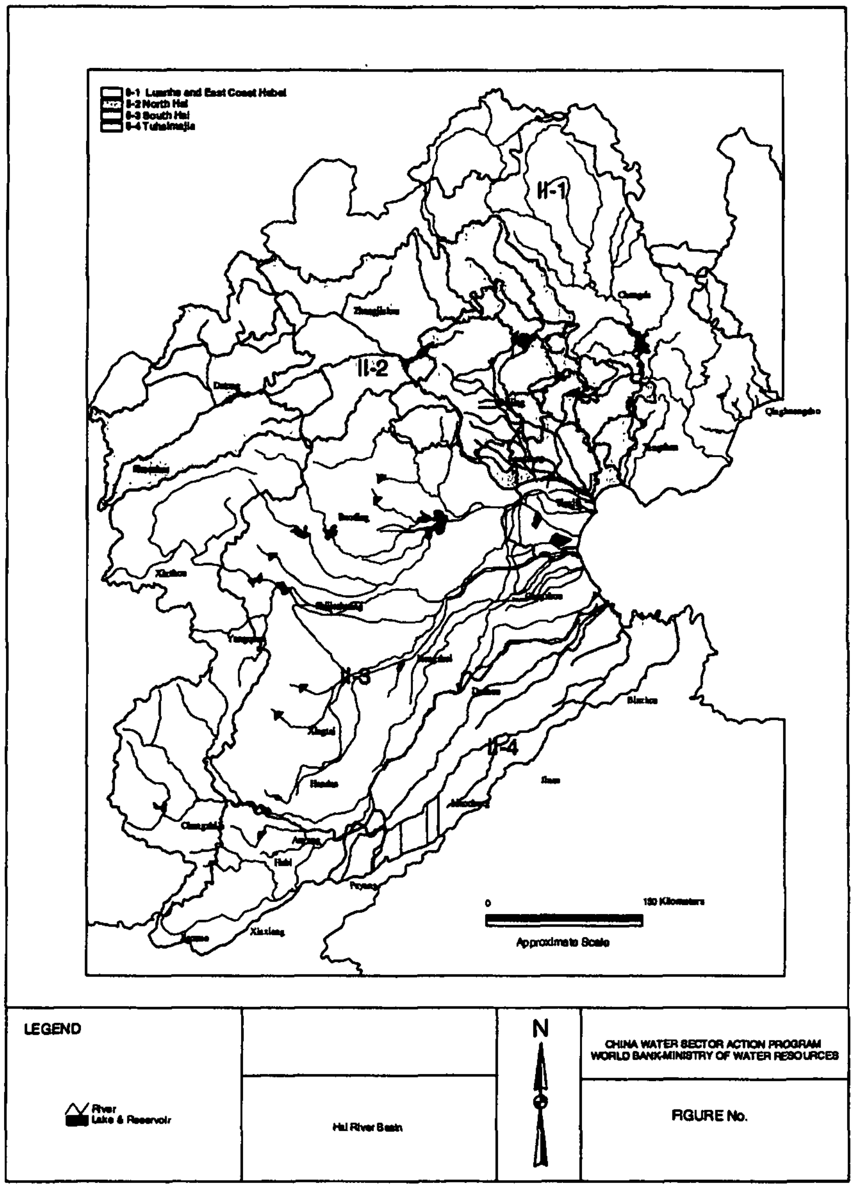


FIGURE 1.3: MAP OF HUAI RIVER BASIN

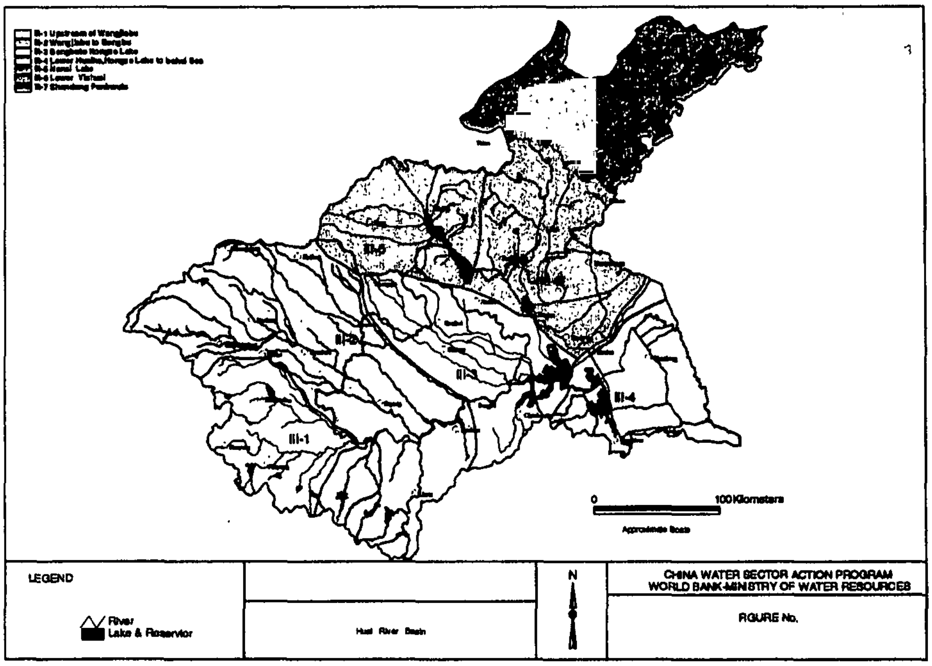


FIGURE 1.4: MAP OF YELLOW RIVER BASIN

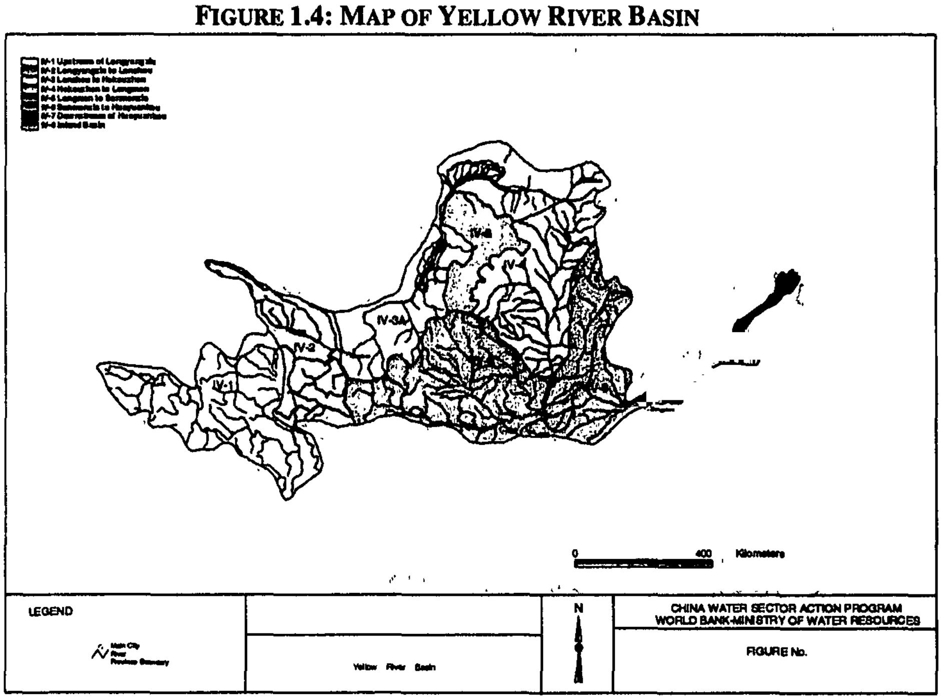
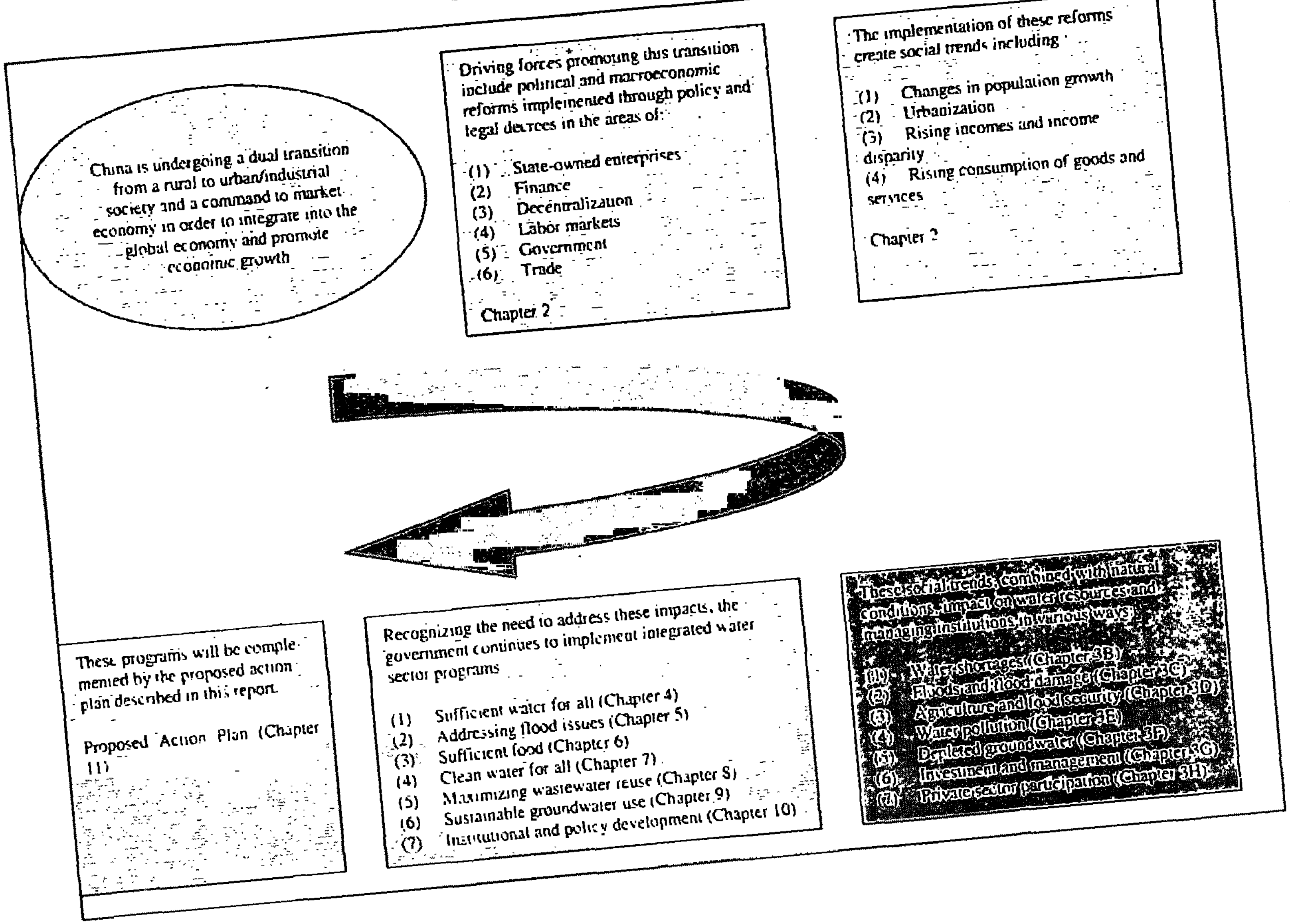


FIGURE 1.5: STRUCTURE OF THE REPORT



E. FOCUS ON THE 3-H BASINS

Introduction

China has experienced unprecedented growth since the onset of reforms in 1978 throughout the country, in virtually all sectors (agriculture, urban, industry) despite the fact that the per capita water availability in all of these sectors has been very low compared to world averages (about 6 percent). This includes the 3-H basins, which have been very water-stressed, especially the Hai basin (which includes the metropolises of Beijing and Tianjin). MWR, which is responsible for overall national water resource development, realizes that the water scarcity has become too severe to enable continuation of this pattern of production-with-very-limited water, however, and has selected the 3-H basins for critical analysis because of its importance to national prosperity, and with the expectation that the findings of the study would have valuable application for other basins in the country. In 1997, the 3-H basins had a population of 424 million (33 percent of China), with the urban population in the 3-H basins accounting for 35 percent of the total. The 3-H basins currently produce some 35 percent of China's gross domestic product (GDP). Details on the reasons for focusing the study on the 3-H basins are given below.

Uneven Rainfall Distribution. The 3-H basins are illustrative of the uneven distribution of rainfall in China, both temporally and spatially, with a heavy rainy season in July to August, and limited or little rain in other months. Dam storage reservoirs and inter- and intrabasin transfers have been used to help solve this problem.

Low Per Capita Water Availability. Overall, China's available per capita water resource is only about one-quarter of world average. The 3-H basins, with only 6.6 percent of China's surface area, have 35 percent of the population and only 13 percent of the water resources; hence per capita availability is among the worst in China. One of the unfortunate consequences has been steadily increasing groundwater extraction reaching levels now at, or considerably above, sustainability.

Floods and Droughts. Uneven rainfall distribution and topographic and geomorphologic factors have made the 3-H basins among the most flood-prone in the country and world, with flood damages some 28.3 percent of the national total. For similar reasons, the 3-H basins are the most drought-prone basins in the country. The 3-H basins include all of the most severely water-deficient cities in the country and more than half of the other water-deficient cities.

Agriculture. Despite the water-shortage problem, the 3-H basins still manage to produce a remarkable percentage of the country's agriculture, up to now, but the future of this sector appears doubtful under present practices because of the higher-priority demands for the urban and industrial sectors, and totally unsustainable groundwater abstraction which is the major reason why agriculture has been able to increase its productivity despite widespread shortages.

Water Pollution. Some 80 percent of the river lengths have become seriously polluted and likewise much of the groundwater. This problem is due to the concentration of heavy industries with high water use and pollution potentials in the 3-H basins and only limited attention to provision of monitoring and enforcement of pollution control measures. This means increased costs to cities and industries for treating these waters before use, and for the farmers this means routine use for irrigation of untreated raw waters—regarded as unacceptable for irrigation by worldwide health standards for irrigation waters.

2. THE CHANGING ECONOMY AND SOCIETY AFFECTING THE WATER SECTOR

A. INTRODUCTION

China is currently undergoing a dual transition from a rural to urban-industrial society and from a command to market economy in order to integrate into the global economy and promote economic growth. Forces promoting this transition are political and macroeconomic reforms implemented through policy and legal decrees in the areas of (a) state-owned enterprises (SOEs); (b) finance; (c) decentralization; (d) labor markets; (e) government; and (f) trades.

The implementation of these reforms create social trends including (a) changes in population growth; (b) urbanization; (c) rising income and income disparities; and (d) rising consumption of goods and services. Those social trends and economic reforms may impact on water resources and the institutions that manage water resources in different ways, requiring complex technical, social and management solutions to address growing water shortages and pollution (see Figure 1.5).

This chapter describes key aspects of the Chinese economy and society (the external environment) in order to understand external pressures that impact on water resources (the internal environment) and their management.

B. BACKGROUND ON THE ECONOMY

The background on China's economy is assessed in terms of six parameters, as follows.

Macroeconomy. China's GDP substantially increased in the past several decades with industry and manufacturing contributing a large proportion of this growth. GDP growth rates were recorded at 6.5 percent in the 1960-70 period, 9.7 percent in 1977-85, and 8.7 percent in the 1996-97 period, with equally impressive increases in foreign trade growth. China's growth since reforms in 1978 has also been cyclical, however, marked by periodic overheating and contractions. The growth rate in agriculture (2 to 5 percent) is consistently lower than in services and industry (8 to 22 percent), confirming the government's policy of industrialization and urbanization. Water consumption patterns continue to reflect the government's economic focus with much lower allocations to agriculture and higher allocation to industry and urban domestic centers.

Industrialization. The first wave of industrialization took place after the establishment of the People's Republic and was concentrated on SOEs. In the 3-H basins the major SOEs affecting use of water and associated pollution include paper-making, textiles, food, brewing, chemicals, and fertilizer. SOEs in industry are allocated generous water quotas, even in water-short areas. SOE air and water pollution levels are high. The government has been reluctant to impose meaningful enforcement because of increased costs of production to SOEs, although this situation is now changing. Economic reforms would shift the balance of industrial production to markets. This should have a beneficial impact on water pollution because private sector pollution control measures are more efficient, especially in realizing savings in economy of scale.

Decentralization. Because centralized control of production is hardly compatible with a modern industrial market economy, the government has been decentralizing decision-making on industrial development to the provincial or local governments, including increasing use of the private sector. Although this fosters improved industrial efficiency from the provincial and local point of view, it is causing serious problems in basin water resource utilization in that for efficient use the total resource must be allocated by a basinwide authority, but such allocation control conflicts with the interest of each province or local government to do the best it can for itself of regardless of basinwide implications. Thus the decentralization policy has weakened MWR's powers for establishing optimal water allocations within basins and for gaining acceptance for diversions, within basins and transbasin, which would promote optimal overall water use.

Trade. China's entry into the world market system has already begun to change existing economic patterns, including (a) shifting of agriculture from its focus on grain farming to include labor-intensive agriculture such as horticulture, livestock, and orchards, which require less water consumption; and (b) use of more efficient industrial manufacturing technologies with better management of pollution control.

Legal and Regulatory Framework. China's legal and regulatory framework for managing water resources has improved since the 1970s but many key problems remain relating to the actual authority of the courts at various levels and lack of effective enforcement mechanics, regarding application and enforcement of pollution control regulations including discharge of industrial effluents into municipal sewerage systems.

Public Finance. Current practices for financing infrastructure of public water resources including municipal water supply and wastewater treatment facilities (except for very large projects) are management at the provincial and local level following their interests and needs. There is increasing use of local financing by provincial and local authorities to avoid central government control. These practices also bypass river basin planning..

C. Background on Social Trends Affecting Water Resources

The changes in the economy described above have resulted in comparable changes in the social systems, as discussed below.

Impact of Population, Demography, and Urbanization. China's controls on family planning and on rural-to-urban migration have helped slow urban growth rates in the 3-H basins but the population is expected to continue to grow for the next 40 years. The evaluations show that (a) urban per capita water consumption in the 3-H basins is considerably higher than rural consumption (see Table 2.1), (b) the increasing urban population and industry have resulted in increasing allocations of available water to urban and industrial uses, (c) this allocation has resulted in serious unmanaged problems of water pollution causing increased cost in urban water supply systems (about 7 percent),[1] and (d) domestic urban water use has increased and now exceeds industrial water use (because of more service sector industries, shifts to high-technology industries, and industrial water reuse). Over the period 1967 to 1997 the average increase in domestic water consumption was 8 percent compared to 2 percent for industry and 5 percent for total urban and industrial water supply. It should be noted that in China, water allocation/supply is considered identical to demand and consumption, i.e., once water is allocated for a particular use it is considered to have been consumed for this use.

---

[1] *Proceedings of 21st Century Urban Water Management in China*, International Seminar, Ministry of Construction, China, September 1999.

TABLE 2.1: URBAN AND RURAL DOMESTIC DAILY PER CAPITA WATER CONSUMPTION IN THE 3-H BASINS AND CHINA (LCD) COMPARED WITH URBANIZATION (PERCENT)

Basins	Urban/Total Population (percent)			Urban daily domestic per capita water consumption (lcd)			Rural daily domestic per capita water consumption (lcd)		
	1980	1993	% Δ	1980	1993	% Δ	1980	1993	% Δ
Hai	22	24	9.1	115	192	40.1	54	54	0.0
Huai	9	17	88.9	105	141	25.6	53	69	30.2
Yellow	17	22	29.4	120	125	4.0	41	54	31.8
Average 3-H	16	21	31.2	113	153	26.1	49	59	20.4
China	16	24	50.0	117	178	34.3	71	73	2.8

Source: NIHWR and IWHR, *China's Water Supply and Demand in the 21st Century*, China Water and Hydropower Publisher, June 1999.

Changes in Employment. Employment patterns have changed to reflect changes in the economy, including the following: (a) declining farm labor force and rising labor for industry and services, (b) shifting of farm labor from grains to more intensive labor production, (c) increase in total urban water use because of unregistered rural-to-urban inmigration. The situation remains difficult for the poorer rural families who have insufficient resources to afford migration to urban centers, and who must continue to farm their land in order to keep it or lose their right to it. Use of water by rural families is usually minimal because of cost, but urban family incomes can afford to use water at "luxury" levels. The study notes that urban water prices are actually too low in comparison with income and willingness to pay, both for households and for industries.

Rising Income and Income Disparity. The substudies on this issue showed that (a) rural farm income in the 3-H basins varies between Y 1,000 and Y 2,000, which is supplemented by income from job opportunities in nearby industries or townships and village enterprises—TVEs); (b) the rural families continue to work their farms, despite attractions of other opportunities, in order to keep their basic rights to this land as their basic income security; (c) urban per capita water use is higher because of higher income and access to facilities such as toilets and hospitals, and because of use by unregistered immigrants; (d) people with low incomes are much more sensitive to price increases; (e) although urban per capita use of water increases with increased income, the proportion of total income for water decreases, and even for low-income households, less than 0.5 percent is spent for water; (f) the 3-H basins' provinces include about half the total national rural poor; and (g) the anticipated increasing demand for goods and services in China, including the 3-H basins, is presenting the opportunity for strong economic growth including increased industry, but this would pose increasing hazards for degradation of water and other natural resources.

D. THE FUTURE ECONOMY IN THE 3-H BASINS

Introduction. Future water use in China would depend heavily on the growth and structure of the economy, and China's recent rapid pace of change is expected to continue for some time before gradually slowing. Reasons for optimism include fairly high literacy, genuine efforts to learn from international experience, a reasonably development-oriented government, high savings and investment rates, a policy of opening to outside trade and direct investment, and the potential for a large domestic market. Nevertheless, many challenges inherited from the prereform planning era would make continuing sustained development more difficult. In particular, internal trade barriers and inefficiencies in fiscal, financial and enterprise governance systems threaten to continue a pattern of wasteful resource use. In a related vein, the relatively fragile basis for maintaining reasonable patterns of income and consumption inequalities would continue to result in widespread nonmarket solutions to problems of unemployment and labor mobility.

Three different economic modeling approaches have been applied in the present studies to develop a vision of China's economy in the year 2050, as well as to estimate the likely economic conditions in the 3-H region. IWHR applied input-output modeling calibrated against national population projection targets and nationally accepted GDP growth targets. A second approach adapted the Solow growth model, applying WB parameters for China. A third approach applied regional growth and investment models to subbasins, which relate income, investment, employment, population movement, natural population growth and structural changes to project future rural and urban populations, and to project GDP growth in the agriculture, urban and rural sectors (Table 2.2).

TABLE 2.2: GDP AND URBANIZATION IN 3-H BASINS ACCORDING TO DIFFERENT ECONOMIC MODELS

	GDP/capita (US$, 1998)	Urbanization (%)
IWHR Input/Output Model	8,500	52.0
Adapted Solow Growth Model	14,100	64.6
Regional Growth and Investment Model	15,000	63.0

Economic Growth. The growth rate potential for China over such a long period of time can be estimated only by looking at the growth of other countries in the past that have modernized from a base similar to China's and with resources and market opportunities that China can also hope to share. China exhibits many characteristics of previously successful East Asian economies—land reform, widespread literacy, heavy investment in public infrastructure, and a high savings rate. At this point China appears to be following the East Asian path and this is the basic assumption made here. Accordingly, this report uses average growth rates of between 6.5 and 7.5 percent for the 2000-to-2020 period and just under 6 percent for 2030 to 2050. Details on forecasted urban, rural and industrial growth rates for the 3-H basins up to year 1950 are given in Table 2.3. These forecasts consider that the global economic environment would be favorable for sustained long-term growth in China.

TABLE 2.3: CHINA'S ECONOMIC STRUCTURE IN 2050

	1997	2050			
	China Total	China Total	Yellow River	Hai Basin	Huai Basin
Population/Labor Force (%)					
Total	100	100	100	100	100
Urban	29	60	65	63	55
Rural	71	29	35	37	45
GDP Structure (%)					
Total GDP	100	100	100	100	100
Agriculture	19	4	3	6	3
Nonagriculture	81	96	97	94	97
Industry	44	36	33	34	41
Services	37	61	64	60	56
Nonagriculture	81	96	97	94	97
Urban	71	78	83	70	61
Rural	10	19	14	24	36
GDP/capita (1998 US$)	729	16,062	12,180	19,311	9,932

Source: SKM substudies.

Reference					
GDP/capita in 1997		729	470	1,063	351
GDP average growth rate (%)		6.3	6.8	6.0	6.7

Economic Structure. With economic growth would come changes in the relative balance of agriculture, industry and services, which is a natural and historical transformation experienced by all modernizing economies. Projections of this study are summarized in Table 2.3. By 2050 the share of GDP from agriculture would have declined to 4 percent. Services would dominate GDP, accounting for 55 to 65 percent of the total. The labor force in agriculture would be only roughly 10 to 15 percent of the total, and 60 to 80 percent of GDP would be produced in urban areas. Some observers in the water resource sector are worried at what appears to be a declining importance of agriculture, but this apprehension is not warranted. Looking only at the overall economic structure disguises the fact that agriculture is still growing. The long-term projections suggest that agricultural GDP in 2050 could well be about Y 10,000 billion (at 1998 comparable prices), compared to Y 1,500 billion in 1998.

Employment. The structure of employment would also change with economic growth. The challenge for China is to provide every opportunity for the agricultural population to move into other sectors. This can come with appropriate land tenure arrangements and more services; improved education, health, transport, communication, and marketing; and strong agricultural research. Employment in services would increase as dramatically as employment in agriculture would decline.

Economic Growth and Water Use. Despite improved efficiency of water use for higher-technology manufacturing processes, overall the growing economy would lead to increased water use by industry in China. Urban and rural water consumption are also set to increase with higher incomes. Table 2.4 shows projected water demand to the year 2050 for a range of different growth scenarios including GDP, urbanization, water prices, population, rural and urban incomes.

TABLE 2.4: NONAGRICULTURE WATER DEMAND FOR THE 3-H BASINS FOR 2000-50 FOR DIFFERENT SCENARIOS

3-H Totals (Billion cubic meters—Bcm)	2000	2010	2020	2030	2040	2050
As estimated case	37.64	45.17	55.02	65.10	71.36	*72.00*
High GDP growth	38.43	49.57	63.98	76.82	80.88	*81.00*
Low GDP growth	36.88	41.22	47.09	53.48	58.55	61.00
High urbanization	37.80	46.22	57.22	67.20	71.27	*72.00*
Low urbanization	37.48	44.22	53.06	62.74	70.47	73.67
No real water price increase	39.16	52.41	71.20	95.53	120.30	139.87
Low real water price increase	37.95	46.62	58.25	71.29	81.72	85.62
High real water price increase	37.49	44.45	53.40	62.19	67.19	65.27
High urban income growth	37.69	45.65	57.84	74.53	91.75	98.32
Low urban income growth	37.60	44.77	53.17	60.66	64.75	64.00
High population growth	37.69	45.47	55.79	66.98	75.46	77.70
Low population growth	37.59	44.88	54.28	63.56	68.77	*70.00*
High income growth	37.67	45.63	57.19	71.85	86.35	94.86
Low income growth	37.61	44.76	53.30	60.84	64.27	*65.00*
High rural income growth	37.65	45.40	55.93	68.09	79.19	86.06
Low rural income growth	37.63	44.97	54.32	63.49	68.68	67.02
High industry production growth	37.73	46.80	60.83	78.68	96.12	107.18
Low industry production growth	37.55	43.85	51.24	58.41	62.50	60.94
High urban price growth	37.64	45.12	54.57	63.18	65.72	*66.00*
Low urban price growth	37.64	45.22	55.39	66.71	75.79	79.33
High rural price growth	37.64	45.15	54.88	64.61	69.96	*70.00*
Low rural price growth	37.64	45.21	55.23	66.00	74.01	76.09
High industry price/domestic price factor	37.52	44.62	53.83	63.13	68.85	67.70
Low industry price/domestic price factor	37.73	45.60	55.95	66.93	74.66	75.71
High rural loss/urban loss factor	42.46	49.85	59.83	71.06	79.30	80.37
Low rural loss / urban loss factor	36.79	44.34	54.17	64.20	70.75	70.54

Note: Numbers in italic for 2050 are estimated.

Land Use. Economic growth and changing economic structure lead to increased urbanization, with more low-density suburban development and increased peri-urban development, increased transport infrastructures, and additional electricity, gas, and water pipelines. Economic growth would continue to take land out of agriculture, but this change in land use does not threaten agriculture or food security. With strong economic growth agriculture would also continue to grow. Within agricultural land, activities would shift away from grains to higher-value crops such as vegetables and orchards. With improvements in transport, communications, and agricultural research, and in intranational and international trade, it is expected that agriculture GDP would grow at a much faster rate than population.

E. FUTURE SOCIAL TRENDS

Population. China has been very successful in its efforts to bring population growth under control. Natural growth rates have been declining significantly for a number of years. Only in the western provinces do natural population growth rates exceed 1 percent per year. In the major cities natural growth rates are about zero, or negative. Nonetheless, overall population would continue to grow (Table 2.5). A common expectation is that it would peak at about 1.6 billion by 2050. With population increasing and incomes increasing, the impact on water demands could be alarming. It is inevitable that prices charged for water would increase, however, in an effort to recover some of the costs of meeting that water demand. Also, this would temper the increase in water demands that might be expected with continued growth of population.

TABLE 2.5: FORECASTED TOTAL, RURAL AND URBAN POPULATION
(Unit: '000 people)

Basins		1997	2000	2010	2020	2030	2040	2050
Hai	Urban	38	39	61	78	88	95	101
	Rural	86	89	80	73	68	64	58
	Total	123	128	141	150	156	159	159
Huai	Urban	44	46	77	105	122	133	140
	Rural	150	157	148	135	127	121	114
	Total	194	203	225	240	250	254	254
Yellow	Urban	32	34	57	77	89	94	97
	Rural	75	79	72	63	59	56	52
	Total	107	113	129	140	147	150	149
3-H total	Urban	114	119	195	259	298	322	338
	Rural	311	325	301	271	254	241	225
	Total	424	443	495	531	553	563	562
3-H total	High	424	445	502	543	571	587	593
	Low	424	442	489	518	535	539	533

Urbanization. Official statistics in China suggest that 30 percent of the present population is urban. The proportion of urban population receiving piped water supply may exceed 90 percent. The present study's water demand projections indicate that the level of urbanization would reach about 60 percent by 2050, but the level of urbanization would not greatly affect the overall urban water demand.

3. WATER RESOURCES AND ISSUES

A. INTRODUCTION

Chapter 2 investigated the "external environment" parameters; that is, how such factors as population growth, GDP growth, and decentralization are likely to affect water resource demand and management. Chapter 3 investigates the current water resource situation in the 3-H basins and delineates the important management problems that need to be resolved. Chapter 3 comprises detailed evaluations that address the following aspects:

- The water resource balances in the basins including past and present withdrawals and water consumptive uses and current water shortage estimates and their consequences such as dry mouths, droughts and water conflicts.

- Past floods and flood damage for each province in the basins and the current Chinese flood control strategy.

- Water supply used for agriculture in the basins and the importance of current irrigation to crop production, including effects of changing structure of the economy and the agricultural sector on incomes and employment resulting from declining water allocation.

- Water quality status in the rivers of the Hai and Huai basins and sources of water pollution including rural and urban and industrial sources.

- Groundwater resources in the basins, including major groundwater management problems and the feasibility of artificial recharge.

- Current water planning in the basins, including interministerial coordination and the successes and failures of existing river basin management with current degrees of decentralization.

These various aspects are reviewed below under the headings of Water Resources and Withdrawals, Consumptive Use, Current Water Shortage Estimates, Dry Mouths, and Water Conflicts. Because of space limitations, only the main findings for each evaluation are included here, but references are made to the supporting tables and figures not included here by showing the numbers of the tables/figures in parentheses.

Chapter 3 provides the basis for the analysis presented in Chapters 4 to 10 where the recommended action plan would be developed.

B. WATER RESOURCES AND WITHDRAWALS

Background

Population growth and lower runoff in recent years have significantly diminished per capita water availability. That water availability in the 3-H basins is very limited is beyond dispute. In 1953 this was only 522 cubic meters (m^3)/year, only 15.4 percent compared to the rest of China. By 1999 this had decreased to about 499 m^3/year.

Most runoff is floodwater that is difficult to capture because (a) runoff is highly variable within years and from year to year, and (b) during wet years, only part of the flow can be captured and this is usually laden with silt.

Of the total runoff since 1994, 38 percent reaches the sea and 62 percent is consumed or lost to evaporation or goes into groundwater recharge. The data indicate this 62 percent use is taxed to its limits. If consumptive use is to be increased, the increase must come either by reducing losses or by finding alternative sources of water (Tables 3.1 and 3.2 MR [Main Report]).

Increasing dependence on groundwater to meet demands confirms the surface water supply constraint (Table 3.1).[2] Overdrafting of groundwater beyond sustainable recharge, which amounts to "mining" of groundwater, has become increasingly serious, especially in the Hai-Luan region, resulting in sharply falling water tables and serious land subsidence (for example in Taiyuan, Jinan and Tianjin). In 1995 it is estimated that groundwater furnished 58 percent of total urban 3-H water demand. Groundwater levels are reported to have dropped by 50 meters and 90 meters in shallow and deep aquifers in areas of the Hai Basin.

TABLE 3.1: UTILIZATION OF GROUNDWATER IN THE 3-H BASINS
(Billion cubic meters)

	Hai-Luan	Huai	Yellow	3-H Total
Utilization of Groundwater in 3-H				
1980	20.2	12.9	8.4	41.5
...	...	...	...	...
1993	21.5	15.6	12.0	49.1
1994	23.4	18.1	12.3	53.8
1995	23.8	17.8	13.1	54.7
1996	23.8	16.5	12.7	53.0
1997	26.4	17.9	13.8	58.1
1998	26.1	17.5	12.7	56.3
Pumping capacity in 1993 (IWHR)	21.9	15.8	12.2	49.9
Estimates of long-term exploitable groundwater:				
1. Long-term average annual recharge (WRA)	26.5	39.3	40.6	106.4
2. IWHR long-term maximum withdrawals	21.0	22.0	15.0	58.0
3. River Basin Commission estimates	21.5	24.0	22.2	67.7
4. World Bank (3-HMS) estimates	17.3	22.0	15.2	54.5

Consumptive Use

Surface water withdrawals, consumptive use, and return flows in the 3-H basins have been collated and summarized (Table 3.4 MR).

Much of the unrecoverable losses are due to evaporation rates being three times average precipitation.

Return flows comprise a major potential source of now unused water, but these flows are usually heavily polluted due to low levels of wastewater treatment and to salinity and irrigation runoff.

[2] Exploitable groundwater is estimated to be about 56 percent of gross recharge after the resources is factored down to allow for management and technical factors.

Water Shortage Related to Economic Value of Water by Sectors

Estimates of current and future water shortages are summarized under categories as follows: (a) current shortages under different runoff probabilities (Table 3.2), (b) irrigation demand and supply (Table 3.6 MR), (c) grain production for different runoff probabilities (Table 3.7 MR), (d) water supply for sector uses for different runoff probabilities, (Table 3.8 MR) and (e) economic value of water for various sector uses. (Table 3.3). Table 3.4 shows the average economic value of water varying with scarcity from Y 1.88/m^3 to Y 2.68/m^3 for the Hai and Y 1.36 to Y 1.71/m^3 for the Yellow.

TABLE 3.2: CURRENT (2000) SHORTAGES UNDER DIFFERENT RUNOFF PROBABILITIES
(Bcm)

Basin	Priority Sectors[a]	Irrigation under:			
		P25	P50	P75	P95
Hai	2.31	4.95	9.45	14.97	22.31
Huai	2.24	0.17	1.70	7.99	28.65
Yellow	1.80	6.65	7.41	9.50	11.02
3-H Total	6.35	11.77	18.56	32.46	61.98

[a] Priority shortages are the same for all runoff probabilities.
P25 25 percent probability of flow
P50 50 percent probability of flow
P75 75 percent probability of flow
P95 95 percent probability of flow

Current 3-H shortages for "priority sectors" (urban, industry, and rural domestic) total about 6.35 billion cubic meters (Bcm)/year (despite very large groundwater mining). Shortages are much higher for irrigation, averaging about 24 percent of demand, resulting in an about 13.7 percent shortfall in grain production.

The estimated relative values of water for various sectors are 3.0 for urban and rural domestic use, 6.0 for urban industry, 4.0 for rural industry, and 2.0 for livestock and "FPF" (fisheries, pasture, forestry). These estimates were based on data produced from the Wanjiazhai Water Transfer Project and other similar water supply projects in north China.

TABLE 3.3: ECONOMIC VALUE OF THE 2000 SOLUTIONS
(Y billion)

	Hai	Huai	Yellow	Total	%
1. No Shortages					
Urban Life	8.70	7.56	4.86	21.12	7
Urban Industry	34.06	51.84	34.81	120.71	37
Rural Life	5.53	7.20	3.14	15.87	5
Rural Industry	6.00	9.12	3.27	18.39	6
Irrigation	46.15	60.43	26.62	133.20	41
Livestock	1.01	2.16	1.06	4.23	1
FPF	2.80	5.70	2.38	10.88	3
Total	104.25	144.01	76.14	324.40	100
%	32	44	23t	100t	
2. Under P25					
Urban Industry	28.36	51.84	33.86	114.06	36
Rural Life	5.53	7.20	3.14	15.87	5
Rural Industry	6.00	9.12	3.27	18.39	6
Irrigation	43.76	60.43	25.13	129.32	41
Livestock	1.01	2.16	1.06	4.23	1
FPF	2.80	5.55	2.30	10.65	3
Total	95.59	143.86	73.61	313.06	100
%	31	46	24	100	
3. Under P50					
Urban Life	8.13	7.56	4.86	20.55	7
Urban Industry	28.36	51.84	33.86	114.06	37
Rural Life	5.53	7.20	3.14	15.87	5
Rural Industry	6.00	9.12	3.27	18.39	6
Irrigation	41.94	59.67	24.92	126.53	41
Livestock	1.01	2.16	1.06	4.23	1
FPF	2.80	5.43	2.38	10.61	3
Total	93.76	142.98	73.49	310.23	100
%	30	46	24	100	

	Hai	Huai	Yellow	Total	%
4. Under P75					
Urban Life	8.13	7.56	4.86	20.55	7
Urban Industry	28.36	51.84	33.86	114.06	38
Rural Life	5.53	7.20	3.14	15.87	5
Rural Industry	6.00	9.12	3.27	18.39	6
Irrigation	38.95	55.65	24.59	119.19	
Livestock	1.01	2.16	1.06	4.23	1
FPF	2.80	4.97	2.38	10.15	3
Total	90.78	138.49	73.16	302.43	100
%	30	46	24	100	
5. Under P95					
Urban Life	8.13	7.56	4.86	20.55	7
Urban Industry	28.36	51.84	33.86	114.06	39
Rural Life	5.53	7.20	3.14	15.87	5
Rural Industry	6.00	9.12	3.27	18.39	6
Irrigation	35.65	51.97	24.37	111.99	38
Livestock	1.01	2.03	1.06	4.10	1
FPF	2.80	3.33	2.38	8.51	3
Total	87.48	133.06	72.94	293.48	100
%	30	45	25	100	
6. Economic Cost of Shortages by Runoff Probability					
P25	8.66	0.15	2.53	11.34	
P50	10.49	1.03	2.65	14.17	
P75	13.47	5.52	2.98	21.97	
P95	16.77	10.95	3.20	30.92	

TABLE 3.4: AVERAGE ECONOMIC VALUE OF WATER IN THE 2000 SOLUTIONS
(Y billion)

	Hai	Huai	Yellow	Total
1. Total Water Supplied (Bcm)				
No shortage	55.31	85.43	55.81	196.55
P25	38.68	58.31	43.06	140.05
P50	36.99	61.69	43.80	142.48
P75	33.93	61.80	44.37	140.10
P95	31.99	61.18	45.32	138.49
2. Total Economic Value of Water Supplied				
No shortage	104.25	144.01	76.14	324.40
P25	95.59	143.86	73.61	313.06
P50	93.76	142.98	73.49	310.23
P75	90.78	138.49	73.16	302.43
P95	87.48	133.06	72.94	293.48
3. Average Economic Value (Yuan/m^3)				
P25	1.88	1.69	1.36	1.65
P50	2.47	2.47	1.65	2.16
P75	2.53	2.32	1.68	2.18
P95	2.68	2.24	1.71	2.24

Dry Mouths

Because of increasing surface water withdrawals, outflows to the sea have been dropping sharply in recent years, especially for the Yellow and Hai rivers, with increasing long periods of low or even no flows in dry years, resulting in severe environmental damages to estuarine and coastal fisheries and aquatic ecology, increasing seawater intrusion, and increasing siltation in the river and canals, thus increasing flooding hazard.

Other serious damages from these low flows are lack of water for withdrawals for supporting irrigation and urban and industrial needs (leading to increased groundwater mining).

Water Conflicts

The usual conflicts in water uses for instream purposes (hydropower, navigation) and offstream withdrawal purposes are intensified by the increasing water shortages. The existing river dam and reservoir systems have different objectives and hence are not operated in a coordinated manner for optimal water use.

While priority uses have been satisfied so far by groundwater mining (which cannot go on much longer), the low priority for irrigation has resulted in increasing cases of no irrigation water for many areas. This has led to intense conflicts between political entities (provinces, counties and irrigation districts). The share of withdrawals for irrigation continues to diminish, from 84 percent in 1980 to 73 percent in 1998.

Entities in upper and middle reaches get first access to runoff, to the disadvantage of downstream entities, and these conflicts are increased with increasing water shortages.

It is obvious that basinwide control of the limited water is becoming essential.

C. FLOODS AND FLOOD CONTROL IN CHINA

Introduction

Flooding damage has been historically severe in the 3-H region because of climatic and topographic factors and this history, including estimates of flood damage since 1950, has been summarized (Table 3.12 MR). Most major rivers are now confined by dikes that are seldom breached, but tributary flows behind the dikes continue to cause widespread and very damaging floods. Despite significant investment in flood control in this period, the unit 3-H flood damage value has increased six times, for example, from Y 1,360/mu to Y 10,500/mu between 1950 and 1989 in the Yishusi basin in the Huai.

Additional serious damage is caused by drainage and waterlogging due to inadequate drainage capacity.

For centuries now, the Chinese have been changing the natural landform of the plains in the 3-H basins by (a) blocking and diverting rivers for irrigation and water supply, (b) interrupting drainage patterns with the establishment of entire cities, levees and dikes to gain protection from the devastation of flooding, (c) encroaching on wetland areas and lake shores by draining these areas for agricultural production and (d) creating "lowlands" by overpumping groundwater thus causing land subsidence beneath cities and rendering these areas prone to waterlogging.

Flooding is the major cause of waterlogging, especially in flood detention basins. However, policies in the 1960s in the Huai basin, for example, actually promoted the removal of flood control works to improve drainage, thus lowering flood protection in favor of improved drainage.

Flood Losses in Provinces

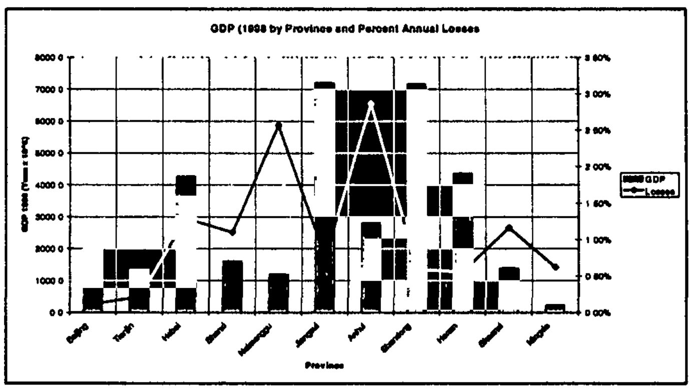
Data on flood losses in the 3-H provinces are presented, collated and summarized in the Flood Annex of Volume 3, organized into the following categories: (a) affected land, (b) total economic losses, (c) average losses for affected areas (Figures 3.1 and 3.2 MR), (d) flood losses compared to GDP (Figure 3.3 MR), (e) loss of life, (f) summary of results of the analyses (Table 3.13 MR), and (g) level of protection (flood standard). Table 3.5 below shows major flood damages in the 3-H basins.

TABLE 3.5: FLOOD DAMAGE LOSSES IN THE MAIN PROVINCES OF THE 3-H BASINS

Basin	Province	Comprehensive losses (yuan/mu, at price of current year)			
	(or tributary basins)	1950-59	1960-69	1970-79	1980-89
Yellow	Whole basin	1,500	3,600	6,000	9,000
Hai	Henan Province	1,500	3,600	6,000	9,000
	Jiangsu Province	1,350	2,250	6,000	10,500
Huai	Henan Province	1,500	3,600	6,000	12,000
	Anhui province	2,250	-	-	9,450
	Yishusi Basin	1,350	2,250	6,000	10,500
3-H Basins average		1,538	3,300	6,000	9,538
Whole Country	(yuan/ha):	2,190	3,255	5,880	12,120

The three worst provinces for flooding are, in order, Anhui, Jiangsu and Henan. The next ranked provinces that suffer significant damage are Shandong, Shaanxi, and Shanxi. Beijing suffers large losses per hectare but the area affected is not large compared to the other provinces. This is not surprising, because the provinces are on the floodplains toward the bottom of the catchments and tend to act as detention basins due to limited flood capacity of outlets to the sea. Figure 3.1 shows average flood losses compared to GDP for some provinces in the 3-H basins.

FIGURE 3.1: GDP AND PERCENT FLOOD LOSSES FOR PROVINCES



The economic data identify the areas that are most affected by flooding and the magnitude of the losses but do not provide a clear picture of the frequency of damage. To explore this issue a detailed review was made of flood standards for facilities for flood control in the 3-H basins including reservoirs, levees, and detention storage. This shows that there are a number of areas that would continue to have very low flood security. The data on flood standards have been combined with the location of the flood losses to provide a rationale for flood management priority projects (described in Chapter 5).

D. CURRENT FLOOD CONTROL IN CHINA

Introduction

The main elements of China's flood control strategy include: (a) dikes to prevent normal annual floods and provide protection against extreme floods; (b) storage reservoirs to retain runoff from high floods; (c) river training to protect vulnerable dikes and banks; (d) dredging to increase channel capacity; (e) floodways to evacuate flows to the sea or away from built-up areas; (f) detention basins to receive diverted flood flows and reduce flood levels downstream; (g) soil and water conservation in catchment areas to moderate siltation; (h) flood-proofing and land use controls to limit damage and preserve the flood control system; (i) flood forecasting to ensure early warning of high water levels; and (j) flood preparedness to ensure availability of resources for flood fighting and relief.

Nonstructural measures have over time been strengthened, for example, in respect of flood proofing, flood forecasting and flood preparedness. Broad controls have been adopted to preserve and enhance the flood management system (for example, by precluding construction in floodways) or to avoid unnecessary loss of life and damage (for example, by relocating people and siting facilities away from high-risk areas such as detention basins). Moreover, following the 1988 Yangtze floods, a decision was taken to reverse encroachment and loss of natural storage capacity by large-scale resettlement and relocation of facilities.

Details for 3-H Basins

Details have been compiled on the many thousands of structural production facilities for flood control built over the decades in each of the 3-H basins.

For the Hai basin, severe flooding in 1963 gave major impetus to flood control in this basin, including construction of additional dams and reservoirs, excavation of additional floodways, and improvements in dikes. Each major tributary channel has reached a flood control standard of 20- to 50-year return period, while Beijing, Tianjin and other large cities are protected against more severe floods. In the case of Beijing, protection is designed to be against the largest flood on record.

For the Huai basin, the middle reach of the Huai above Hongze Lake can now withstand the flood of 1954 corresponding to a 40-year flood, and the main stem below Hongze Lake can withstand a 50-year flood. Most main tributaries can withstand a 10- to 20-year flood and cities are protected generally against the 50- to 100-year flood. There is far less protection in smaller upstream catchments.

For the Yellow River basin, the just completed construction of the Xiaolangdi dam and reservoir has been very timely in alleviating the severe flood hazard in the lower river basin area with its major concentration of population and industry.

Overall it is concluded that the 3-H flood hazard is either static or increasing. Flood damage areas are fairly well documented but these depend on the types of storms and floods and many smaller catchments can produce very locally damaging floods. On average Jiangsu, Anhui, Shandong, Shanxi, Hebei and Beijing seem to incur the highest economic losses from flooding. It is difficult to conclude whether past flood control strategies have provided appropriate protection; there is no doubt, however, that without previous flood control efforts, the 3-H basins would have been much worse off. The question is, are these flood protective measures the most cost-effective and what opportunities are there (a) to develop systematic methodologies to prioritize flood-prone areas and protect key assets and (b) to augment flood protection with nonstructural measures? This is investigated in Chapter 5.

Flood Control Infrastructure in the 3-H Basins

TABLE 3.6: FLOOD CONTROL INFRASTRUCTURE IN THE 3-H BASINS

	Flood Control
Hai	1,915 reservoirs, 30 large reservoirs with gross storage of 27 Bcm and flood storage of 10.5 Bcm (controlling 80 percent of mountainous area). Sediments reduce active storage by about 20 to 30 percent. At least 18 large reservoirs need upgrading to meet safety standards, 50 excavated floodways, 8 widened major river channels. Total flood discharge capacity is 24,680 m^3/s. Major channels have lost 30 to 50 percent of the flood-carrying capacity due to sedimentation. There are 28,000 km of dikes providing protection against a 40- to 50-year flood. There are 23 detention basins (11 controlled) with storage of 11.4 Bcm and a population of over 3 million; 5 have 1-in-10-year frequency. Most have typically 40- to 50-year return period.

	Flood Control
Huai	3,500 reservoirs with storage over 32 Bcm. 17 large reservoirs with gross storage 29.8 Bcm (13.5 Bcm from Hongze Lake with 10.4 Bcm flood storage. There are 32,000 km of dikes. Floodway capacity in the Yangtze has increased from 6,000 to 12,000 m^3/s. Gross storage of detention basin is 28 Bcm, 7 major detention basins account for 20 Bcm with population of over 1 million and frequency period of 5-10 years. There are 1,700 reservoirs in the Yishusi basin. Nansi and Luoma Lakes provide 5.4 Bcm and 1.9 Bcm gross storage, respectively, and flood storage of 3.8 Bcm and 1.7 Bcm. The discharge capacity of New Yi and New Shu are 7,000 m^3/s and 4,000 m^3/s to the sea. Some 10,000 km of dikes have been raised along the Grand Canal, Nansi Lake and lower reaches of the Yi and Shu Rivers.
Yellow	Sanmenxia (3 Bcm) and Xiaolangdi (12.6 Bcm) with-purpose projects with a number of additional dams providing 25 Bcm gross storage. Silting of dams and river is a major problem in the Yellow Basin arising mostly from the Loess Plateau. There are 1,400 km of dikes along the banks of the lower Yellow, 400 km enclosing detention basins. Dike raising is ongoing work since the riverbed is aggrading by 3-5 cm/year above the surrounding plains. There are detention basins in Dongping Lake (3 Bcm and population of 0.4 million), Beijindi (8 Bcm and population 1.7 million). Once Xiaolangdi is completed, the placed frequency of use 1:100 years for Dongping (23.000 m^3/s at Huayuankou), and 1:1,000 for Beijindi (37,000 m^3/s).

E. WATER FOR AGRICULTURE

Introduction

Given that the population increased to 1.25 billion by 1998, the matching increase in agricultural productivity can be considered to be a remarkable achievement brought about by economic reforms (particularly the Household Responsibility System), liberalization of commodity markets, increased irrigation and fertilizer use, and a very effective agricultural research system. While the focus of the past two decades to expand output was remarkably successful, the lack of attention to quality has resulted in overproduction of low-quality grains, cotton, and other crops. Over the next two decades the agricultural sector faces the task of expanding production and improving quality to meet the needs of a population expected to reach 1.45 billion by 2020 (1.6 billion by 2050). Food supplies would need to increase by 16 percent to provide only for the increased population. Rising incomes are also causing changes in consumption patterns and consumers are now demanding better quality products, outside of season. This is requiring adjustments from the agricultural sector to improve its responsiveness to domestic markets, but also international markets, especially when China accesses the World Trade Organization (WTO).

Agricultural Output in 3-H Basins Relative to National Output

A detailed analysis of this issue was completed, with the information summarized on (a) grain production increases and production growth rates, from 1979 to 1998; (Table 3.14 MR); (b) output of major crops in the 3-H basins as a percentage of national output (Table 3.15 MR); (c) normalized, actual, and potential 3-H production, 1997 (Table 3.17 MR); (d) groundwater and surface water irrigation areas (Table 3.18 MR); (e) multiple cropping index in the 3-H region (Table 3.19 MR); (f) yield difference between irrigated and unirrigated farmland (Table 3.20 MR); (g) grains production in 3-H basins and China, 1998 (Table 3.21 MR); (h) marginal value of irrigation water applied to various crops for each 3-H basin (Table 3.22 MR); (i) average growth rates in agricultural subsectors from 1978 to 1998 (Table 3.23 MR); (j) gross value of agricultural output (Figure 3.4 MR); (k) farmer income changes in Ningxia province (Figure 3.5 MR); and (l) farmer income in Hebei province (Figure 3.6 MR).

The information noted above is briefly summarized as follows:

- The contribution of the 3-H basins to national agricultural output is quite significant. The 3-H basins produce 35 to 37 percent of China's GDP and income and contain about 36 percent of the rural population and agricultural labor. The 3-H basins produce much of the nation's grain; the area is clearly the nation's wheat basket and ranks second to the northeast region in the production of corn (but is a relatively modest producer of rice). It is also an important producer of oilseeds and cotton.

- It is difficult to estimate the impact of lower water availability on crop production mainly because of incomplete data sets for irrigation water use. The importance of irrigation water and the impact of reduced rainfall on crop yields, however, were evaluated for 1997/98. Normalized production refers to the statistical estimation of yield trends and the application of those yield coefficients to areas planted. The derivation of yield growth coefficients normalizes all factors of production and implicitly assumes a consistent growth rate in their use or application, and includes technology, pest control, fertilizer, and other input use (including water). Thus if there has been a consistent decline in water use (not just a one-year drought), that impact is factored into the yield trend. Given the rate of productivity growth of land and water over the past two decades, with essentially constant supplies of land and water, further marginal declines in irrigation supplies would unlikely reverse the production trend, assuming continued onfarm investment in water-saving technology and continued public investments in agricultural research and technology transfer.

- It is significant to note that according to Table 3.7 below, some 83 percent of irrigated land from groundwater sources are in the 3-H basins while irrigated land from surface water in the 3-H basins accounts for only about one third of national irrigation area. Thus groundwater plays a much more critical role in irrigation in the 3-H basins compared to irrigation areas in the rest of China. It is likely that the large increases in crop production described above have been facilitated by increased groundwater pumping and that this level of exploitation is not sustainable. In order to continue with the current level of crop production or current increases in crop production, alternative water sources would likely have to be developed.

- Competitive use of scarce water in north China continues to cause declining supplies to agriculture. The main grain crops in the 3-H basins include wheat, corn, millet and soybean, and the main cash crops are cotton, peanut and sesame. The production of such crops in the 3-H basins area in 1998 is more than 45 percent of that of the whole country. Moreover, the 3-H area is the main area for summer grains production, with a production output accounting for 74 percent of that of China. The 3-H plains area accounts for 62 percent of the total, thereby playing an important role in food security of China.

TABLE 3.7: GROUNDWATER AND SURFACE WATER IRRIGATION AREA
('000 ha)

Province	1989	1990	1991*	1992	1993	1994	1995	1996	1997
Groundwater									
Beijing	257	237	247	256	253	260	262	266	264
Tianjin	131	131	157	182	182	183	186	185	189
Hebei	3,161	3,213	3,298	3,382	3,408	3,460	3,526	3,618	3,690
Jiangsu	933	790	841	891	849	817	816	795	801
Anhui	381	423	469	514	542	573	611	635	697
Shandong	2,698	2,762	2,964	3,166	3,193	3,224	3,256	3,328	3,393
Henan	2,502	2,415	2,480	2,545	2,626	2,703	2,807	2,956	3,091
3-H-a	10,063	9,971	10,454	10,936	11,053	11,220	11,464	11,783	12,125
Shanxi	518	524	534	543	548	555	563	571	581
Neimenggu	627	722	793	863	897	929	914	959	1,038
Shaanxi	485	500	476	451	472	403	425	428	437
Gansu	221	232	233	234	239	243	249	258	269
Qinghai	5	5	5	5	5	5	5	5	5
Ningxia	25	28	21	14	19	19	19	19	20
3-H-b	1,881	2,011	2,061	2,110	2,180	2,154	2,175	2,240	2,350
3-H	11,944	11,982	12,514	13,046	13,233	13,374	13,639	14,023	14,475
National	14,673	14,823	15,441	16,058	16,264	16,326	16,703	17,348	17,348
% of 3-H to National	81.4	80.8	79.9	81.2	81.4	81.9	81.7	80.8	83.4

Province	1989	1990	1991*	1992	1993	1994	1995	1996	1997
Surface Water									
Beijing	107	135	121	107	107	102	103	100	106
Tianjin	223	231	212	193	194	195	194	196	194
Hebei	721	750	748	745	763	783	805	827	859
Jiangsu	3,088	3,193	3,129	3,065	3,097	3,137	3,140	3,173	3,162
Anhui	2,177	2,213	2,238	2,262	2,297	2,323	2,350	2,366	2,383
Shandong	1,900	1,960	1,869	1,777	1,818	1,828	1,844	1,819	1,799
Henan	1,423	1,152	1,207	1,262	1,272	1,260	1,278	1,283	1,297
3-H-a	9,639	9,634	9,523	9,411	9,548	9,628	9,714	9,764	9,800
Shanxi	621	631	638	644	646	653	659	656	664
Neimenggu	1,120	1,127	1,125	1,123	1,158	1,144	1,185	1,225	1,302
Shaanxi	771	776	826	876	870	951	947	956	961
Gansu	761	767	787	807	823	842	857	873	881
Qinghai	299	307	316	325	330	338	339	343	345
Ningxia	322	334	350	366	372	376	387	393	400
3-H-b	3,894	3,942	4,042	4,141	4,199	4,304	4,374	4,446	4,553
3-H	13,533	13,576	13,564	13,552	13,747	13,932	14,088	14,210	14,353
National	36,056	36,117	36,260	36,403	36,717	36,895	37,116	37,397	37,630
% of 3-H to National	38	38	37	37	37	38	38	38	38

Note: In the above tables, "groundwater irrigation area" = "irrigation area by pump-well + irrigation area by mobile motors + spray & drip irrigation area", in fact, it includes some areas where conjunctive irrigation both by surface and groundwater is used. "Surface water irrigation area" = "total effective irrigation area" – "groundwater irrigation area".

*: the data of corresponding irrigation areas are not available for 1991, while an average value of 1990 and 1992 is used for 1991.

Source: Water Resources Yearbook, 1990-98.

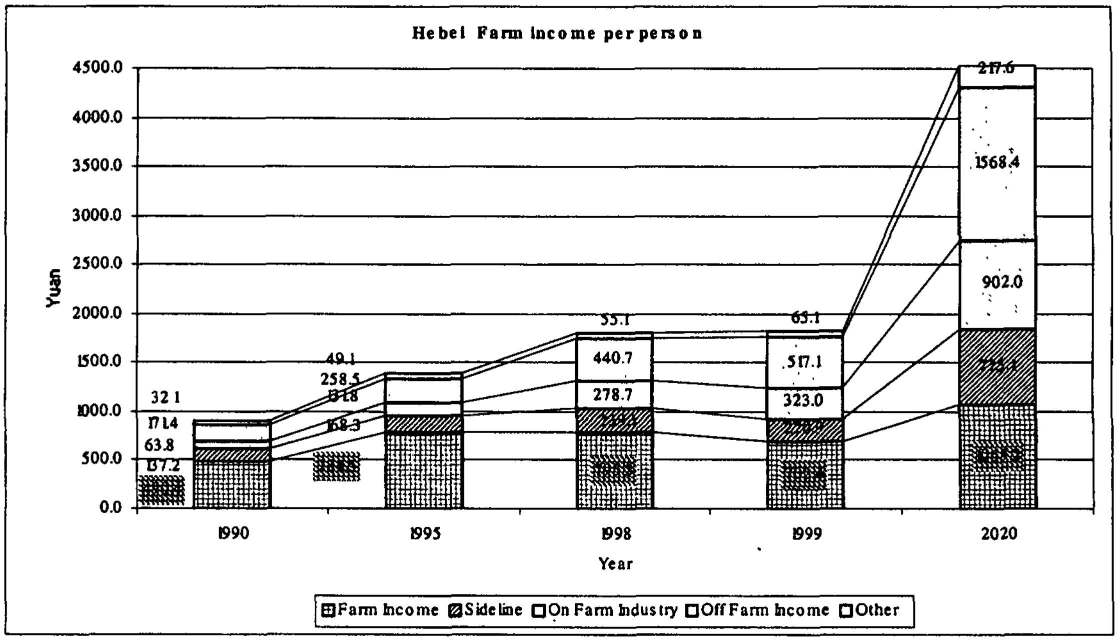
Changing Agricultural Sector Employment

The diminishing volumes of water available to agriculture (Figure 6.1 MR) are occurring in parallel with changes in composition of the agricultural sector and the relative importance of the agricultural sector relative to other developing sectors such as industry and services where water has a higher marginal value. The relative importance of agriculture has declined, not only in its contribution to GDP but in terms of rural incomes and employment, but this characteristic is common to most developing countries. Projections to 2050 forecast that this trend would continue and that by 2050, agriculture's share of GDP would decline from the present 20 percent to about 4 percent.

Research shows that national trends in agricultural employment have varied among regions depending on (a) natural resource endowment and geographic location, (b) ability of workers to migrate to seek off-farm employment, and (c) lack of credits for initial investments. As noted earlier, it is difficult for poorer rural families to migrate to urban areas, and at higher income levels, the main factors inhibiting labor migration is the difficulty of migrants to qualify for health, education and housing facilities that are tied to SOE employment. Despite rural labor migration to city fringes, urban labor markets remain rigid mainly due to SOE-linked employment and the social benefits structure.

Although irrigated agriculture has declined in importance both within the sector and as a source of income, it still represents a major component of farmers' income and this is likely to continue for several decades (Figure 3.2). It is unlikely that all farmers would have the same opportunity to diversify their income and so many would stay dependent on water for their basic livelihood. Western mountainous provinces are areas where this dependence is likely to be greater than floodplain provinces. One of the challenges for the government is to improve opportunities for inland/western provinces to take advantages of this shifting structure of agriculture.

FIGURE 3.2: FARMERS' INCOME CHANGES IN HEBEI PROVINCE



F. WATER POLLUTION

Introduction

Surface and groundwater quality in China has been seriously degraded due to lack of effective pollution control, combined with rising population and industrial operations (including export business), especially in the last two decades. Causes of pollution from point sources include rapid urbanization, industrial development, rising population, and the growth in the number of TVEs and livestock operations in rural areas. Diffuse release of nutrients and pesticides from agriculture are also becoming important sources of shallow groundwater and surface water contamination. Point-source pollutants of concern include parameters for organics such as combined oxygen demand (COD) and biological oxygen demand (BOD), phenols, ammonia nitrogen, and inorganics, such as heavy metals while nonpoint-source pollutant parameters include nonionic ammonia, total phosphorus, total nitrogen, and COD. Figures 3.3 and 3.4 show the current status of water quality according to State Environmental Protection Administration (SEPA) classification standards. The current quality status of surface water in the 3-H basins is such that most rivers and lakes fail to meet SEPA's standards required for the designated beneficial uses of the water. The decline in water quality in each of the three basins as of 1995 was alarming, with all registering in excess of 80 percent of their lengths being classified as seriously polluted.

This dramatic decline in surface and groundwater quality continues despite efforts by regulatory authorities including SEPA, Environmental Protection Bureaus (EPBs), and MWR to arrest and reverse the trend with improved control of obvious sources of pollution such as SOEs and attempts to close small highly polluting TVEs. Water quality has continued to decline, especially during periods of low flow around December through January in the lower reaches of most rivers where the cumulative effects of upstream discharges and runoff tend to concentrate.

This trend suggests that there are many sources generating pollutants (identified with COD as the primary water quality indicator for degradable organics) in addition to obvious sources like large enterprises. These other sources include (a) agricultural runoff, (b) TVEs, (c) livestock operations, and (d) urban and rural life. The extent of their impact on water quality is not certain, however, because the information necessary to document water quality changes is patchy, sometimes unreliable and often difficult to obtain from the ministries concerned with monitoring. Similarly, monitoring data for effluent discharges are not comprehensive which makes it difficult to relate pollution loads to ambient water quality. In addition, given current SEPA/EPB capabilities and policy, only obvious major industrial sources tend to be monitored and many smaller sources are overlooked despite their large collective contribution to the total pollution load.

Chapter 3 Section E of the MR presents the study's detailed evaluations, which support the conclusions noted above. These evaluations, which focus on the Hai and Huai basins, are summarized as follows:

- **Sources of Water Pollution**. This analysis clearly differentiates between point and nonpoint sources (previously, some large point sources such as cattle farms and TVEs were classified as nonpoint). Current understanding of pollution sources and their contributions in the Hai and Huai are shown in Figure 3.5 below.

- The analysis includes development of a "Water Pollution Management Decision Support System" (WPM-DSS) model, which provides a systematic compilation of water use data consistent with basinwide water assessments, and calculates COD loads and wastewater quantities for major sources. The model was run in a "forward" usage where pollution from urban and rural industry and municipal and livestock sources were subjected to intervention from wastewater treatment plants (WWTPs), reuse and pollution prevention programs, and the resulting water quality improvements were determined.

- Within the industrial pollution sources, the study confirmed paper-making as the single largest COD contributor in both the Hai and Huai basins (Figures 3.6 and 3.7). Those surveys monitored only enterprises discharging 100 m^3/day or more wastewater but urban areas also have many industries discharging less than 100 m^3/day wastewater and so the WPM-DSS model accounted for these by adding these contributions to the category of urban industry sources. The classification of industries for modeling purposes was based on the SEPA survey for the Hai and Huai basins. The list includes paper-making, fertilizer, chemicals, pharmaceuticals, food, brewing; textile, leather and tanning, power, steel metallurgy, oil, machinery, light industry, mining and coking.

- The SEPA survey provides an important base for the development of the WPM-DSS model. However the COD loads reported in this survey say nothing about toxic loads generated by industries, which are by far the most health-threatening aspect of industrial pollution. Therefore, a methodology was developed to estimate toxic load pollution from the six most polluting industry classes defined in the model. These toxic loads are calculated for major cities in the Hai and Huai basins for 2000 by (a) referring to the Chinese Standards (SEPA 1979-97) which list mercury, cadmium, chromium, arsenic, lead, nickel and phenol as Class A (toxic) pollutants, (b) identifying the type of industries that discharge such pollutants (for example, tanneries are known to produce toxic chromium), and (c) locating the cities where these industries exist (from SEPA Survey information) (Figure 3.9 below).

- The WPM-DSS model calculated loads and wastewater from municipal sources (that is, sanitary sewage) based on water consumption and population and COD generation rate per person (0.04 kg/person/day). Urban municipal sources produce 0.5 and 0.6 million tons a year COD in the Hai and Huai basins.

FIGURE 3.3: WATER QUALITY CLASSIFICATION IN THE HAI RIVER BASIN IN 1995

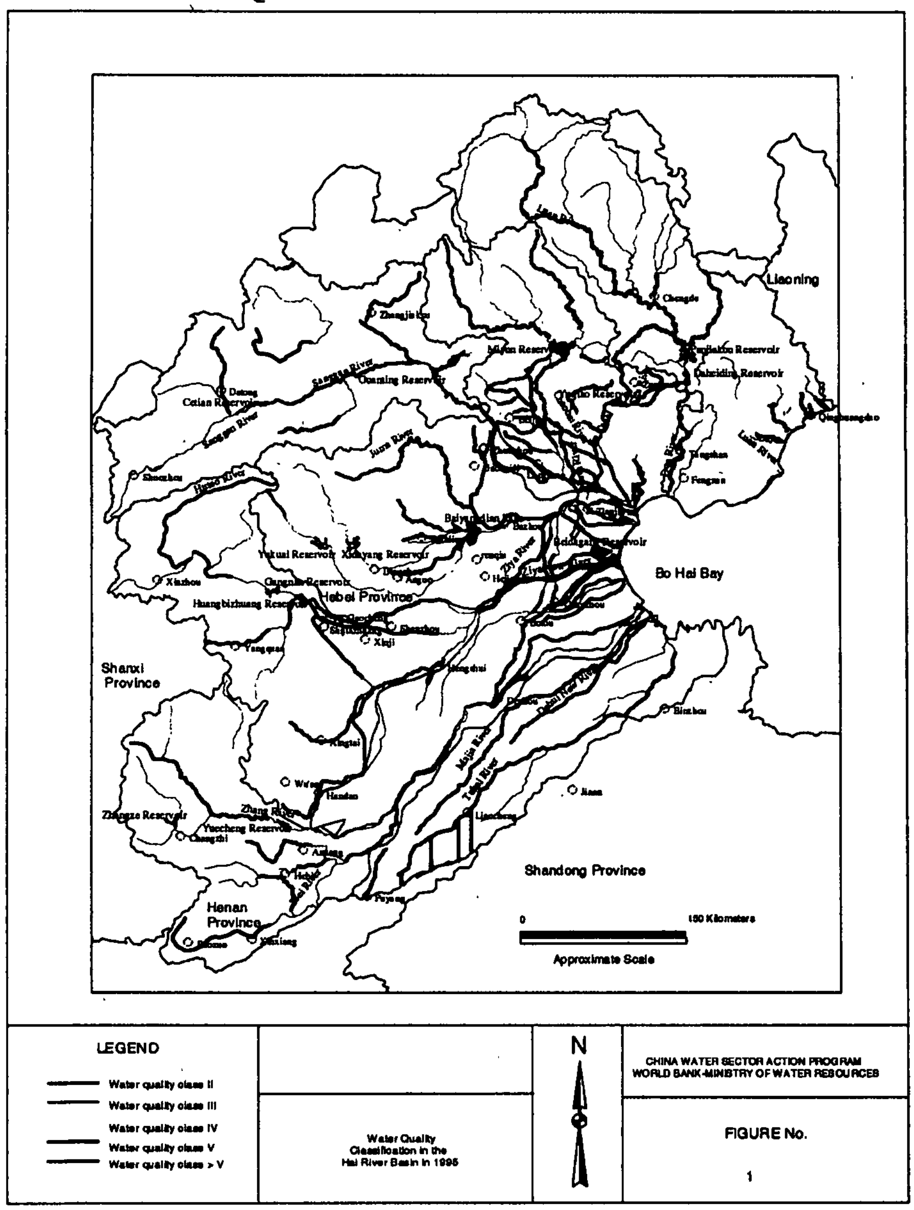


FIGURE 3.4: WATER QUALITY CLASSIFICATION IN THE HUAI RIVER BASIN IN 1998

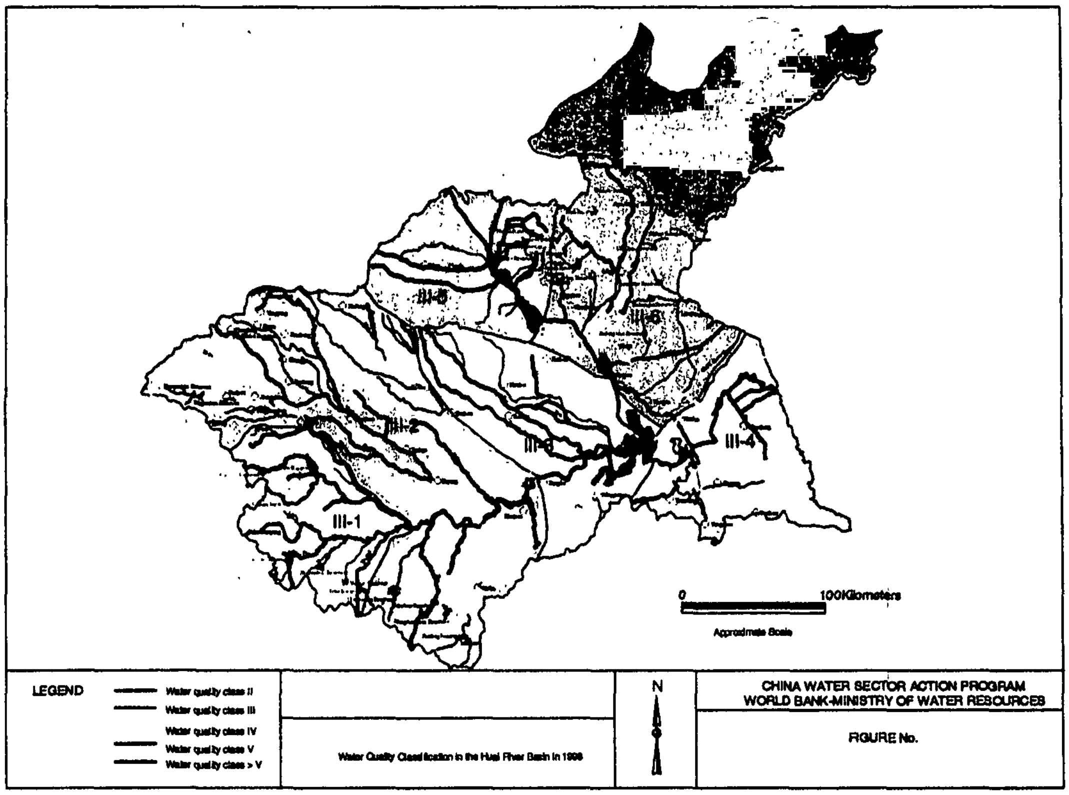


FIGURE 3.5: POLLUTION SOURCES IN THE HAI AND HUAI BASINS

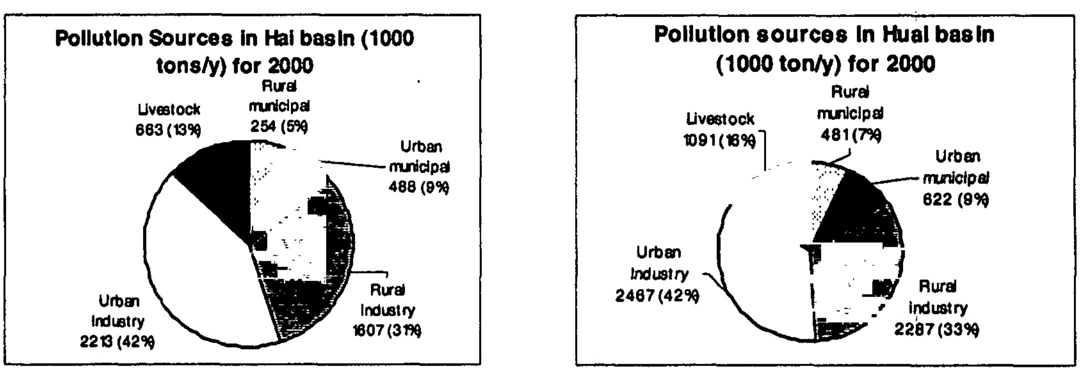


FIGURE 3.6: COD LOAD PERCENTAGE BY VARIOUS INDUSTRIES IN HAI BASIN (1995)

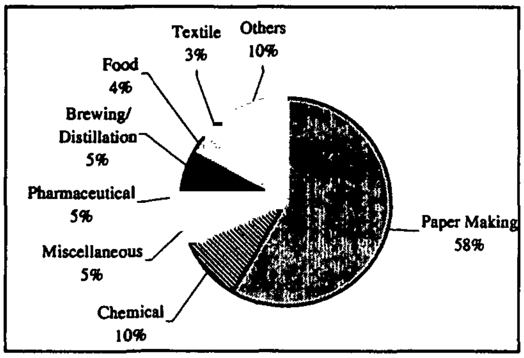
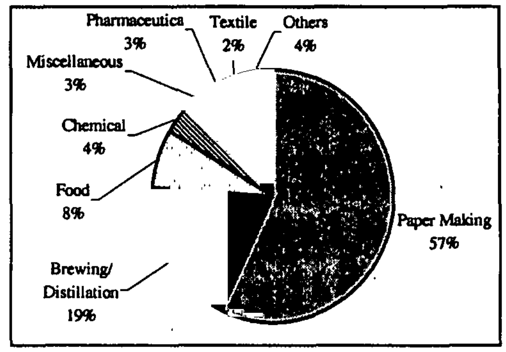


FIGURE 3.7: COD LOADS PERCENTAGES OF VARIOUS INDUSTRIES IN HUAI BASIN (1997)



- Major rural sources are shown in Table 3.24 MR, including contributions from livestock and from TVEs. The number of rural TVEs in the 3-H basins is estimated to be around 9.56 million as shown in Table 3.25 MR. Types of TVEs include (a) nonmetal (21 percent); (b) food and drink (8 percent); (c) textile (6 percent); (d) unnamed (may include paper) 36 percent; (e) mechanical (3 percent); (f) chemical (2 percent); and (g) metal (4 percent). Nearly half of China's TVEs are in the 3-H basin. In 1997, the government issued regulations controlling TVEs in terms of numbers and type of production, and proposed improved planning rules for TVE "industrial parks" to help control wastewater. The success of these regulations is difficult to gauge because of their relatively recent implementation but, in principle, the laws make a lot of sense despite some unrealistic time frames which decree that by 2000, TVEs would not exceed prescribed standards. The current situation with regards to TVEs is that their contribution to water pollution varies in different provinces or even counties, but that in aggregate they represent a major threat to water quality, especially in the floodplain provinces of the 3-H basins such as Shandong, Anhui, Hebei and Henan.

- The study on rural pollution sources includes evaluation of rural household water supply and sanitation practices, including (a) health hazards as well as sources of COD, for various types of excreta management including dry latrines and pour-flush toilet and pit systems, and (b) pollution contributions from inattention to solid waste management.

The WPM-DSS model also identified the major cities in the Hai and Huai basins that produce COD loads from municipal and industry sources. Cities producing toxic COD loads were also identified. Figures 3.8 and 3.9 show WPM-DSS results.

The study identified that there are a few cities that contribute most of the pollution loads in the basins. For example, in the Hai Basin, six cities contribute 50 percent of the pollution load and some 36 cities contribute 95 percent of the pollution load. This has clear implications for the action plan in terms of prioritizing key cities to focus pollution control activities (see Figure 3.10 below).

FIGURE 3.8: 2000 COD POLLUTION LOADS FOR PRIORITY CITIES IN THE HAI BASIN UNDER THE BASE CASE

(tons/day)

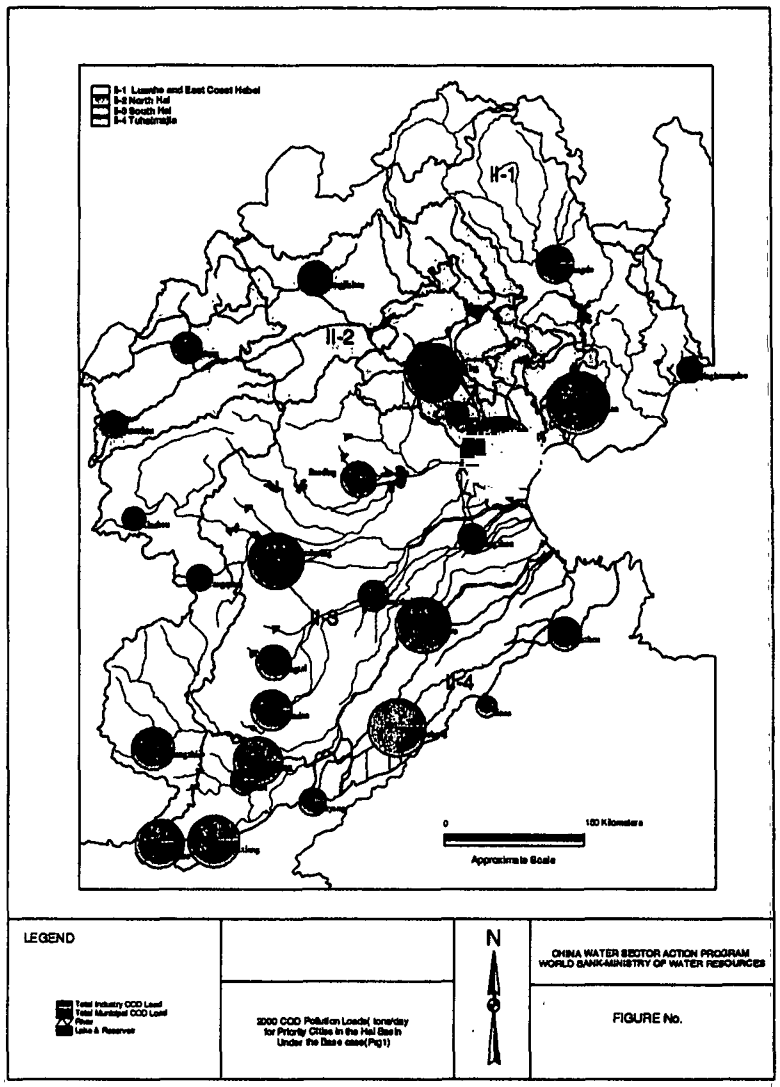


FIGURE 3.9: 2000 TOXIC COD POLLUTION LOADS FOR PRIORITY CITIES IN THE HAI BASIN UNDER THE BASE CASE
(tons/day)

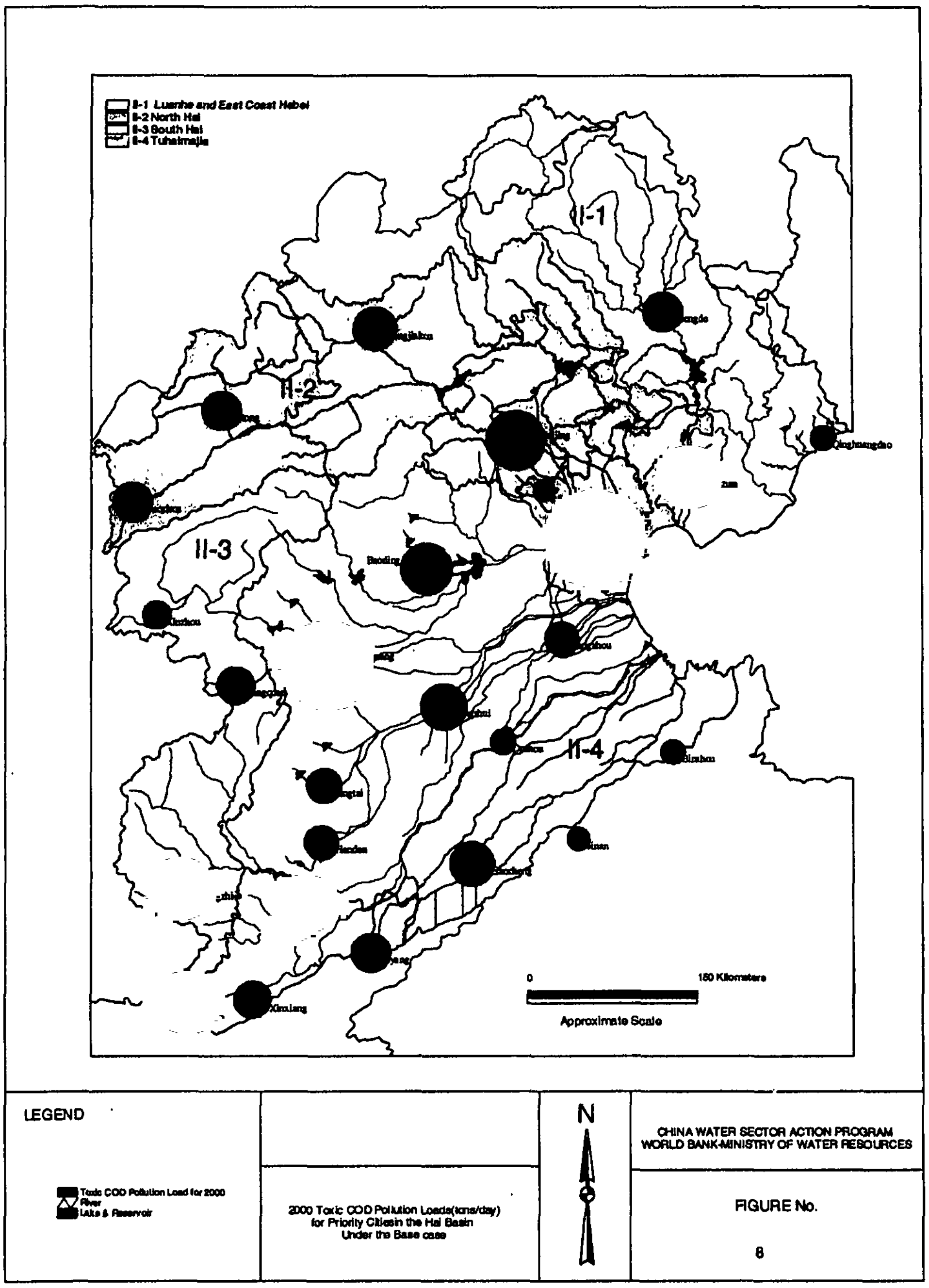
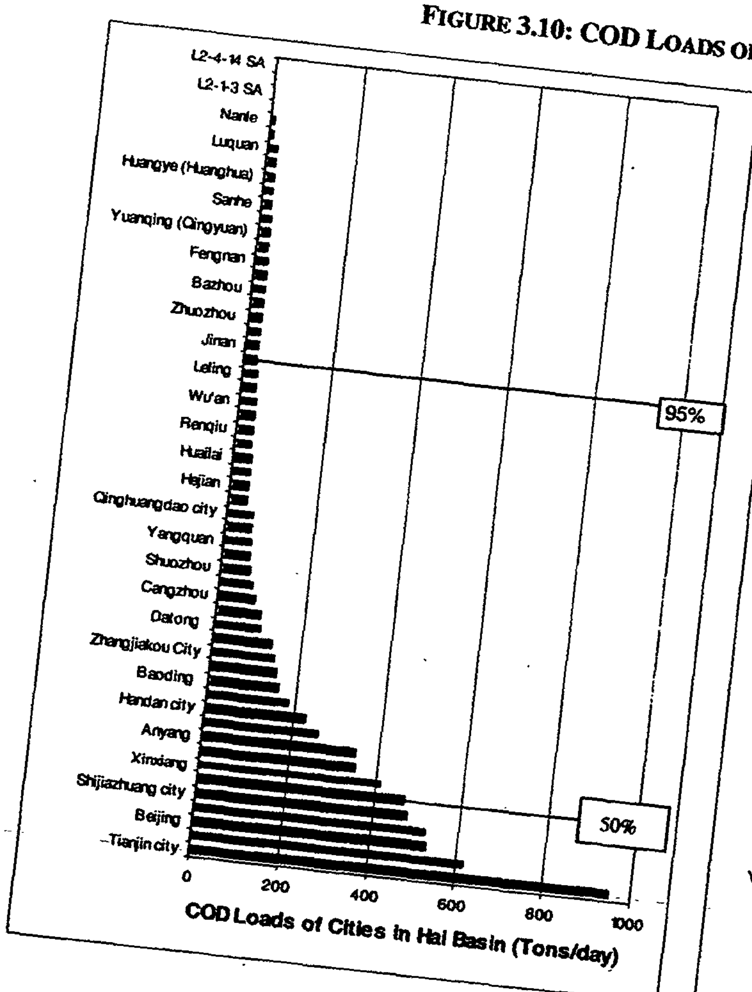
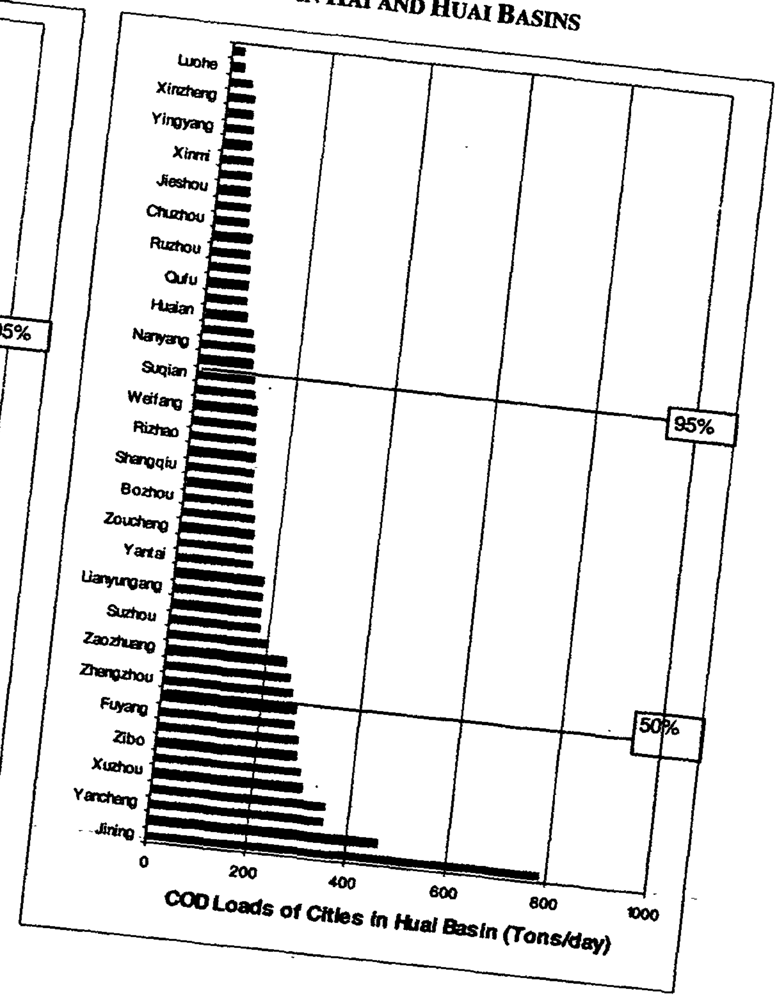


FIGURE 3.10: COD LOADS OF PRIORITY CITIES IN HAI AND HUAI BASINS





G. DEPLETED GROUNDWATER RESOURCES

Introduction

When compared to total water resources in the Hai, Huai and Yellow basins, groundwater represents 48, 38 and 35 percent, respectively, of total water resources compared to 19 percent for the rest of China. This highlights the relative importance of groundwater in the 3-H basins. Table 3.8 shows groundwater resources in basins in China.

The aquifers containing valuable groundwater can be divided into (a) mountain and plains, and (b) shallow and deep aquifers. The deeper aquifers contain better-quality water and are recharged by horizontal processes, while the shallow aquifers with generally higher salinity (especially in coastal areas) are recharged by infiltration of rainfall from directly above.

TABLE 3.8: LONG-TERM MEAN GROUNDWATER RESOURCES OF THE BASINS IN CHINA (Bcm)

	Basins	Mountainous area	Plain area	Repeat calculated	Total	% of Total
1	Songhua-Liao River	31.9	33.0	2.4	62.5	7.6
2	Hai River	12.5	17.8	3.8	26.5	3.2
3	Huai River	10.7	29.7	1.1	39.3	4.7
4	Yellow River	29.2	15.7	4.3	40.6	4.9
5	Yangtze River	221.8	26.1	1.5	246.4	29.7
6	Pearl River	102.8	9.3	0.5	111.6	13.5
7	Southeast rivers	56.2	5.2	0.1	61.3	7.4
8	West-east rivers	154.4			154.4	18.6
9	Inland rivers	56.7	50.6	21.1	86.2	10.4
	Total	676.2	187.4	34.8	828.8	

Repeat Calculated = groundwater flow from mountainous area to plain area (i.e., double counted).

Major Groundwater Problems in 3-H Basins

The physical evidence of unsustainable groundwater use in 3-H basins is obvious and simple: falling groundwater and pressure levels. This phenomenon has been occurring in many areas in the 3-H basins, especially the Hai Plains. Figure 3.11 shows that in some areas, shallow groundwater level differences between 1958 and 1998 are up to 50 meters while deep groundwater-level differences in the same period are up to 90 meters. This occurs in very isolated areas but there are still vast areas where the water levels in the aquifers have dropped 50 meters. In Volume 3, Annex 3.2, Table A3.2-5 shows the severity of falling shallow and deep groundwater levels for major cities in the 3-H basins. The worst affected cities include Shangqiu, Zibo, Zhumadian, Zhengzhou, Xuzhou, Suxian, Heze, Qingdao, Kinyi and Jining. The sustainability of groundwater resources in the 3-H area is shown in Table 3.9. Ratios greater than 1 indicate unsustainable use.

Falling groundwater levels due to overpumping cause (a) water quality degradation, (b) seawater intrusion and (c) ground subsidence. Groundwater quality degradation refers to the migration of poorer quality groundwater into good-quality aquifers. By a similar process, seawater intrusion in coastal aquifers is common in some 72 coastal areas, including the major cities of Dalian, Qinhuangdao, and Laizhou (Table 3.28 MR).

Pollution is another major problem affecting groundwater in the 3-H basins. Shallow groundwater is particularly at risk from contamination by nonpoint-source pollutants used in agriculture, including fertilizer and pesticides. Other processes that cause shallow groundwater pollution include point-source contamination from municipalities and towns, industries, TVEs and livestock operations. Volume 3, Annex 3.2, Table A3.2-3 shows depreciation in groundwater quality for different cities in the 3-H basins.

FIGURE 3.11: DIFFERENCE BETWEEN SHALLOW GROUNDWATER LEVELS IN 1958 AND 1998 IN THE HAI BASIN PLAINS

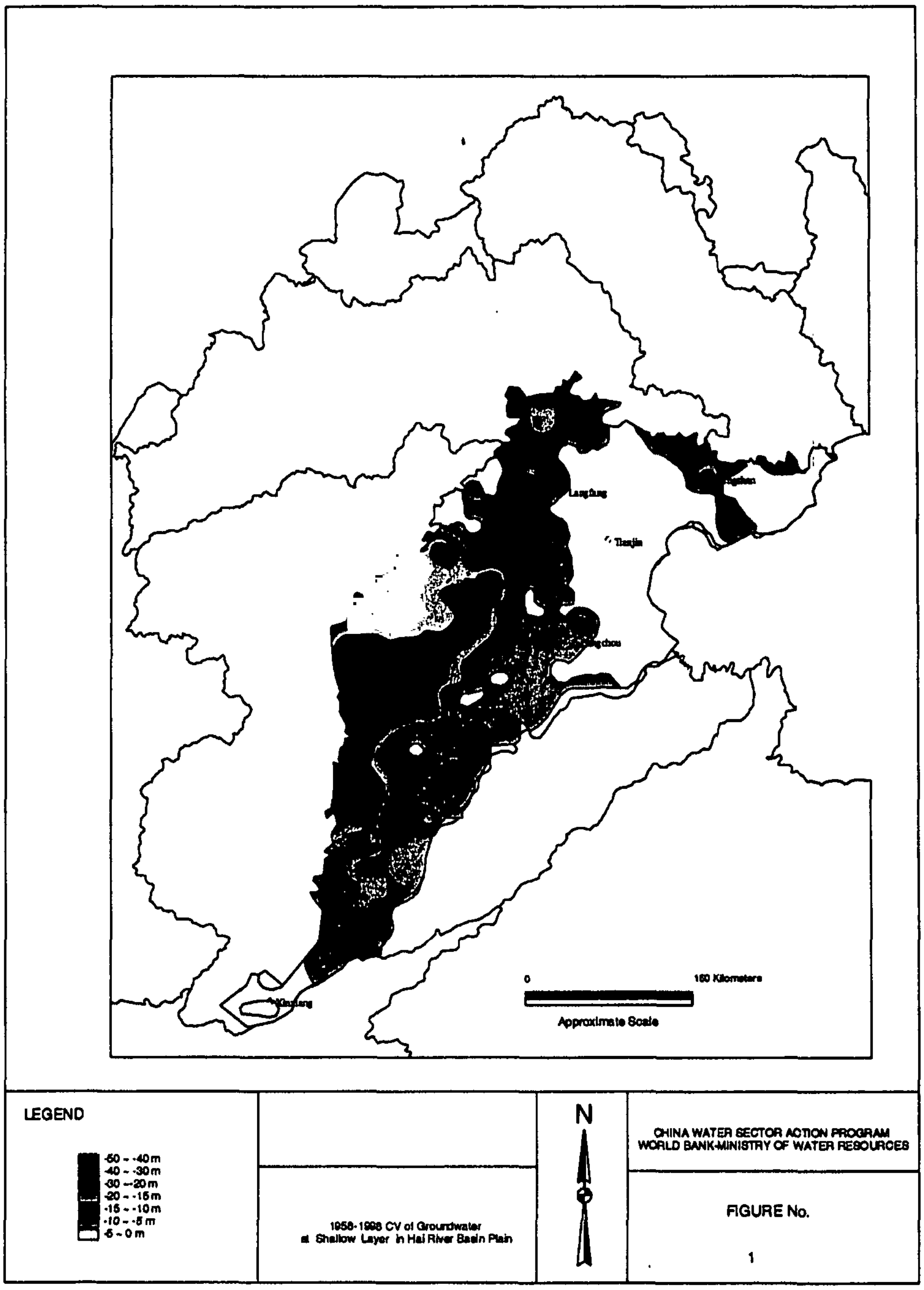


TABLE 3.9: GROUNDWATER RESOURCES AND USE IN 3-H AREAS
(Mcm)

River Basin	No.	Subarea	Exploitable fresh groundwater	Use of groundwater in 1997	Use/exploitable for 1997
Hai Basin	2-1	Luanhe and East Hebei coastal area	1,238	1,494	1.21
	2-2	Hai river north system	3,227	5,667	1.76
	2-3	Hai river south system	9,791	15,953	1.63
	2-4	Tuhai and Majia river system	3,036	4,254	1.40
	2	Basin total (or average)	17,292	27,368	1.58
Huai Basin	3-1	Upper area of Wangjiaba lake	2,272	1,693	0.75
	3-2	Between Wang and Beng area	6,639	6,787	1.02
	3-3	Between Bang and Hong lake	3,031	914	0.30
	3-4	Lower reaches of Huai river	1,765	591	0.33
	3-5	Southern four lakes area	3,620	3,051	0.84
	3-6	Yi and Shu river	2,590	1,392	0.54
	3-7	Shandong peninsula	4,071	4,011	0.98
	3	Basin total (or average)	23,988	18,439	0.77
Yellow Basin	4-1	Between the river source and Lonyang gorge	Uncalculated	22	Uncalculated
	4-2	Between Lonyang gorge and Lanzhou city	878	508	0.58
	4-3	Between Lanzhou and Hekou	3,201	4,020	1.26
	4-4	Between Hekou and Longmen	1,304	1,031	0.79
	4-5	Between Longmen and Sanmen gorge	6,841	5,093	0.74
	4-6	Between Sanmen gorge and Huayuankou	2,076	1,066	0.51
	4-7	Downstream of Huanyuankou	3,127	2,028	0.65
	4-8	Inland area	815	106	0.13
	4	Basin total (or average)	18,242	13,874	0.76
Total			59,522	59,681	1.003

Ground subsidence is one of the most costly and dangerous effects of overpumping. Whole areas of Tianjin and Beijing suffer from subsidence causing settlement of structures, bridge collapse, stormwater drainage problems, and reduction in flood protection. Other cities affected by this problem include Taiyuan, Shijiazhuang, and Shanghai.

Current Groundwater Management

As for surface waters, there are the same conflicts between the national and the provincial and local agencies in terms of controlling usage and pollution of groundwater. In addition, people need groundwater to sustain their income and to maintain their quality of life; local government officials cannot deny the population this basic right.

The allocation mechanisms and licensing of groundwater extraction relies on a permit system administered by local bureaus that requires individuals who plan to use groundwater to disclose standard information such as (a) duration of extraction, (b) water use objectives, (c) allowable water volumes, (d) location, (e) means of extraction, and so forth. Having considered existing water allocation commitments as described above, the local bureaus would study the individual's application and accept, modify or refuse the application.

Due to a large population, heavy dependence on irrigation in agriculture and fast industrialization, groundwater management has become an urgent matter. The major issues arising with current groundwater management include (a) possible interference in the planning process from realities of economic development and the need to find some water, (b) multiple responsibilities by different government agencies, and (c) insufficient monitoring of both groundwater extraction and groundwater quality. These factors prevent the application of an effective groundwater management program needed as part of a competent water management system for basins overall.

H. PRESENT SITUATION ON WATER SECTOR MANAGEMENT

Introduction

Water has played a pivotal role in promoting the development of the Chinese economy. Because of difficult climatic and topographic conditions, water resource management has always had to rely heavily on engineering structures for flood control, power, irrigation, municipal and industry supplies, and navigation for grain transport and other goods. Uncontrolled water in the form of flooding and in recent decades waterlogging have also been China's great tragedies, causing untold damage to the economy. More recently, uncontrolled wastewater discharge is also challenging economic growth although this is more difficult to quantify.

The key unresolved issues that have to be addressed, for achieving the desired integrated 3-H strategy-development plan, include those of flooding, water pollution control, and adequate institutional and financing mechanics. These issues are discussed in detail in later chapters.

The establishment of MWR in 1949 was a major step by the government in recognizing the importance of water management, but MWR's charter focused on flood control and irrigation. Recognition of the need for more integrated management resulted in adoption of five new important laws, namely (a) the 1984 Water Pollution Control Law (revised in 1996), (b) the 1988 Water Law (reviewed in 1999), (c) the 1989 Environmental Protection Law, (d) the 1991 Water and Soil Conservation Law, and (e) the 1997 Flood Control Law. Of these, the 1988 Water Law is the fundamental "umbrella" law for water management, with MWR designated to implement the law. Seven interprovincial basin commissions have been created within MWR and numerous organizational initiatives have been taken at national, provincial and local levels. The 1988 government reorganization included the consolidation of authority for water matters within MWR. The growth in ability of provincial and local governments to arrange their own financing for many projects (outside MWR control), however, has compounded the integration problem. It is critical to move ahead with new legislation as needed to achieve the desired integrated Action Plan for the 3-H basins and for most other river basins in China.

Key Findings

Chapter 3 Section H in the Main Report discusses these issues in considerable detail, with key findings as follows:

- According to the official government structure, departments and bureaus of water conservancies at the provincial levels and water conservancy stations and water user associations at the community level are vertically integrated with MWR. They also report to and depend on the provincial governments, especially in relation to administration of laws and importantly for funding. In the case of bureaus at the local government levels in the water sector, the line of responsibility for functions lies clearly with the ministries. But because the bureaus are employees of the provincial or county governments, the focus of their activities remains with the provincial or county governments; thus management planning activities may be scaled or modified to suit local government imperatives.. As a result, well-meaning principles (such as water allocation based on watershed or polluter-pays principles) are increasingly in conflict with the economic interests of the provinces. Administrative bodies (whose financial viability depends on provincial budgets) empowered by the laws to enforce rules and regulations at the local level (such as water bureaus) are often under pressure to act in the interest of the local government to the detriment of sound overall water or environmental resource management and planning. Thus, vertical relationships between ministries, departments, bureaus, and so on, have been challenged by stronger alliances between the local governments and these local administrative bodies.

- Considerable overlap exists between the different ministries and inconsistent and fragmented responsibilities are a major issue. While the primary legislation discussed above calls for integrated and comprehensive management, in practice different ministries and agencies are primarily responsible for implementation of specific acts of legislation, and inconsistencies and conflicts arise between different agencies in the exercise of their respective mandates. In addition, as competition has intensified between provinces due to (a) increasing economic activity, (b) population growth, and (c) new imperatives of regional responsibility systems, local governments have had to acquire de facto planning and management rights of natural resource to sustain economic growth. Thus, micro-planning and management at provincial and local levels limited by administrative boundaries is the current reality in the water sector.

- While river basin commissions (RBCMs) have been established pursuant to the Water Law, the RBCMs are commissions only in name, having no separate governing board or corporate status. The RBCMs are agencies of MWR and perform those functions that MWR delegates to them. It is difficult for the RBCMs to enforce provisions of basin plans on other sector ministries and provincial governments, and the functions that they perform overlap with activities undertaken at the provincial and local levels. In principle, RBCMs prepare basin development and operating plans in full consultation with the provinces, sectoral ministries and other stakeholders. In practice, there are few formal consultation mechanisms, and the main directives and decisions affecting RBCM activities are received vertically from MWR.

I. Investment in the Water Sector and Private Sector Participation

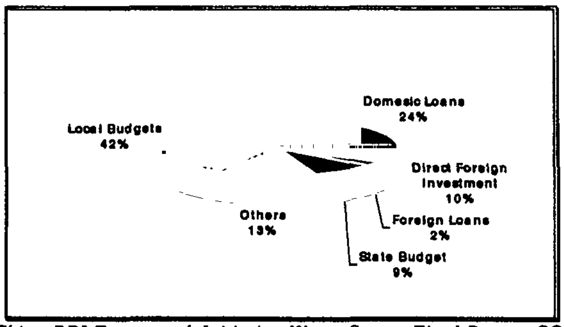
Investment in water resource projects as a percentage of total national investment rose from 2.1 percent in 1950 to 5.2 percent in the 1958-79 period and then declined back to 2.5 percent in the 1985-90 period, highlighting a rise in activity in the late 1950s lasting for about 20 years.

Typically, funding for investment in water sector projects has been derived from four main sources. These include (a) national government capital investment, for large-scale projects, (b) national and provincial/municipal governments in partnership, subsidizing operation and maintenance (O&M) costs[3] for irrigation and drainage, flood control and waterlogging, soil conservation, rural and urban drinking water supply and wastewater treatment (the extent and continuity of this funding depends on the government's financial position), (c) special funds allocated by the national government for special economic and poverty programs that fluctuate in accordance with national government policy, and (d) cost sharing and labor contributions by beneficiaries for smaller-scale water projects.

Traditional funding mechanisms from government sources suffer from important drawbacks relating, first, to the lack of accountability of the decisionmakers and, second, to the fluctuating political and financial position of the government. Private sector investment on the other hand is independent of the political and financial status of the government and would be more efficient because of market-based decision-making. In addition, foreign and Chinese private investment can mobilize funds and technology that may not be available to the government. Foreign investment in capital construction projects in China for 1998 is shown in Figure 3.12 below (based on data from the *China Statistical Yearbook 1999*).

[3] O&M includes staff salaries, traveling fees, meeting and office expenditures as well as larger-scale repair/overhauls, rehabilitation and reconstruction costs.

FIGURE 3.12: SOURCE OF FUNDS FOR CAPITAL CONSTRUCTION PROJECTS, 1998



Source: China PPI Framework Initiative-Water Sector Final Report, SOGREAH.

Private and public sector participation in infrastructure (PPI) in the Chinese water sector is important because it can facilitate (a) the injection of capital investment; (b) the optimization of operating capital expenditures; (c) the introduction of new technology; (d) the improvement of customer services; (e) the insulation of public services from short-term political changes; (f) the reduction or redirection of public subsidies; (g) the reduction of payrolls; and so forth.

Many different forms of private sector participation are being experimented with, ranking from operation and management contracts, to municipal and joint build-operate-transfer (BOT) ventures, to concessions. In addition, the degree of municipal ownership further distinguishes ventures in China (see Figure 3.18 MR). The majority of contracts in existence today in China are BOT type below US$30 million, which do not require State Development Planning Commission (SDPC) approval. Table 3.35 MR summarizes some advantages and disadvantages of the various private sector participation schemes in operation in China today.

However, the role of PPI as a financing vehicle has been limited up to now (see Table 3.34 MR) and accounted for only 4 percent of total water supply investment between 1992 and 1998 (7.5 percent prior to 1997 and 3 percent thereafter, probably due to lower investor confidence from the Asian financial crisis).

The major issues facing increased PPI in water supply include:

- Low water and wastewater tariffs;
- The need to improve local operator knowledge of water and wastewater treatment, operator knowledge and transparency of fixed asset valuation, depreciation techniques, and international accounting and reporting methods;
- Institutional problems that impact on investment and on management of infrastructure, including decentralization, multiple ministerial responsibilities, and investment decisions that focus on new infrastructure rather than maintenance;
- Inconsistent implementation of the water law and other relevant laws;
- Existing laws in relation to foreign direct investment that (a) prohibit foreign investment in water supply, drainage, gas, and heat power supply networks in urban areas; (b) specify BOT projects as experimental, that is, allows foreign involvement in water and wastewater treatment; and (c) possibly allow foreign involvement in conveyance systems. The effect of these decrees is to

effectively limit foreign investment.[4] In the case of wastewater treatment, the lack of a clear tariff is the major impediment. In addition, limited opportunities currently exist for local operators to improve their knowledge on how to operate water treatment or wastewater treatment plants effectively, by exposure to foreign expertise.

- Financial issues include (a) the inability of foreign enterprises to borrow in renminbi; (b) inadequate credit support; (c) the small size of water projects to attract financiers who have little interest in projects under US$100 million; and (d) the desire to limit returns on investment to between 10 and 12 percent through misinterpretation of the new tariff regulations.

- Lack of independent regulators. Currently the responsibility rests with the Price Bureaus, and these entities have more concern for inflation and social issues than for efficient service delivery.

[4] Water treatment represents only about 30 percent of capital expenditure and 20 percent of operating costs.

4. SUFFICIENT WATER FOR ALL

A. Introduction

Next to controlling the damage from floods, the primary concern of Chinese water authorities has been the provision of water supplies in quantities sufficient to sustain human life, permit continuing growth in the industrial sector, and maintain an adequate supply of food production. Over the past several decades, these objectives have been increasingly difficult to meet in much of the 3-H region. As was shown in Chapter 3, withdrawals for consumption have probably reached their maximum levels and current levels of consumptive use (the sum of beneficial consumption and irrevocable losses) within 3-H basins are undoubtedly unsustainable because of increasing overmining of groundwater and increasing damage to economics and ecology in the lower river reaches. In order to understand the dynamics of supply-demand balances, and assist in planning to minimize the impacts of future imbalances, various institutions have projected water demand into the future, tabulated the likely increases in water supply forthcoming from water sector projects, and suggested ways to deal with probable future shortages.

Chapter 4 evaluates the parameters involved in the dynamics of supply versus demand, in order to determine feasible options for balancing supply and demand to enable continuing sustainable development.

B. Water Demand Projections

Introduction

Review of water supply demand projections for the 3-H basins shows that future demands cannot be met within the limits of sustainable withdrawals unless the price of water would increase from low and sometimes subsidized levels to levels that reflect the full cost of supply. This shows that household and municipal demands would be about 18.5 Bcm, rural life and industry demands 15.8 Bcm, and industrial demands 33.1 Bcm, totaling 67.4 Bcm for these three sectors by 2050, compared to the 1997 total of 32.8 Bcm. (For details of water demand by sectors and supply by sources under different runoff probabilities, see Annex 4.1, Volume 3.)

Earlier Estimates of Future Water Demands

Estimates of future 3-H water demands to 2050, covering a series of studies by different agencies made over the period from 1992 to 1999, were summarized (Table 4.1 MR). The two striking aspects of these studies are (a) all of the projections much exceed likely future sustainable supply (which would be around 140 Bcm/year as noted later), but (b) in recognition of this problem each successive study came up with a lesser total demand (but still well above the sustainable withdrawal limit).

Reviews were made for each of these studies in detail, in order to delineate the "lessons learned" to serve as the basis for preparing an updated projection as part of the present study. The most important of these are the following:

- The Irrigation and Power Planning Design Institute (IPPDI) 1992 study was the first comprehensive evaluation of supply and demand for the 3-H basins. However, it did not consider price, impacts on water demand, and did not distinguish between "withdrawals" and "consumptive use." The estimates on industrial growth were much too low (hence industry has since had to make do with increasingly smaller unit supplies) and agricultural production increased markedly despite the lack of supply.

- With respect to the IWHR/1993 study, both urbanization and industrialization expanded rapidly but with lesser withdrawals than predicted, and agricultural production increased markedly without significant change in withdrawals, probable due to increase in water price since about 1993 and recognition that the actually available supply limitation is much below projected demand.

- The IWHR studies were updated in 1999, as part of the present study and assisted by the study consultant, based on the government's stated objective of increasing water prices to reflect full costs of supply.

Analytical Approach for Water Resources and Model Assumptions

The analysis of water resources seeks to define a perspective plan for policy recommendations and investments in the water sector of the 3-H basins over the next 50 years. In doing so, it is critically important that the program should be based on a quantitatively consistent picture of future water supplies and demands. The review of the previous studies presented above showed that the current approach could not produce realistic and consistent sets of demands from which to calculated supplies.

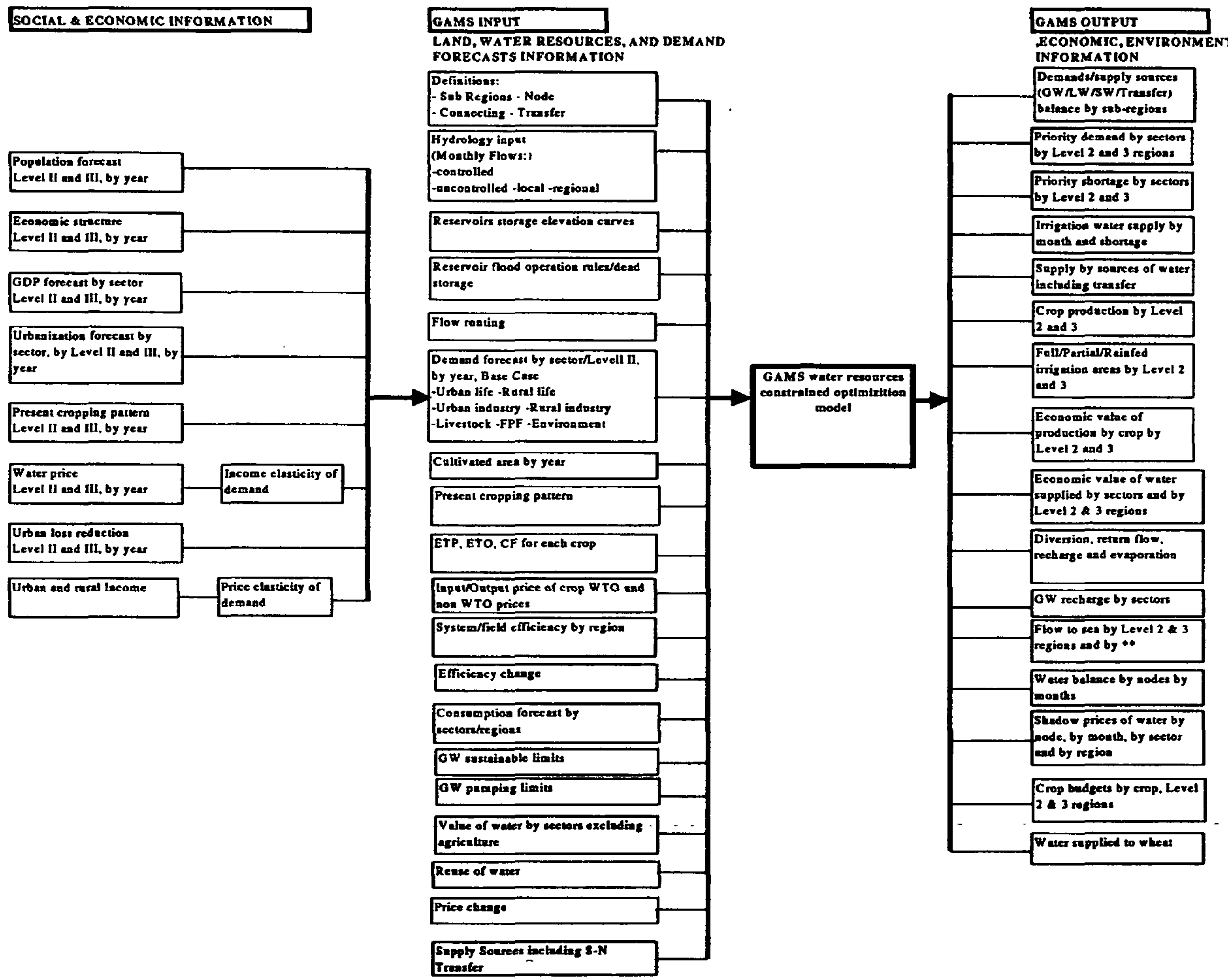
This picture is complex because of a high degree of uncertainty in determining (a) surface water runoff, (b) sustainable groundwater resources, (c) usability of polluted water for consumption, (d) the efficiency of the water storage, allocation and delivery system, (e) future water prices and water demands for different sectors, and (f) the future structure of the north China economy.

Partial analyses (for example, spreadsheet) have limited value in such exercises because they cannot take into account simultaneously (a) the interaction of the numerous elements comprising a water system, and (b) they have no "guiding hand" to steer the results toward some "best" outcome. Simulation models are far more useful where uncertainty is prevalent. Thus they are particularly relevant to water sector analysis. However, their results depend on built-in decision rules that do not necessarily produce an optimum solution (from the economic perspective). Nor do they have the ability to produce marginal valuations (shadow prices) of key resources.

In this study, a constrained optimization approach is pursued for the basin-level models because it is assumed that the relevant Chinese authorities wish to obtain maximum economic benefit from the operation of the system as well as to maximize the returns to investments in the system, subject to a variety of hydrological, physical, and agronomic constraints. Additional constraints related to equity or distributional issues can be imposed. A linear programming (LP) structure is employed because it the most common and most efficient means of solving linear models, and permits the attainment of the optimum economic solution.

The main groups of data fields used in the 3-H basin Modeling System are presented in Figure 4.1. Important aspects of water demand and supply are discussed in the following sections.

FIGURE 4.1: WATER RESOURCES CONSTRAINED OPTIMIZATION MODEL



Present and Projected Estimates of Demand

The present study, utilizing the most advanced modeling techniques and a series of substudies, prepared updated estimates of future water demand, taking into account the new pricing policy and recognition of the limits of the total available 3-H supply. The results of the substudies are summarized in a series of table:, (a) future price and price growth rates used to derive water demand projections (Table 4.5 MR), (b) price elasticity of demand (Table 4.6 MR), (c) income elasticity of demand (Table 4.7 MR), (d) demand structure for different sectors (Table 4.8 MR), (e) water consumption for urban and domestic and rural households (Table 4.9 MR), (f) projected irrigation demand for Hai, Huai, and Yellow river basins (Table 4.10 MR), (g) assumptions of GDP prices and growth for demand consumption (Table 4.11 MR), and (h) water demand sensitivities (Table 4.12 MR), plus Figure 4.1 MR on changes in proportion of total demand for different sectors. The significant findings of the substudies are given below. Note that these results are inputs into the 3-H modeling system (3-HMS) described above (see Figure 4.1)

(a) Future Economic Growth Structure. Projections by the WB, and independent analysis in this study, concur that by 2020, agriculture in China would be contributing about 7 percent of GDP, compared to about 20 percent in 1998. Projections to the year 2050 made for this report show that by 2050, the share of GDP from agriculture would have declined to 4 percent (see Table 2.2 MR). Similarly, agriculture's GDP share in the Yellow, Hai and Huai River basins would have fallen to the 3-to-6 percent range. In all basins, and throughout China, services would dominate GDP, accounting for 55 to 65 percent of the total. In sum, the economies of these regions and of all of China would be very different from what they are today. Instead of half or more their labor force in agriculture, they would have only roughly 10 to 15 percent. Furthermore, with the exception of the Huai River Basin, these populations would be largely urban. For all regions, 60 to 80 percent of GDP would be produced in urban areas. Overall, China's expected healthy growth and normal structural changes indicate a very different economic environment in 2050 than that at the turn of the century. These changes form the backdrop for understanding expected changes in volumes and patterns of water usage. The key results are (a) strong development would continue in both industry and agriculture, which would require a strong service sector, (b) industrial and domestic demands would continue to dominate overall water use, with agricultural withdrawals continuing to decline in the next several decades, and (c) most important, future pricing policies (relating to future income) together with population would be the key parameters for determining future demand estimates.

(b) Household Response to Price and Income Changes. The demand projections utilized a generalized demand model that has proven to be very reliable in forecasting impacts of price and income changes on water demand in developing countries, including testing against time series data for a number of cities in China. Income elasticity of demand for domestic water diminishes as household incomes increase (Tables 4.5, 4.6, 4.7 MR).

(c) Industry Response to GDP and Price Changes. While there is a limit to how much water a household can consume, industries, and commercial enterprises can consume very large amounts of water, and do consume large amounts when the price is very low but usage is quite sensitive to rising prices. The marginal value of water in industrial production varies among sectors with an average of Y 5/m^3. Average price elasticity of industrial water demand was estimated to be about −1.2, and income elasticities were estimated to range around 0.2.

(d) Agricultural Response to Price Change. With respect to the price of water supplied to agriculture, while there has been much government policy discussion about raising prices to cover the costs of O&M since the 1960s, current prices still hover around Y 0.01/m^3 to Y 0.20/m^3. As part of the present study a farm modeling methodology was developed to provide a basis for analyzing the impact of increasing the price of irrigation water on water use. The results show that on a per hectare (or per mu) basis, increasing the price per cubic meter beyond, say, Y 0.15/m^3, would reduce consumption per unit area, provided the price is clearly related to the quantity used by the farmer, and if the price signal is not distorted by other charges lumped on the farmer. For prices up to Y 0.15/m^3, however, the response in water demand may be negligible.

Future Demand by Sectors

- **Overall Demand**: Based on the economic and social parameters described above, the study produced demand projections for the 3-H basins from 1997 to 2050 for the P75 year (3 out of 4 years), for different sectors including urban life and industry, rural life and industry, and agriculture (comprising irrigation, livestock, fisheries, and pastures and forestry) (Table 4.1).

TABLE 4.1: DEMAND STRUCTURE FOR DIFFERENT SECTORS FOR P75 YEAR (Bcm)

	Demand Structure 75% Probability							Growth Structure (%)			
	1997	2000	2010	2020	2030	2040	2050	2000	2030	2050	
Hai Basin											
Urban Life	2.61	2.90	3.85	4.87	5.82	6.69	7.49	6	10	13	
Urban Industry	5.28	5.68	6.78	7.49	7.84	7.90	7.92	11	14	14	
Rural Life	1.84	1.84	2.00	2.12	2.21	2.11	2.02	4	4	3	
Rural Industry	1.35	1.50	1.88	2.12	2.19	2.24	2.28	3	4	4	
Irrigation	37.48	37.55	37.83	38.13	38.13	38.13	38.13	75	67	65	
Livestock	0.48	0.54	0.54	0.53	0.52	0.50	0.47	1	1	1	
Fisheries/ Pasture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0	
Total	49.05	50.00	52.87	55.26	56.71	57.57	58.30	100	100	100	
Huai Basin											
Urban Life	2.40	2.52	3.24	4.20	5.04	6.00	6.96	4	4	5	
Urban Industry	7.68	8.64	12.00	14.52	15.12	14.76	14.64	12	16	18	
Rural Life	2.40	2.40	2.54	2.64	2.74	2.80	2.88	3	3	3	
Rural Industry	1.68	2.28	2.88	3.60	4.08	4.20	4.68	3	4	4	
Irrigation	51.21	51.18	51.40	51.40	51.40	51.40	51.40	71	66	63	
Livestock	1.08	1.08	1.08	1.20	1.44	1.44	1.68	2	1	1	
Fisheries/ Pasture	3.10	3.80	4.20	4.50	4.80	4.80	4.80	5	5	5	
Total	69.55	71.90	77.34	82.06	84.62	85.40	87.04	100	100	100	
Yellow Basin											
Urban Life	1.48	1.62	2.10	2.60	3.10	3.61	4.07	3	4	5	
Urban Industry	5.21	5.80	7.67	9.39	10.28	10.63	10.56	12	15	17	
Rural Life	1.16	1.05	1.15	1.30	1.32	1.45	1.53	2	2	2	
Rural Industry	0.69	0.82	1.21	1.65	2.00	2.24	2.44	2	2	3	
Irrigation	35.70	35.45	35.67	35.75	35.75	35.75	35.75	76	70	66	
Livestock	0.46	0.53	0.58	0.68	0.79	0.89	0.99	1	1	1	
Fisheries/ Pasture	1.25	1.59	2.27	3.04	3.04	3.04	3.04	3	4	6	
Total	45.95	46.86	50.65	54.41	56.28	57.61	58.38	100	100	100	
	Total Demand 75% Probability							Growth Rates (%)			
3-H Basin	1997	2000	2010	2020	2030	2040	2050	"2000-2010"	"2010-2030"	"2030-2050"	"2050-1997"
Urban Life	6.49	7.04	9.19	11.67	13.96	16.30	18.52	2.70	2.11	1.42	2.00
Urban Industry	18.17	20.12	26.45	31.40	33.24	33.29	33.12	2.77	1.15	-0.02	1.14
Rural Life	5.40	5.29	5.69	6.06	6.27	6.36	6.43	0.73	0.48	0.12	0.33
Rural Industry	3.72	4.60	5.97	7.37	8.27	8.68	9.40	2.63	1.64	0.65	1.76
Irrigation	124.39	124.18	124.90	125.28	125.28	125.28	125.28	0.06	0.02	0.00	0.01
Livestock	2.02	2.15	2.20	2.41	2.75	2.83	3.14	0.23	1.13	0.66	0.84
Fisheries/ Pasture	4.35	5.39	6.47	7.54	7.84	7.84	7.84	1.84	0.96	0.00	1.12
Total	164.55	168.76	180.86	191.73	197.61	200.58	203.72	0.69	0.44	0.15	0.40

- **Urban/Rural Domestic Consumption**: Total domestic consumption includes institutional consumption plus households plus losses (Table 4.9 MR). In the coming decades household consumption would become the more important proportion of the total domestic consumption, and, as water prices increase, losses would become lower as well. Overall, the water consumption by urban domestic consumers would nearly triple from 6.5 Bcm to 18.5 Bcm a year in the 3-H basins. However, as for other sectors, the rate of growth would continue to decline but still remain higher than other sectors in the case of urban life.

- **Rural Industry**: Rural industry demands were estimated based on parameters similar to those for urban industry (Table 4.9 MR).

- **Agricultural Demands**: The demands for agriculture water were calculated using a different approach than for industry or household demands (Table 4.10 MR). Water supply to agriculture is very low relative to demand and so it is difficult to estimate the response to supply because the usage of water is well below the demand curve and the use of water is dictated more by shortage management than by price. The projections of net and gross monthly irrigation water demand in Bcm were calculated from the 3-H modeling system (described above) which includes the parameters of irrigation areas (rainfed and irrigated), cropping patterns, crop water requirements, irrigation efficiency factors, crop prices, value of irrigation water, and rainfed probabilities. The model optimizes crop area grown and resulting yield of crops in order to maximize the value of irrigation water. The result show that agriculture's share of total demand would decline from about 70-77 percent to 65 percent in the 3-H basins, but the actual demand would remain static around 125 Bcm a year.

Demand Sensitivity to Social and Economic Changes. The existing studies project only to about year 2020, and to make further projections the present study used a growth forecast which stretched to 2050 in order to map out a long-term planning horizon sufficient to guide investment due to the long-term nature of strategic planning in the water resource sector. This is especially the case with respect to large infrastructure projects such as south-north (S-N) transfer and the wastewater treatment plants required throughout the 3-H basins. A long-term forecast is also desirable to reflect the impact of possible high or low growth paths on water demand, supply and shortages. Thus the demand sensitivity analysis provided guidance on determining the effects on these parameters of various of economic and social growth scenarios (Table 4.12 MR). This resulted in detailed estimates of 3-H water demand sensitivity as affected by various types of growth and by price changes up to year 2050 (Table 4.13 MR). It should be noted that hydrologic variations in rainfall have a much more significant impact on demand than all the other parameters.

Demand Changes with Efficiency Improvement, Reuse and Price Increase. The complexities indicated by the water demand sensitivity analysis (Table 4.12 MR) showed the need to focus the evaluation on the base case demand and to determine how best to manage the demand for the base case by using two approaches: (a) improving the efficiency of irrigation supply systems (which are the largest water consumers) by an estimated 10 percent using improvement measures described in Chapter 6 along with programs already under way for improving efficiency in use of urban and rural priority supplies, and (b) increasing the price for all nonagricultural uses by 10 percent per year above the prices established till 2050 earlier for the base case. This resulted in a projection of demand changes under different growth scenarios for different results of probability from 95 to 25 percent (Table 4.2). The four scenarios considered included the (i) base case (BC), (ii) base case with 10 percent efficiency improvement (BC/10PEI), (iii) BC/10PEI plus reuse, and (iv) BC/10PEI plus reuse and price increase.

C. WATER SUPPLY PROJECTIONS

Introduction

Water supply capability depends not only on available water resources, as described in Chapter 3, but also on the capacity of the physical structures that capture, store and convey it to consumers. There is a definite resource constraint in northern China, which is hovering not far above recent levels of withdrawals, at least in the Hai and Yellow basins. Both the above-described studies by IPPDI and IWHR also projected water supply capacity, compared projected "demand" with projected supply capacity, and concluded that future shortages must be met from some combination of demand curtailment and supply augmentation including water transfers including within-basin transfers and transbasin diversion. The two most important water supply projections are those by IPPDI (1992) and IWHR (1993).

TABLE 4.2: DEMAND CHANGES UNDER DIFFERENT SCENARIOS

	1997	2000	2010	2020	2030	2040	2050
			Base Case				
95% Probability	190.59	192.46	205.20	216.34	221.82	224.73	228.03
75% Probability	166.62	168.74	180.96	192.03	197.51	200.42	203.72
50% Probability	153.34	155.73	167.76	178.83	184.31	187.22	190.52
25% Probability	144.75	147.31	159.25	170.65	175.78	178.69	181.99
			Efficiency 10% Improvement				
95% Probability	190.59	192.46	200.94	206.74	208.39	211.30	214.60
75% Probability	166.62	168.74	177.44	184.00	186.44	189.35	192.65
50% Probability	153.34	155.73	164.49	171.54	174.18	177.09	180.39
25% Probability	144.75	147.31	156.23	164.02	166.52	169.43	172.73
			Efficiency 10% Improvement + Reuse				
95% Probability	190.59	192.46	200.94	206.74	208.39	211.30	214.60
75% Probability	166.62	168.74	177.44	184.00	186.44	189.35	192.65
50% Probability	153.34	155.73	164.49	171.54	174.18	177.09	180.39
25% Probability	144.75	147.31	156.23	164.02	166.52	169.43	172.73
			Efficiency 10% Improvement + Reuse + Price Increase				
95% Probability	190.59	192.46	199.70	204.83	205.50	206.86	207.84
75% Probability	166.62	168.74	176.20	182.09	183.55	184.91	185.89
50% Probability	153.34	155.73	163.25	169.63	171.29	172.65	173.63
25% Probability	144.75	147.31	154.99	162.08	163.63	164.99	165.97

- The IPPDI study utilized the "P75" design basis for river flows (the river volume level met three years out of four), which has been widely used since including by the present study, representing a reasonable conservative basis for supply estimating purposes. It is important to note that the P75 river volumes are considerably less than mean annual flows, and also that it is not feasible (if not impossible) to capture much of the P75 flow which occurs in the flood season; moreover this flood flow is typically laden with silt. The target, therefore, is to capture all that can be captured of the actual river flow.

- The IPPDI study (Table 4.14 MR) projected the total 3-H supply (including groundwater) to increase from 119.8 Bcm in 1980 to 155.5 Bcm, an increase of 35.7 Bcm, but this expectation fell short because of delays in constructing new water supply improvement projects and because of an unanticipated shortage of O&M funds for maintaining existing facilities at design capacity.

The IWHR study (Tables 4.15, 4.16, 4.17 MR) updated the IPPDI study and extended this to 2010 with a marked lowering of expectations when considering all of China, but with about the same results for the 3-H basins. Supply increases would come from new dams, enlarged canals, and within-basin transfers. IWHR included consideration of some S-N interbasin transfer including some 9.2 Bcm for the 3-H basins, but planning for such an interbasin transfer is still in the early stages. As yet there is no consensus on which transfer pattern to use but there is consensus that such a transfer is inevitable.

World Bank Projections

Following much discussion with Chinese water resource specialists and consultations on other studies described above, the WB study incorporated findings to date into the 3-HMS developed for water resource allocation for the present study. The study's summarized results (Table 4.18 MR) show that the total supply for the 3-H basins is projected to increase from the 1997 level of 128.4 Bcm to 145.7 Bcm in 2050, which is only about 17 Bcm in addition to current supplies. In effect, there is very limited scope for additional water supply from sources within the 3-H basins if sustainable groundwater withdrawals are respected.

Regarding the structure of water supply for the 3-H basins (Figure 4.2 MR), surface water is derived from runoff in the mountain areas, local water is runoff from local mountains, and groundwater is a shallow and deep groundwater mix. In the case of the Hai, groundwater is the major current source of water supply and this would stay the case despite only slight increases in groundwater withdrawals. The same observation can be made for surface and local water supply. Transfers are projected to become more important, contributing from 13 percent in 2000 to 18 percent in 2050 for the Hai, and from 16 percent in 2000 to 17 percent in 2050 for the Huai. In the Huai basin, local water supply is much more important than in the Hai basin, sharing about a third of total supply with groundwater. In the Yellow river basin, groundwater and local sources make up the bulk of the water supply.

While within the 3-H basins, different sources contribute different volumes of water supply, the relative contributions from the different sources would stay almost the same as today's. According to projections made with the 3-H basins modeling system for P75 years, the total water supplied in 2000 in the 3-H basins is calculated at 131.8 Bcm and this is projected to increase by only 13.9 Bcm to 145.7 Bcm. This represents an additional 3 Bcm in the Hai, 6.7 Bcm in the Huai, and 4.2 Bcm in the Yellow river basin. For P95 years, the 3-H total for 2050 is 133.5 Bcm (Table 4.3).

TABLE 4.3: TOTAL SUPPLY FOR 95 PERCENT PROBABILITY UNDER BASE CASE
(Bcm/year)

	1997	2000	2010	2020	2030	2040	2050
Hai	31.17	31.95	32.67	32.33	33.15	32.89	32.63
Huai	54.57	55.37	59.69	60.07	60.41	60.62	60.48
Yellow	36.40	36.95	38.59	39.27	39.68	39.99	40.18
Total	122.13	124.27	130.94	131.67	133.24	133.50	133.28

The base case scenario represents limited additional supplies from local and surface water, groundwater and "small" transfers. This indicates that all sources are already being tapped to the maximum and very little change can be expected in the future. Thus the conclusion that the 3-H basins have reached a "brick wall" supply constraint is indeed valid and that the S-N water transfer would be essential. Estimates at this, including both transfer options (Middle Route and East Route) show that the basic transfer needs would be 12.2 Bcm in 2010 and 19.4 Bcm[5] by 2050 (Table 4.4). The East transfer moves water along an eastern Route via Jiangsu, Anhui, Shandong, East Hebei to Tianjin. The middle transfer would move water through Hubei, Henan, Hebei, Beijing and Tianjin (see Figure 4.4 MR). This would increase total P95 year supply to 135.5 Bcm in 2010 and 148.6 Bcm by 2050 (Table 4.5).

TABLE 4.4: S-N WATER TRANSFER CAPACITY
(Bcm/year)

	2000	2010	2020	2030	2040	2050
Middle Transfer	0	7.01	11.95	11.95	11.95	11.95
East Transfer	0	5.21	7.49	7.49	7.49	7.49
Total	0	12.22	19.44	19.44	19.44	19.44

[5] This is the design capacity which has to take into account peaking requirements under very extreme drought events. It is not necessarily the transferred volumes. That is why numbers in Table 4.3 may not coincide with the numbers in Table 4.5.

TABLE 4.5: TOTAL SUPPLY FOR 95 PERCENT PROBABILITY WITH S-N TRANSFER
(Bcm/year)

	1997	2000	2010	2020	2030	2040	2050
Hai	31.17	31.95	33.67	41.00	42.85	42.87	42.77
Huai	54.57	55.37	64.07	66.98	67.07	67.20	67.46
Yellow	36.40	36.95	37.77	37.31	37.92	38.31	38.32
Total	122.13	124.27	135.50	145.29	147.85	148.39	148.55

D. WATER BALANCES IN THE FUTURE

Base Case Water Balance

The question is, what would be the water balance in the future under this base case scenario? Given growing demands and limited possible supply increase, it is likely that current shortages would continue to grow.

Table 4.6 has been prepared, based on the information given earlier, to show the future 3-H picture on the supply/demand balance including shortages for the base case scenario. This scenario assumes no additional supplies on demand management other than ongoing governmental programs. The estimates also assume (a) efficiency improvement in irrigation (7 to 8 percent), (b) reduction in unaccounted-for water in priority uses (from 30 to 25 percent to 15 to 10 percent), (c) price increases for water at about 10 percent per year till 2050 in real terms, and (d) reduction in water pollution in urban areas to enable at least 5 percent reuse.

TABLE 4.6: FUTURE SUPPLY-DEMAND BALANCES AND SHORTAGES FOR THE 3-H BASINS FOR BASE CASE SCENARIO (P75)

		1997	2000	2010	2020	2030	2040	2050
3-H Basin	Total Demand	164.5	168.8	180.9	191.7	197.6	200.6	203.7
	Total Supply	128.4	131.8	140.9	144.4	145.4	146.6	145.7
	Priority Shortage	4.9	5.6	7.6	10.9	12.5	13.1	14.8
	Shortage Irrigation	32.2	32.1	32.5	36.7	38.7	39.8	41.7
	Total Shortage	**37.2**	**37.7**	**40.1**	**47.6**	**51.2**	**52.9**	**56.5**

Discussion. Shortages would continue to occur as demand for water outpaces supply. Given government policy of satisfying urban municipal and industrial needs first, supplies to agriculture would not increase beyond current levels. Urban shortages would continue to grow because of high demand in comparison to supply. The effect of different flow probability years on agriculture is significant. For example in the Huai basin, shortages to agriculture are reduced dramatically for a P25 year compared to a P95 year. Despite preferential allocation, urban shortages would tend to remain constant most strikingly in the Hai basin. This is because even during wet years when more surface and local water is available, water pollution limits the use of this water and so the shortages remain fairly constant. Urban centers are forced to use groundwater instead. Overall, shortages in dry years would show up in the agricultural sector first and then industry and municipalities last. In wet years, the shortages would decline in agriculture but remain relatively constant in the urban centers. The trend in urban shortages in the Huai and Yellow basins suggest that additional flows may be available to dilute polluted waters so that it may become an acceptable raw water supply with the current level of treatment technology. In addition, given the spatial and temporal variability of water supply and despite preferential allocation for urban industry and municipal consumers, it may be impossible to satisfy priority needs ahead of agriculture if water cannot be transferred to the parts of the basin where the water shortages are most severe. In summary, total shortages would continue to increase for all three basins from the present time to 2050 under the base case scenario. The full 3-H water balance calculated for different probability flows to year 2050 is presented in Annex 4.2, Volume 3.

Water Balance with Projected Improvements

The picture on the base case supply-and-demand projections shows these projections are already far apart (1997 to 2000). Even with the assumed improvements, the shortage amounts to 56.7 Bcm for a P75/moderately year and 95 Bcm for a P95 very dry year. Improving this situation would require additional measures including (a) increasing irrigation efficiency by an additional 10 percent; (b) increasing reuse from 5 to 15 percent for priority supplies, (c) increasing prices in real terms by a further 10 percent per year, and (d) increasing S-N east and middle transfer by about 19.7 Bcm per year. Using the 3-H modeling system (3-HMS), this study computerized the effectives of each of the sound water shortage reduction measures (Table 4.7).

TABLE 4.7: 3-H BASINS WATER SHORTAGES UNDER DIFFERENT SCENARIOS
(Bcm)

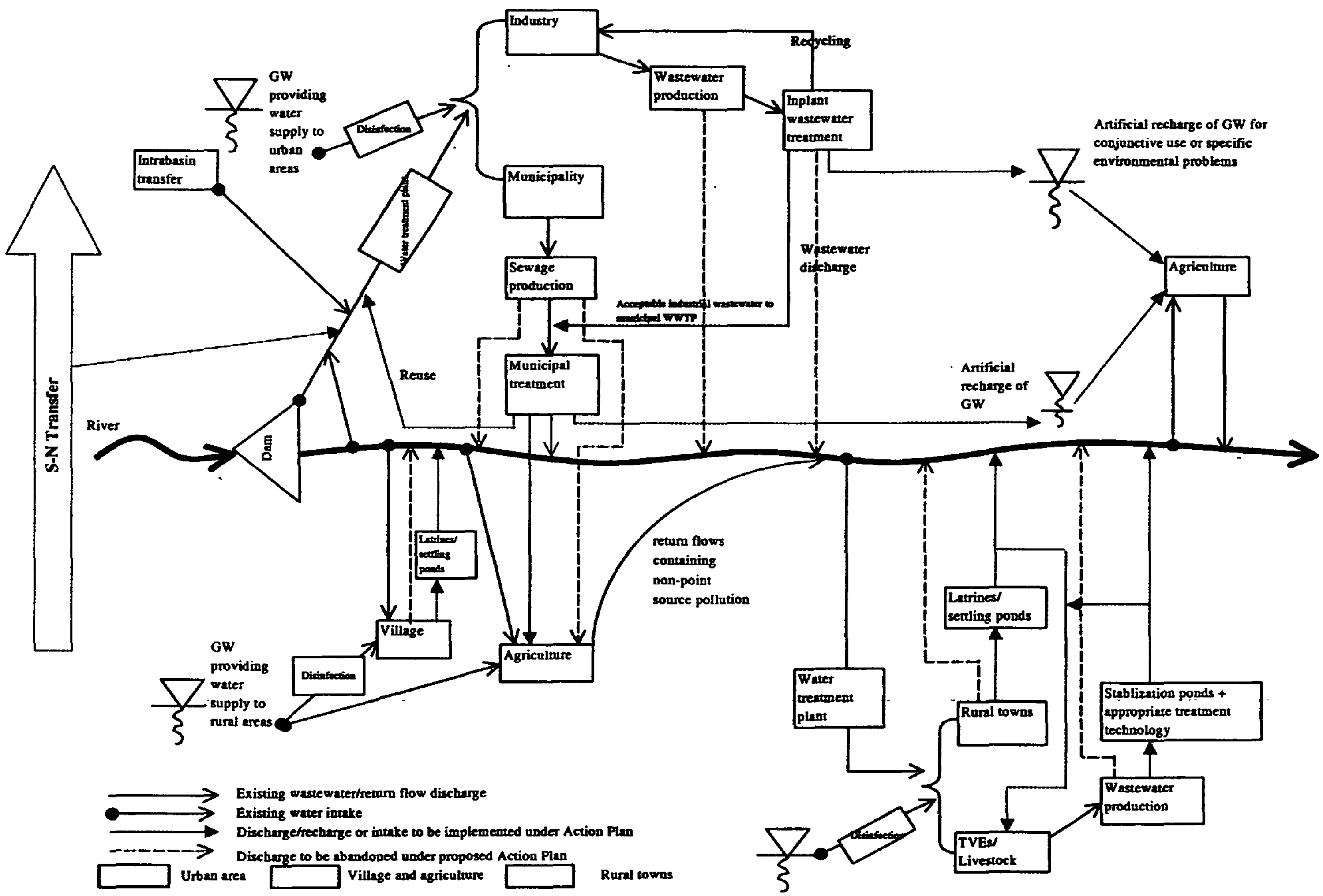
	3-H Basins Priority Water Shortages under P95						
	1997	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**
Base Case	5.81	6.21	9.19	12.96	14.64	15.74	17.46
Efficiency 10%	5.81	6.21	9.19	12.96	14.64	15.74	17.46
Efficiency 10% + reuse	5.81	6.21	7.84	10.04	10.72	11.72	12.85
Efficiency 10% + reuse + price increase	5.81	6.21	7.40	9.03	9.52	10.06	10.14
Efficiency 10% + reuse + price increase + S-N-E	5.81	6.21	5.42	5.52	5.87	6.41	6.54
Efficiency 10% + reuse + price increase + S-N	5.81	6.21	4.21	2.23	1.73	2.03	2.06
	3-H Basins Irrigation Water Shortages under P75						
	1997	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**
Base Case	32.13	32.49	32.39	36.66	38.74	39.82	41.08
Efficiency 10%	32.13	32.49	29.94	30.99	30.94	32.05	33.23
Efficiency 10% + reuse	32.13	32.49	31.80	33.43	33.72	34.89	36.15
Efficiency 10% + reuse + price increase	32.13	32.49	31.42	32.87	32.69	33.30	33.49
Efficiency 10% + reuse + price increase + S-N-E	32.13	32.49	30.47	30.48	30.60	31.20	31.38
Efficiency 10% + reuse + price increase + S-N	32.13	32.49	29.97	28.11	28.08	28.66	28.91
	3-H Basins Total Water Shortages under P75						
	1997	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**
Base Case	37.88	38.84	40.73	48.35	52.14	54.32	56.70
Efficiency 10%	37.88	38.84	38.28	42.68	44.33	46.54	48.84
Efficiency 10% + Reuse 15%	37.88	38.84	38.54	41.64	42.46	44.54	46.82
Efficiency 10% + Reuse 15% +Price increase	37.88	38.84	37.86	40.46	40.50	41.53	42.02
Efficiency 10% + Reuse + Price increases + S-N-E	37.88	38.84	35.26	35.18	35.37	36.38	36.78
Efficiency 10% + Reuse 15% + Price Increase + S-N	37.88	38.84	33.56	29.60	28.87	29.68	30.06

S-N: East + Middle routes; S-N-E: East Route only.

Figure 4.2 shows the prepared integrated water and wastewater utilization plan for urban areas, agriculture and rural farms and the existing situation. It can be seen that wastewater treatment, reuse, recycling and artificial recharge are integral components of the proposed action plan and that water quality improvements would reduce water scarcity.

The action plan recommends 5 to 15 percent wastewater reuse. However reuse cannot be implemented without increased wastewater treatment. Thus the action plan recommends that 95 percent of industrial wastewater should be treated by 2020 and secondary municipal treatment plants should be operating in P1 and P2 cities also by 2020.

FIGURE 4.2 EXISTING AND PROPOSED INTEGRATED WATER AND WASTEWATER UTILIZATION FOR URBAN AREAS, AGRICULTURE AND RURAL TOWNS



From these calculations, priority shortages are reduced from 17. 5 Bcm in 2050 to 2.1 Bcm, and total shortage from 56.7 Bcm to 30.1 Bcm (Table 4.8).

TABLE 4.8: EFFECTIVENESS OF EACH WATER SHORTAGE REDUCTION MEASURE
(Percent)

	Shortage Reduction		
	Irrigation Shortage	Priority Shortage	Total Water Shortage
Base Case	-	-	-
Efficiency 10% Improvement	19	-	14
Reuse increase 15%	-7	26	4
Price increase by 10%	6	16	8
S-N East Transfer	5	21	9
S-N Full Transfer	6	26	12
Total Reduction	**30**	**88**	**47**

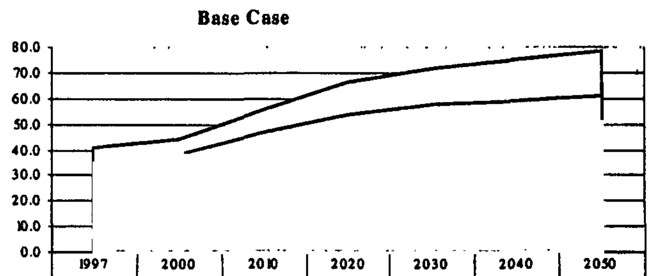
It is important to note that inherent in the process of modeling demand, supply and water shortages, the model routines would attempt to maximize the net economic output of water for urban, rural, industrial and agricultural sectors by (a) allocating water from different sources including surface water, groundwater, local water and intrabasin transfers and (b) shifting water from low-priority sectors (agriculture) to high-priority sectors (life and industry). Thus, a substantial percentage of water initially allocated to agriculture becomes a source of water for priority uses.

Figure 4.3 below shows how the optimization model shifts water from the different supplies available into priority uses. The priority supplies of 35.2 Bcm are calculated for a P95 year and guaranteed through to 2050. Additional supplies come from intrabasin and local supplies including groundwater and from irrigation. In the base case, the volume of water shifted out of agriculture to reach optimum economic efficiency is 2.5 Bcm in 2000, increasing to 16.1 Bcm in 2050. Priority shortages remain however at 6.2 Bcm, growing to 17.5 Bcm in 2050. Shifting additional water out of irrigation is not the solution to the remaining shortages since this would result in suboptimum condition with respect to net economic output from water. Under the base case scenario and with the constraints imposed, the optimization calculations show that tolerating the priority shortages at the level shown (17.5 Bcm in 2050) assures maximizing of economic benefits from water distributed across urban and rural life, industry and irrigated agriculture uses.

Fortunately, other options to further reduce priority shortages are available as investigated in the previous paragraphs. The implementation of water use efficiency improvement in irrigation districts and reuse of wastewater in urban centers combine to increase water supply to priority uses. Thus, 17.4 Bcm is shifted out of agriculture in 2050 and priority shortages are reduced to 10.1 Bcm also in 2050.

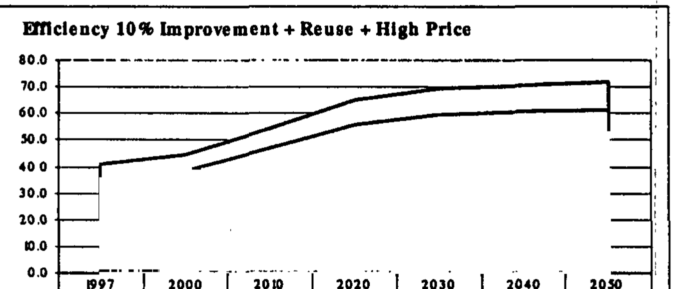
Graphical drawings (Figure 4.5 MR) were presented to illustrate the overall 3-H picture on supply/demand for different probability groups up to 2050. Figure 4.4, included here, gives the detailed pictures for the Hai Basin.

FIGURE 4.3: WATER DEMAND AND SUPPLY SOURCES UNDER DIFFERENT SCENARIOS



	1997	2000	2010	2020	2030	2040	2050
Priority Shortage	5.8	6.2	9.2	13.0	14.6	15.7	17.5
Intra-basin+ local suppliesetc	0.0	0.6	6.8	8.0	9.6	9.9	9.7
Supply Shift from Irrig		2.5	4.8	10.5	12.8	14.3	16.1
Priority Supply	35.2	35.2	35.2	35.2	35.2	35.2	35.2

Priority Supply Supply Shift from Irrig Intra-basin+ local suppliesetc Priority Shortage



	1997	2000	2010	2020	2030	2040	2050
Priority Shortage	5.8	6.2	7.4	9.0	9.5	10.1	10.1
Intra-basin+ local supplies etc	0.0	0.6	5.5	7.3	8.6	8.7	8.9
Supply Shift from Irrig	0.0	2.5	6.6	13.3	16.0	16.7	17.4
Priority Supply	35.2	35.2	35.2	35.2	35.2	35.2	35.2

Priority Supply Supply Shift from Irrig Intra-basin+ local supplies etc Priority Shortage

E. ECONOMIC VALUE OF WATER AND OF WATER SHORTAGES

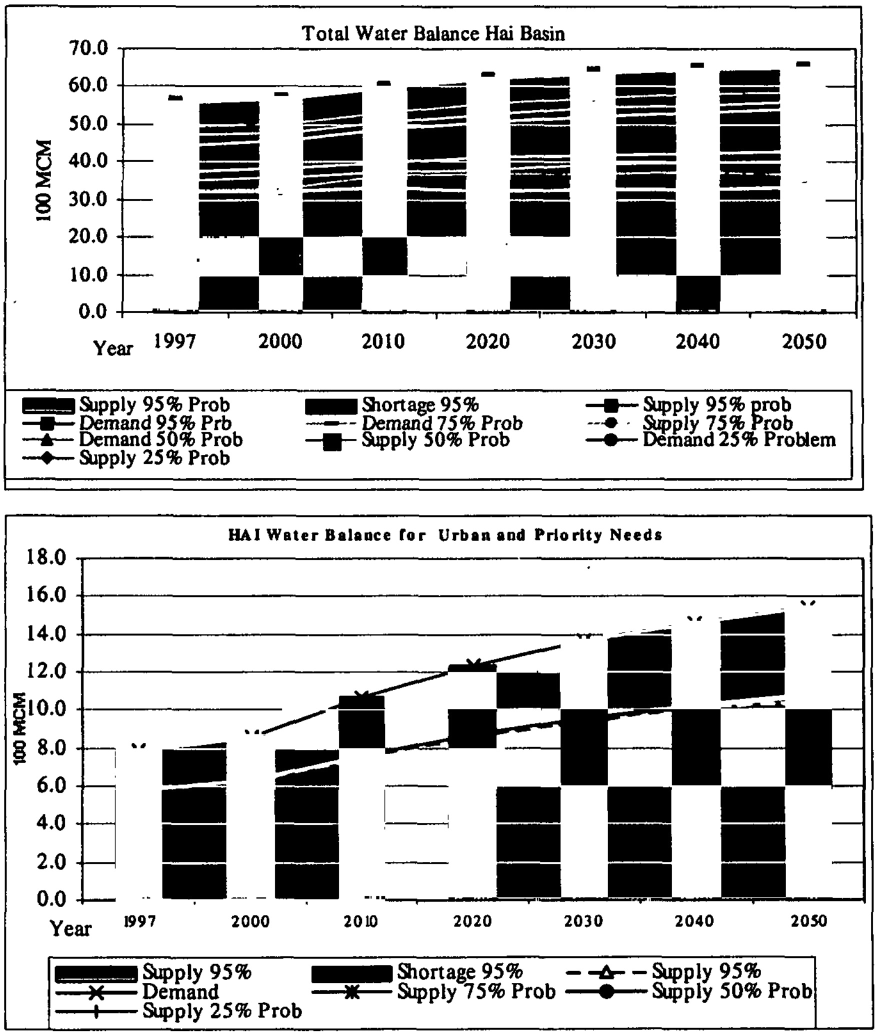
Economic Value of Water

The economic value of water has been estimated from several projects including the Wanjiazhai Water Transfer Project using input-output analysis and has been averaged for the regions. Those values are summarized as reasonable for the 3-H basins, as follows in Table 4.9.

TABLE 4.9: ECONOMIC VALUE OF WATER FOR DIFFERENT SECTORS

Water for different sectors	Value (Y/m^3)
Irrigation water (Irrig)	0.8 - 1.6
Urban Industry (Urbind)	6.0
Rural Industry (Rurind)	4.0
Urban Domestic (Urblife)	3.0
Rural Domestic (Rurlife)	3.0
Livestock (Livestock)	2.0
Fisheries/pasture/Forestry (FPF)	1.5

FIGURE 4.4: TOTAL SUPPLIES AND DEMAND FOR DIFFERENT PROBABILITY FLOWS FOR THE HAI BASINS



The 3-HMS computed the economic value of water supplied to different sectors for the 3-H basins up to 2050 P95 year and for P75 year without interbasin transfer (Table 4.29 MR). Irrigation accounts for 33 to 34 percent of the total value of the water supplied for 2050 while urban industry accounts for 45 percent and all other sectors account for 22 percent. The table above also shows that the value of water supplied rises from Y 245 billion in 1997 to Y 343 billion in 2030-50 in the case of a P75 year. The value of water rises during wet years (i.e., from a P75 to a P95 year) because more water is supplied and used by agriculture and industry. However the value of water in Y/m^3 rises from a wet year to a dry year (P25 to P95), reflecting increased scarcity in dry years. The value of irrigation water expressed as a percentage of total value would decline from nearly one-half to one-third and the percentage value of water sold to rural and urban industry would rise. Thus water would be increasingly directed to higher marginal values.

Economic Value of Water Shortages

The study developed a detailed methodology using the 3-HMS to assess the optimum allocation of the water resources according to an economic objective function. Shortage losses were estimated for the entire range of hydrologic conditions (Table 4.30 MR). Shortages over the whole hydrologic regime increase from 28.6 Bcm/1997 to 46.1 Bcm/2050, and comparable losses due to shortages increase from Y 57.8 billion to Y 111.4 billion.

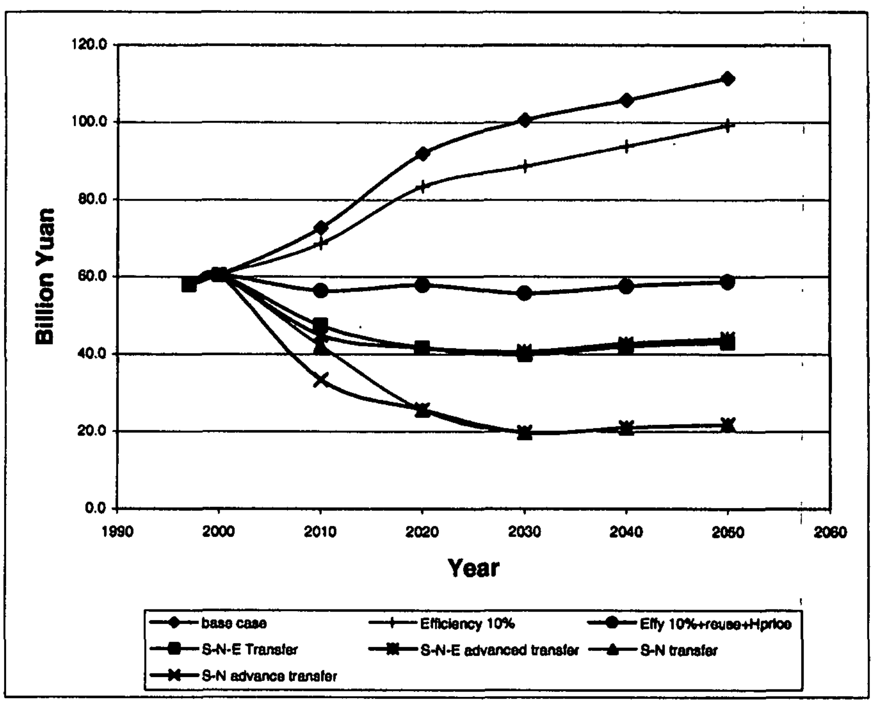
The model runs estimated reductions in demand to be obtained by special improvement measures, to obtain annual losses in billion yuan, and discounted water shortage values (Table 4.31 MR). The shortage losses can be significantly reduced from Y 645 billion for the base case to Y 412 billion (discounted value for both), with total losses reduced to Y 233 billion. The effectiveness of each measure in terms of shortage reduction, reduction benefits and costs is given in Table 4.10.

TABLE 4.10: SHORTAGE REDUCTION DISCOUNTED BENEFITS AND COSTS

Action	Shortage Reduction (%)	Shortage Reduction Benefits (%)	Shortage Reduction Costs (%)
Price increases	17	11.7	0
Reuse and pollution control	9	23.5	18
Efficiency improvements	30	11.7	51
S-N East transfer	19	26.0	9
S-N Middle Transfer	26	27.1	21
Total	100	100.0	100
Discounted in Billion Yuan		233	217

Figure 4.5 shows economic losses due to water shortages under different scenarios for individual years. The difference in loss between base case and implementing all the measures (including S-N advanced) is significant even from 2010 onward; this is, nearly Y 40 billion.

FIGURE 4.5: ECONOMIC LOSSES DUE TO WATER SHORTAGE UNDER DIFFERENT SCENARIOS
(Billion Yuan/Year)



The question then is whether these measures are worth the cost of their implementation. These evaluations showed that about half the costs would be for efficiency improvements with only 30 percent for S-N transfer and 20 percent for reuse.

The overall findings are that even with a 12 percent discount factor, the shortage costs are less than the discounted benefits, hence all improvement measures must be implemented including the interbasin transfer. This would ensure that shortages for priority uses would be substantially reduced (Figures 4.13 and 4.14 MR) and the shortage for agriculture would be contained at tolerable limits.

F. Action Plan for Balancing Supply and Demand

From the exercise reported in Section D, we may conclude that future domestic, municipal, and industrial water demands can never be fully met *at the level of aggregation of the basin.* However due to spatial and temporal variations in rainfall and the fact that neither surface nor groundwater is fully mobile within basins, some areas would have water surpluses and others may have shortages. The following measures describe the key elements of the action plan which if implemented would reduce shortages for all sectors.

(i) Management Scenarios

Increasing the efficiency of irrigation system by a further 10 percent;
Increasing reuse from 5 to 15 percent for priority supplies;
Increasing prices by a further 10 percent per year over the existing price increases in real terms;
Increasing the supply by the S-N East and Middle transfer by about 19.7 Bcm/year.

Additional options include:

Intrabasin water allocation;
Intersectoral water allocation.

(ii) Increased Efficiency of Irrigation and Municipal Water Supply Networks

The government has recognized the need for higher-efficiency use of water and in the last few years has implemented the State Office of Comprehensive Agricultural Development (SOCAD), Large Irrigation Schemes (LISs) and water-saving technology programs. The action plan calls for increased commitment to these fundamental programs to lift efficiency of supply to 18 percent. This is described more fully in the section on agriculture.

(iii) Wastewater Reuse

In 1997, urban water consumption was about 24.8 Bcm in 3-H, which generated about 17.6 Bcm of wastewater (Table 4.34 MR). According to the *Water Bulletin*, no more than 0.67 Bcm (4 percent) was collected and reused.[6] The remainder evaporated, was returned to the rivers, or recharged local groundwater. Anecdotal evidence suggests that some was collected and used by irrigators, which is verified by reports that the use of untreated sewage and industrial effluent has led to illness.

By 2010, we project urban wastewater volumes would be about 25 Bcm in 3-H, and by 2050, 33.5 Bcm. If properly collected, treated and distributed, this represents a large volume of potential water supplies—nearly one-third of current consumption. With the growth of cities would come increased demands for locally produced vegetables, and these water supplies can be made available locally. Sale of treated wastewater could well offset much of the costs of treatment; marginal returns to vegetable farming are at least Y 2/m^3.

---

[6] IWHR, *Water Bulletin*, 1997. Under "Withdrawals" is a category termed "Others" which includes reuse and seawater; 0.67 Bcm is the total of "Others."

The action plan proposes to augment priority supplies by recovering wastewater generated in urban areas from municipal and industrial consumers. The technical, infrastructure, financial and institutional requirements of this aspect of the action plan are discussed in full in Chapter 7 (Pollution) and Chapter 8 (Wastewater Reuse). Wastewater reuse rate should increase from the current government, base case of 5 to 15 percent in order to achieve the proposed reductions in shortage.

(iv) Water Pricing

Water prices assumed in the modeling studies indicate that the base price and high price tariffs for urban and rural priority supplies should follow mean/average prices as indicated below in Table 4.11. It should be noted that these prices represent average prices for all priority water supplies and these would vary from region to region depending on the cost of source development, transmission, treatment and distribution. For example the mean/average value assumed for the base case in 2000 is Y 1.12/m^3 but it must be noted that the 2000 prices are based on the discussion presented in Section E and increase by 5 percent annually.

TABLE 4.11: WATER TARIFF ASSUMPTIONS FOR BASE AND HIGH PRICE CASES IN REAL TERMS

Year	Base Case Tariff			High Tariff		
	Low	Mean	High	Low	Mean	High
2000	0.9	1.1	2.9	0.9	1.1	2.9
2010	1.1	1.5	3.8	1.4	1.9	4.8
2020	1.4	1.9	4.9	1.7	2.3	5.9
2030	1.8	2.4	6.2	2.1	2.8	7.2
2040	2.3	3.0	7.9	2.8	3.7	9.6
2050	2.8	3.7	9.6	3.6	4.7	12.3

(v) South-North (S-N) Water Transfer

Despite possible/feasible price increase, efficiency gains and reuse improvements, the 3-H would continue to be short of water as demonstrated in Chapter 4. Therefore it can be concluded that proposed demand management programs (efficiency improvements and price increases) and supply enhancement (reuse) would not be sufficient to ensure some kind of equilibrium between supply and demand. The only feasible addition to the proposed action plan, one that has been already extensively investigated by the Chinese government, is the S-N transfer whereby water would transferred from the Yangtze River to the Hai and Huai basins.

The action plan recommends further investigations of the S-N transfer. Preliminary costs are estimated at Y 245.0 billion (Y 70.9 billion for the eastern route and Y 174.1 billion for the middle route), representing almost 30 percent of total action plan costs. Shortage reductions resulting from the S-N Transfer are approximately 45 percent of total but account for about 53 percent of the total Y 233 billion expected benefits while costing about 30 percent of the total Y 217 billion in implementation costs for the entire action plan. Refer to Table 4.33 MR.

Other Supply Augmentation Needed to Complement the S-N Transfer. The route of the S-N Transfer was described in Figures 4.3 above. There would be many cities along the route receiving water from this new source and it is likely that many existing water supply systems would need to be modified and rehabilitated to maximize the use of this new water. The new sources would be derived from three sources including (a) local water, (b) groundwater, (c) surface and/or S-N transfer. In the Huai basin, all three sources would be utilized while in the Hai basin, most of the new water would be derived from the S-N transfer because the other sources are already fully committed or overcommitted as discussed in Chapter 3 on water resources. In the Yellow basin, there would be no new water from the S-N transfer but most of the new supplies would be derived from groundwater and local water resource expansion.

The main components of the additional supplies are (a) source development and transmission, Y 0.46/m^3, (b) water treatment, Y 0.38/m^3, (c) network rehabilitation, Y 0.24/m^3, (d) others (including design, supervision, contingency) Y 0.26/m^3. Items (a) to (d) were calculated on a per cubic meter and percentage basis from previous water supply augmentation projects recently completed in north China including Beijing, Shijiangzhuang, Tangshan, and Handan. These ratios were used to produce the expected costs in supply augmentation for the proposed action plan as shown in Table 4.36 MR.

(vi) Intrabasin Water Allocations

As a natural consequence of multiple, often conflicting objectives and fragmented control, intrabasin water allocations are far from optimal. In Chapter 3 the problem of conflicting objectives and managerial control was described as it related to instream demands vs. offstream demands.

It is clear that provinces within the upper reach in particular, and those in the middle reach, have been consistently and widely exceeding the limits. The results have been chronic shortages in the downstream areas, and drying up of the lower reach of the river. The year 1997 was exceptionally dry (about P90), yet the upper reach provinces withdrew nearly 10 Bcm in excess of their allocation.

Virtually all of the upper and middle reach withdrawals go for irrigation. Clearly, these withdrawals are uneconomic at the margin, given the wide disparity in application rates. In 1997, irrigation rates, in m^3/mu, were 809 in the upper reach, 249 in the middle reach, and 304 in the lower reach.[7] Nearly 12 percent of upper reach irrigation supplies go to paddy, while the marginal returns to irrigation water in the middle and lower reaches are very high.

Although average rates of irrigation would naturally vary widely due to climate, rainfall and cropping pattern, such discrepancies cannot be justified and clearly point to the opportunity for achieving higher agricultural output and incomes from a more equitable water distribution which cannot occur under the current river basin management system.

(vii) Intersectoral Water Allocations

North China's water sector managers have been playing a delicate balancing act in recent years, attempting to satisfy human needs for water, give enough water to industry to allow continued rapid growth, and at the same time, give enough water to agriculture to maintain food production at near self-sufficiency levels and give farmers adequate incomes. These are all virtually impossible tasks under a system where allocations are made essentially without the aid of market mechanisms. Instead, how much water a consumer has access to depends on what type of consumer he is, where he is located, and whether he has access to groundwater. An optimal economic allocation of water over time, space, and sectors is simply not possible to calculate, and would be impossible to enforce were it calculable.

Fortunately, such a calculation is not necessary. A wide body of economic theory emphatically tells us that market mechanisms, if allowed to operate, would move us in the direction of optimal allocations of scarce resources such as water, and correspondingly lead to higher welfare of the market participants. Where two or more parties enter into an exchange agreement, they do so to the mutual benefit of each, and to the benefit of society as a whole. Several examples of spontaneous water markets have appeared in north China. Typically, these involve groups of farmers selling water to industries or cities. It has also involved cities selling treated wastewater to nearby farmers. When such transactions occur, the implication is clear: the buyer has a higher marginal benefit than the seller. The equalization of marginal benefits tends toward a higher overall benefit.

---

[7] IWHR unpublished data.

Although water resources in China are owned by the state, and water trading has been illegal, ad hoc rights to the use of water have clearly been established. The recently imposed water licensing system legalizes and quantifies these rights. To gain the benefits from market mechanisms, China only needs to sanction and promote water trading among the various groups holding these rights. The result would be that water flows from the lower economic uses to the higher, to the benefit of all.

The 3-HMS has defined optimal priority and irrigation water allocations based on market mechanisms and the resulting supplies to different sector groups were shown in Table 4.22 MR. However, shortages would remain for key sectors such as urban industry and urban life and these would vary according to rainfall or dry versus wet conditions. As noted in section C (ii) b, optimal allocation among sectors would minimize the economic value of water shortages. The 3-HMS developed for this study played a key role in setting broad allocation scenarios at the Basin 2 level by replicating market mechanisms that maximize the value of water. It is recommended that further work be done to refine the suite of models used here both for the 3-H basins and for other basins in China.

Overall Assessment. North China has several significant economic advantages in terms of location, infrastructure, and a vibrant educated population, but it has a serious disadvantage in water availability. The need is for clear recognition by the government that the water shortage problem is now critically threatening continuing development and implementation of an Action Strategy and Plan which would enable continuing sustainable development. It would not be easy to do this because of institutional constraints, but it is clearly feasible and it is up to the government to face up to the reality and to "bite the bullet," especially in terms of establishing the institutional reforms needed to enable the central and provincial and local governments to cooperate effectively.

Need for Environmental Impact Assessment (EIA)

It is important to point out that this study does not purport to evaluate the social or environmental feasibility of specific S-N transfer alternatives, but only to demonstrate that S-N transfer schemes could be economically justified within a mix of actions to improve water resource management. Specific feasibility studies and environmental/social assessments need to be carried out separately in the context of planning for the S-N transfer projects. Detailed EIAs and social assessments need to be undertaken, especially for S-N transfer, prior to implementation to ensure all negative impacts on the environment and society are identified, internalized and offset. For example, it is estimated that some 200,000 people would need to be resettled by raising of the Danjiangkou Reservoir, and another 50,000 people along the S-N middle route. In addition, the impact of drawing 12 Bcm of water per year from the Han River would have some negative impact in the downstream basin of the Han River below Danjiangkou Reservoir. Plans exist to supplement this loss of water by diverting water from the main stem of the Yangtze River at the Three Gorges Dam. The timing of this diversion needs to be determined. Although the Eastern route is well defined and the canal is located along existing canals, there might be a few people who might have to move at the pumping stations where more land would be required for the new stations. For the eastern route, because the snails are found in the Yangtze River, schistosomiasis may be one of the public health impacts if adequate control measures not taken. The Eastern transfer would also have problems of water quality since there are large number of cities and industries located along the Grand Canal. Although there are many projects presently under way to clean up the Grand Canal, the success of these projects would have to be confirmed prior to implementation of the Eastern Transfer Project.

Preliminary EIAs have been completed for all the routes, and the offsetting measures and costs have been included in the preliminary cost estimates to internalize the environmental effects. The cost for resettlement included in these preliminary estimates is about Y 10 billion. Additional costs have been included for environmental protection measures for schistosomiasis and other public health effects of the Eastern route, up to Y 5 billion. The water pollution control measures are being taken care of by the government and by external funding (WB, Japan Bank for International

Cooperation and others) to dramatically reduce the waste load into the Grand Canal. If these measures are not adequate, the government would have to invest in additional interceptors and treatment plants to ensure all wastes are collected, treated and disposed of properly.

In addition, increased volumes of water supplied to cities along the S-N route would necessitate improved wastewater treatment infrastructure and the institutional mechanisms to support sustainable operation. The pollution control action plan described in Chapter 7 is based on increased water supply from the S-N transfer and the additional wastewater produced.

5. FLOODS AND FLOOD DAMAGE

A. INTRODUCTION

Following the description of past flood damages in the 3-H basins and in China in Chapter 3, this chapter summarizes the government's current approach to flood protection and existing flood protection standards. A discussion of appropriate flood protection standards with structural and nonstructural methods is then presented and this is followed by the development of a methodology for assessing and ranking proposed flood protection projects. Finally, a list of proposed priority projects is presented based on the methodology developed and on current government strategy.

B. SUMMARY OF THE CURRENT FLOOD CONTROL STRATEGY

Tabulations were prepared (Tables 5.1 and 5.2 MR) that summarize the existing flooding situation in each of the 3-H basins including (a) delineation of key problems, (b) strategy policy, and (c) actions for implementing policy.

The primary problems are the magnitude of flood flows on main stems and also on tributaries compared to the limited flood storage capacity afforded by reservoirs, together with progressive occupation of flood-prone areas over the centuries prompted by population growth and increasing economic activity.

Other serious problems include (a) inadequate drainage and waterlogging in floodplain areas, (b) blockage of flood drainage in middle river reaches causing back-flooding into tributaries, (c) inadequate protection capacity of dikes, levees, and river training works in floodplain areas, and (d) for the Yellow River, very high river silt concentration resulting in continuing riverbed deposition. The strategies and related actions have focused on construction of various types of engineering works aimed at lessening the level of damage, particularly for the densely occupied flood-prone regions.

C. LEVEL OF PROTECTION (FLOOD STANDARD)

The economic data identify the areas that are most affected by flooding and the magnitude of the losses but do not provide an adequate picture of the frequency of damage. The Flood Annex includes a detailed description of the flood standards for reservoirs, levees, detention storage, and river systems in the 3-H basins. This shows that (a) there are a number of areas that would have very low flood security, and (b) flood damages would decrease if the flood standard for major works were increased.

The data on flood standards have been combined with the location of the flood losses to provide a rationale for flood management priority projects. The flood control works in the Yellow River, Huai, and Hai basins include thousands of reservoirs, levees, river training works, major flood diversion channels, flood detention storages, and safety facilities in temporary detention areas. There are many major reservoirs with $10^8 m^3$ capacity or more, including 30 in the Hai basin, 15 in the Yellow basin, and 35 in the Hai basin. These were reviewed in Table 3.6 in Chapter 3, section C on floods.

MWR has established flood design standards for the 3-H basins (Table 5.3 MR), ranging from 20-year to 50-year protection, but actual protection is considerably less, especially in densely populated lowland areas. Particularly serious is the situation for the 193 cities located in the 3-H basins, in that the flood standard for the majority of these (79 percent) is equal or lower than 20 years.

D. Appropriate Standards for Flood Protection

Structural Measures

Investments required for flood protection are large and demand careful consideration of peoples' ability to pay versus the level of protection required. Not all areas need to be protected to the same extent and the standard of protection would vary depending on the value of the assets protected by physical works or by other nonstructural measures combined with the risk of flooding for that area. Thus for example, flood detention basins have a higher risk of flooding and if these contain valuable assets such as large industries, hospitals, roads, and so on (as is often the case in China and in the 3-H basins especially) then the level of protection should be high.

In theory, economic analysis provides a basis for optimizing flood protection interventions at each location. However, estimation of flood control benefits is very difficult in the 3-H basins because of the level of development and intensity of land use.

Choice of flood protection works can only be finalized within an overall river basin context. Reservoir operating rules that favor flood protection may be at the expense of other values, and alternatives need to be evaluated within a comprehensive planning framework for river basins. A key principle is that effective flood plan management identifies areas at risk, evaluates the level of risk, and then attaches regulations to the use of that land compatible with the defined risk. Moreover, as development proceeds and incomes rise, both capacity-to-pay and willingness-to-pay for flood control services increase.

It should be noted that flood protection standards for rural areas in China outside some detention basins are significantly higher than those typical in other countries for agricultural land. This reflects the fact that rural areas in China are densely populated and it is not just a question of protecting agricultural land but also villages and settlements.

The summary recommendation of the present study is that MWR should undertake a comprehensive review of flood protection standards to ensure that they correspond to implicit willingness-to-pay in different, appropriate contexts. Given limitations on resources, feasibility studies should still be used to rank potential projects, with alternatives evaluated in relation to other purposes within the context of comprehensive river basin planning.

Nonstructural Measures

Nonstructural measures have received less emphasis than structural measures in the history of flood management in modern China. Nevertheless this is changing, and progress has been made in providing safety measures in high-risk detention areas, in implementing flood forecasting and monitoring networks, and in preparing flood warning systems and flood emergency response plans. Moreover, the 1997 Flood Control Law provides a basis for evolving a better balance of engineering and nonengineering measures in the future. In many cases it can be shown that nonstructural measures are extremely cost-effective in reducing flood losses. These include house-raising, flood warning, flood forecasting, and land use zoning.

The occupation of the floodplain areas between levees remains a serious problem, but given existing land use and population pressures, little can be done other than implementing damage mitigation strategies. These include the construction of polders, river training works, flood zoning and regulations on land use, and resettlement assistance. The use of detention basins is equally controversial and for similar reasons are widely inhabited; removing people from these areas is hardly an option.

The guiding principles for planning nonstructural measures for these seriously affected lowland areas include (a) using up-to-date technology in flood forecasting and flood warning, (b) using measures to reduce the frequency of use of these areas, (c) assigning priority to achieving a high standard of safety for residents with respect to buildings, refuges, and evacuation routes, (d) assuring that emergency response plans are effective and are regularly tested, (e) using community education to raise and maintain awareness of the flood risk and ensure that the populations at risk are prepared and would respond during flood emergencies, and (f) exploring options for compensation, flood insurance, and related measures.

Flood forecasting and warning systems are already in use in the 3-H basins, but improvements are delineated based on review of experience with the present methodology.

Balance Between Structural and Nonstructural Measures

The present study recognizes that the historical focus on flood control with structural measures has been the linchpin of the government's strategy for many decades, and it is unrealistic to expect any profound change in flood control strategy on environmental, economic, social or engineering grounds. However physical works alone are insufficient and China has progressively adopted nonstructural measures that complement the physical protection afforded by dikes and storage reservoirs, and this has helped contain damages and reduce lives lost during flood events. The long-term goal is to determine the optimum balance between structural and nonstructural measures that is attuned to China's evolving situation and to move toward comprehensive floodplain management approaches.

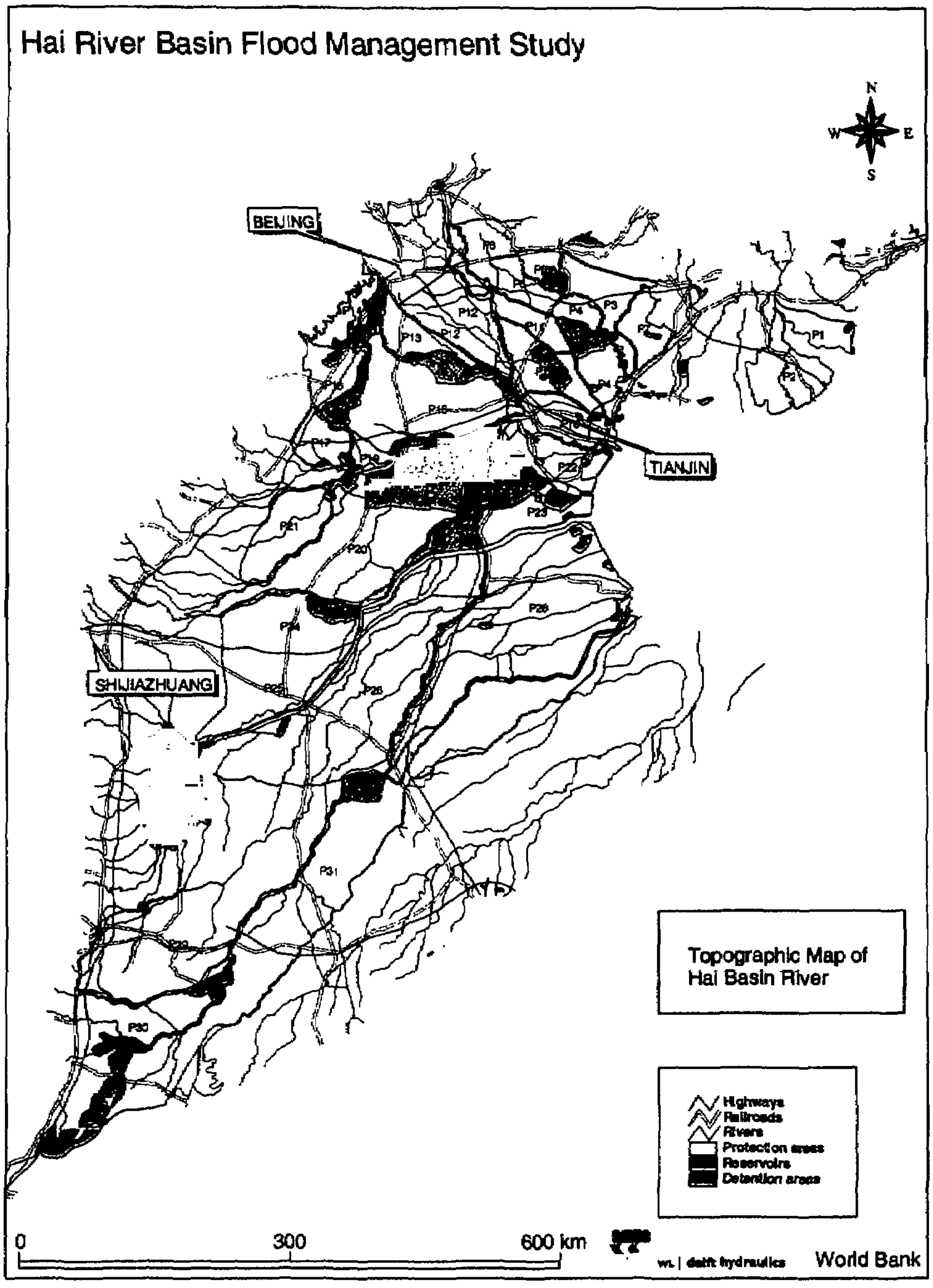
However, given the intensity of economic/social development in the floodplain and detention basins in the 3-H, there is little choice but to continue developing structural intervention programs in parallel with proposed nonstructural solutions. But it must also be recognized that the potential costs associated with such programs are far in excess of the government funding capacity. Thus, the proposed Action Plan calls for a review of current flood protection standards to ensure that key assets in the 3-H basins are adequately protected along with appropriate mechanisms for cost sharing and investment financing.

E. Development of Flood Protection Methodology

The essential purpose of developing a flood protection methodology is to minimize flood damage to key assets by assigning higher protection levels to these areas and lower protection levels to areas with lower-valued assets. It is economically profitable to protect areas with a higher potential damage, such as cities like Tianjin, with a higher safety level than areas with a lower potential damage such as rural areas, hence the concept of zones. For example, some 31 protection areas or zones have been identified in the Hai basin as shown in Figure 5.1 (included here).

Applying this methodology to the Hai basin, for example, based on the loss rate, the total economic value in the protection area and the return time of floods in years, the accumulated annual damage (AAD) are calculated and this represents the "benefit" side of the cost-benefit analysis. Flood loss rates were determined for three different flood depths including (a) below 1.5 m depth (flood is considered serious but not life-threatening), (b) above 1.5 m depth but under 4 m (flood is considered disastrous and there would be casualties), and (c) above 4 m depth, a flood is likely to be catastrophic and it is assumed that economic losses would approach 100 percent, that is, loss of all assets and the value of one year of production. Figure 5.2 MR shows the AAD map prepared for the basin for a flood above 1.5 m but below 4 m depth.

FIGURE 5.1: MAP SHOWING 31 PROTECTION AREAS IN THE HAI BASIN



F. ACTION PLAN FOR FLOOD CONTROL

Basic Principles

The 3-H basins are huge catchments but there is a need for a holistic approach to flood management for the whole basin. It is necessary to consider all the effects of any proposed works on the whole basin, not just the local effect. While the pressure is high to solve problems downstream with physical works, it is beneficial to try to move up the catchment to solve the problems. More and more, engineers are trying to solve hydrological problems by source control rather than use of "end-of-pipe" solutions. Of course there are many problems that cannot be solved immediately by source control but "end-of-pipe" solutions should be seen as a last resort, not the optimal solution.

Siltation is an especially serious problem in the Yellow River basin, resulting in huge problems in the lowlands where continuing heightening of levees would make them increasingly costly and posing an increasing hazard of failure so that, if they should fail, the results would be catastrophic.

Detention basins are a vital part of the flood control system of the 3-H basins, to function as storages from time to time, and there is a need to minimize damage caused by such floods. This can take the form of land-use control to restrict development in the basins but this may not be practical. Another suggestion is to build elevated roads at least 20 meters wide, to be used as internal check dams to limit flooding but more importantly to provide a safe refuge and means of egress from the basins in times of flood.

Priority Projects

Utilizing the principles noted above, Chapter 5 concludes with a preliminary delineation of indicated priority projects for each of the 3-H basins, including both structural and nonstructural measures, with details given in the Flood Management Annex. These include some eight projects for the Hai basin, seven projects for the Yellow basin, and eight for the Huai basin. In addition suggestions are given for "secondary priority projects" including attention to 32 major cities with protection at 10 years or less, as shown in Table 5.4 MR. As noted above, these are indicative preliminary recommendations because the present study is limited to the strategy level. The proposals are summarized in Tables 5.1 and 5.2.

TABLE 5.1 TYPICAL PROBLEMS AND SOLUTIONS

Flood Control Measure	Issue/Problem	Government Strategy
Flood control reservoir	Dam safety; foundation; seepage; earthquake damage; abutment slippage; embankment settlement; inadequate spillway design	Focus on rehabilitation of existing reservoir; accelerate construction of storage and detention basins; harness river courses; increase flood drainage capacity
	Sediment management	Dams for sediment control (for example Xiaolangdi, upper tributaries of Yongding River);
	Scouring	Design/operation modifications
	Multipurpose use	Revise balance between: 1. Flood control 2. Hydropower 3. Water supply 4. Sediment management Using improved flood forecasting and improved standards downstream
Levees	Failure, low engineering standards; lack of maintenance; subsidence; sediment deposition; waterlogging/poor drainage behind levees	1. Strengthening levees; raising levees; dams for sediment control; warping; gated penstocks or outfall structures within levees; 2. Drainage systems to drain local runoff to the nearest outfall; 3. Excavated sumps behind the levees near the outfalls.

Flood Control Measure	Issue/Problem	Government Strategy
River training works, river engineering	1. Instability of river course; protecting from erosion; 2. Restricted capacity of river 3. Falling ocean outfall capacity due to lower flows, high silt content	1. Change in river courses 2. River channel enlargement 3. River diversion channels 4. Ocean outfall maintenance and dredging tidal barrages
Soil conservation	Natural erosion of Loess Plateau	Planting field crops and orchards on high-yielding terraces and plant trees/shrubs grasses on sloped land for fuel, timber, fodder; small dams in gullies

TABLE 5.2: CITIES WITH LOW LEVEL OF FLOOD PROTECTION

Ref. No	Province	City	River	Nonagricultural pop. (1995) (10^4)	Total output of 1995 (10^8)	Flood control standard (year ARI)	Flood loss in 1997 (Yuan 10^8)
2	Tianjin	Tianjin	Haihe	477.56	2363.94	10	1.2
5	Hebei	Xiangtai	Qilihe	36.06	86.64	5	
16	Jiangsu	Nanjing	Yangtze	229.85	764.50	10	
17	Jiangsu	Xuzhou	Old Huang River	100.20	277.00	10	
22	Jiangsu	Dongtai	Taidonghe	22.55	150.00	10	
35	Jiangxi	Jingdezhen	Yangtze	30.57	110.45	5	
36	Jiangxi	Xinyu	Yuanhe	24.11	112.47	10	0.03
37	Jiangxi	Pingxiang	Pingshuihe	47.26	177.30	10	0.8
39	Shandong	Laizhou	Nanyanghe	31.09	235.00	10	
43	Shandong	Zibo	Xiaofuhe	141.78	719.00	10	
44	Shandong	Gaomi	Xiaokanghe	20.57	180.60	10	
48	Shandong	Feicheng	Kangwanghe	31.36	100.36	10	
49	Shandong	Rizhao		32.65	195.10	10	0.28
50	Shandong	Rongcheng	Chuanchenghe	20.81	204.00	10	0.04
53	Shandong	Tengzhou	Chenghe	46.49	110.80	10	
54	Shandong	Zoucheng	Nanshahe	33.14	120.00	10	
55	Shandong	Heze	Dongyuhe	29.23	58.20	10	
56	Shandong	Dongying	Guanglihe	47.10	179.36	10	
61	Henan	Jiaozuo	Qunyinghe	50.91	81.44	10	0.31
62	Henan	Xinxiang	Weihe	55.93	111.72	13	0.2
63	Henan	Xuchang	Qingyihe	25.37	59.56	10	
64	Henan	Luoyang	Yiluohe	95.29	133.20	5	
66	Henan	Kaifeng	Huijihe	55.17	76.68	5	
68	Hubei	Jingzhou	Yangtze	70.41	54.57	10	
71	Hubei	Yichang	Yangtze	45.93	61.79	10	
72	Hubei	Xiantao	Han River	39.81	65.25	10	
74	Hubei	Qianjiang	Han River	30.55	104.50	10	
81	Chongqing	Chongqing	Yangtze	281.11	694.45	5	3.01
82	Sichuan	Chengdu	Min River	205.05	907.89	10	
84	Sichuan	Yibin	Min River	27.43	74.89	6.5	
86	Guizhou	Zunyi	Xiang River	32.70	53.25	10	0.03
93	Qinghai	Xining	Huangshuihe	58.67	57.36	10	0.712

The key gap to be filled is preparation of a comprehensive master water resources development plan for each basin, to ensure that each proposed project would contribute to overall optimal basin development. Meanwhile dependence must be placed on requiring for all proposed new projects, that the individual project feasibility study and its associated EIA include consideration to the extent possible of the overall basin development needs. This is the same strategy as recommended by the November 2000 report of the World Commission on Dams.

6. SUFFICIENT FOOD FOR ALL

A. INTRODUCTION

During the last two decades, despite only marginal increases in inputs of water and land, there have been large increases in agricultural production including crops, livestock, fisheries, and forests. Increases in crop production have been made possible due to higher uses of fertilizers, increased irrigation, agricultural research, and technology transfer. This marginal increase in water supply for agriculture is expected to continue in the future even with possible additional interbasin transfers because the water requirement of current cropping practices far exceeds current and future levels of withdrawals, indicating that this pattern of requirements can never be met. In addition, the government's policy has promoted preferential supply to industry and municipalities in urban centers and so agriculture is likely to continue to have less water allocated and shortages to agriculture would continue into the future (Figure 6.1 MR).

The indication is that existing agricultural practices must continue to change to suit the reality of a limited water supply. With improved protection of intellectual property rights, private investment should be encouraged to fill the gap, as is the trend worldwide. Labor productivity in agriculture is very low in China, generally because of the low land/labor ratio, which is unlikely to change until significant numbers of workers find employment in other sectors. Rural incomes in the 3-H basins were found to be more dependent on crops than the national average and thus households would be relatively more affected by a decrease in water availability. Declining government investments in irrigation affect the operation and maintenance of irrigation infrastructure and new forms of institutional management have evolved to increase community participation to improve the efficiency of management. Increasing the use of water-saving technology is also an effective way to compensate for declining water availability and the government has renewed interest in this potential.

B. IMPLICATIONS OF LESS WATER AND LAND

As discussed in Chapter 4, it seems certain that agriculture would have to cope with a decreasing or at best static water supply in the coming decades. This trend already started in the 3-H basins in the last decade.

Despite this decreasing water supply, crop production has managed to increase or at least be maintained for most years in the 3-H basins. The reasons for this are not entirely certain because there are many variables that can influence productivity including (a) water, (b) fertilizers, (c) energy, (d) labor, (e) land, and so on. According to some studies, yields may be more responsive to these factors than to irrigation, and this indicates why it has been possible to increase crop production even with a diminishing irrigation supply. In order to get more information on these relationships, the government's research program has devised various ways of quantifying the contribution of each input to total yield including short- and long-run elasticity for input factors. The present study has reviewed the several research and development studies on this issue conducted by Chinese and international agencies, and has followed this up by using a combined economic/hydrologic model (the "3-HMS: 3-H modeling system," described in the Annex 3.1, Volume 3) to determine the impact of changes in water availability on crop production in the 3-H basins, in terms of water elasticity for different flow probabilities (Table 6.3 MR). While increased irrigated area contributes only marginally to increased productivity, it is evident that in the 3-H basins, water is the single most important input factor to maintain productivity. These results also show that increasing irrigated area would not increase productivity significantly but that maintaining existing areas with adequate water supply and combining other input factors such as fertilizers, research, and so on should be the focus of agricultural policy in the 3-H basins.

The results of the modeling exercise undertaken to investigate the impact of water for the 3-H basins crop production reveal the following trends:

- Figure 6.1 shows the current mix of full, partial and low irrigated areas in the 3-H basins. Notable features of this map include the fact that the Huai is almost entirely fully irrigated and this would continue in the foreseeable decades. By comparison, the Hai basin comprises a mix of the three irrigation types but partial irrigation predominates. In the next decades, full irrigation areas would almost disappear in the Hai, replaced by low or partial irrigation. Some land may also be taken out of agriculture altogether. The Yellow Basin is unlikely to change. Maps showing 2020 and 2050 scenarios are shown in Annex 6.1, Volume 3.

- More surface agricultural area would be going to rainfed agriculture in the 3-H basins. For a very dry year, the 93.5 million mu (21 percent of cultivated area) in 2000 that rely on rainfed agriculture would increase to some 129 million mu by 2050 (28 percent). The trend is similar for a wet year (P25) where 14.6 million mu (3 percent) would increase to 32.6 million mu (7 percent). In the case of partially irrigated agriculture, the trend is that the current 240 million mu (52 percent) would decline to some 220 million mu (48 percent) by 2050 for a very dry year (P95), and from 90 (20 percent) to 84 million mu (18 percent) for a wet year (P25). As expected, fully irrigated areas would decline from 125 million mu (27 percent) to 113 million mu (24 percent) for a P95 year and from 355 (77 percent) to 345 million mu (75 percent) for a wet year. These results are shown in full in tables and in graphics in Annex 6.1, Volume 3.

- As water resource availability declines, the model shows that total grain production and total production value also decline. In addition, due to changes in the structure of agriculture discussed in Chapter 3, grain production is likely to decline (particularly in the Yellow basin) between now and 2050 even with constant flow probability. The model predicts that total crop production in the 3-H basins, would decline from Y 111 billion in 2000 to Y 108 billion in 2050 for a dry year and from Y 131 to Y 129 billion for a wet year between 2000 and 2050 (Table 6.1).

TABLE 6.1: TOTAL PRODUCTION VALUE FOR THE 3-H BASINS FOR DIFFERENT PROBABILITIES FROM 2000 TO 2050
(Y billion)

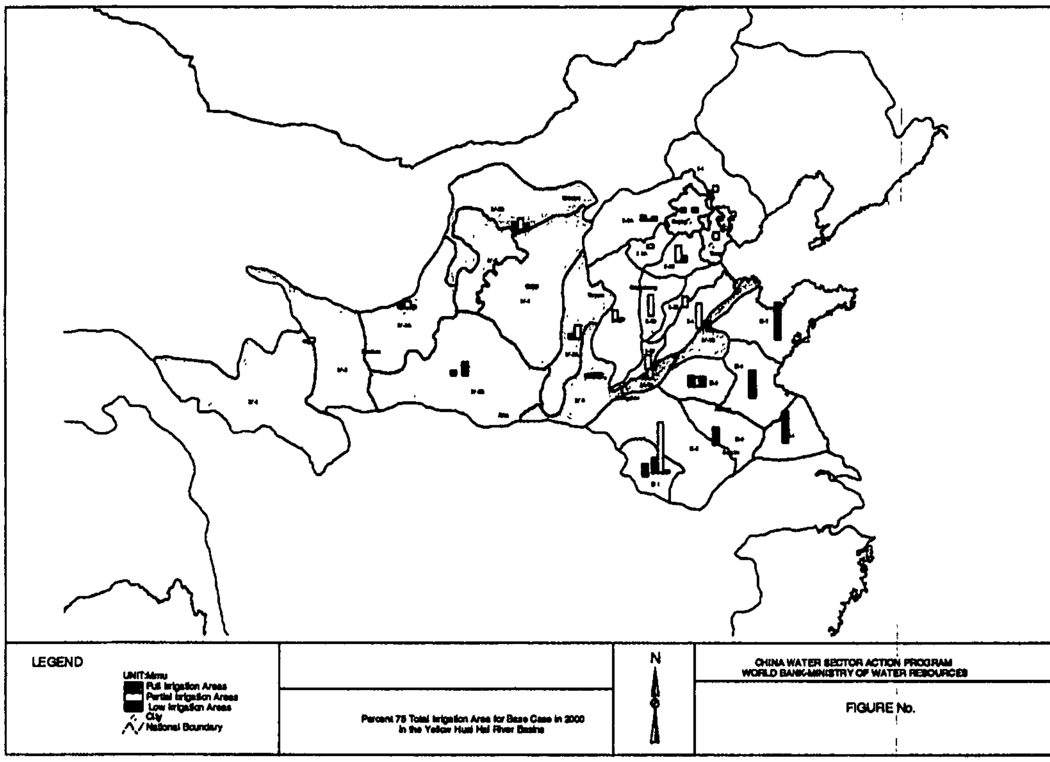
	1997	2000	2010	2020	2030	2040	2050
95% probability	112.0	111.1	112.9	110.5	109.5	108.9	107.8
75% probability	121.9	120.1	123.0	121.3	120.3	119.8	119.2
50% probability	127.5	125.9	127.6	126.6	126.1	125.7	125.4
25% probability	130.8	129.5	131.2	130.5	130.0	129.7	129.4

C. IMPLICATIONS OF WTO ACCESSION

Relaxation of various international trade constraints would permit greater integration with foreign agricultural markets. Details of conditions of China's entry into WTO have not been fully disclosed, but several general conditions have been released, some of which impact on the agricultural economy of the 3–H basins. Certain elements relating to WTO accession would require phasing out of various licenses and trade subsidies and allowing greater private sector participation, including the reallocation of unused State Trading Enterprise quotas to the private sector.

Currently domestic rice prices are similar to international prices, but domestic wheat, corn and soybean prices are considerably above international prices. Therefore, China's grain farmers would face a declining trend for real grain prices over the next several years, encouraging them to improve production efficiency at a rate similar to that achieved internationally by improved water use efficiency.

FIGURE 6.1: TOTAL IRRIGATION AREA IN 3-H IN 2000, P75, BASE CASE

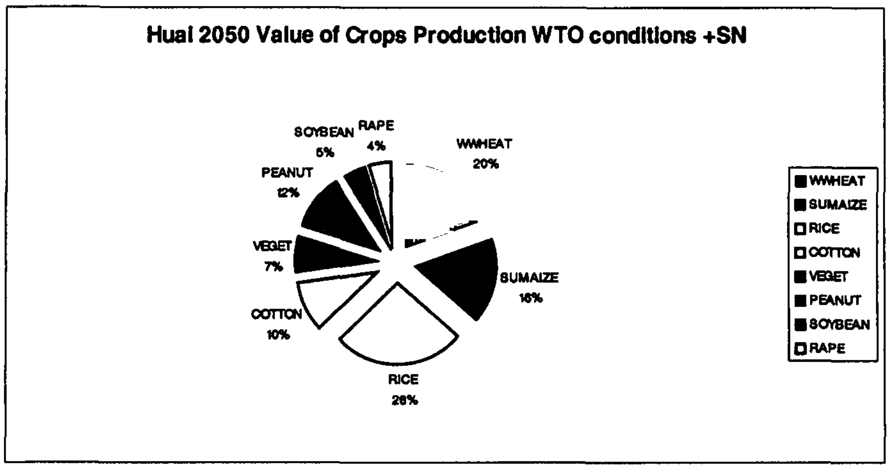


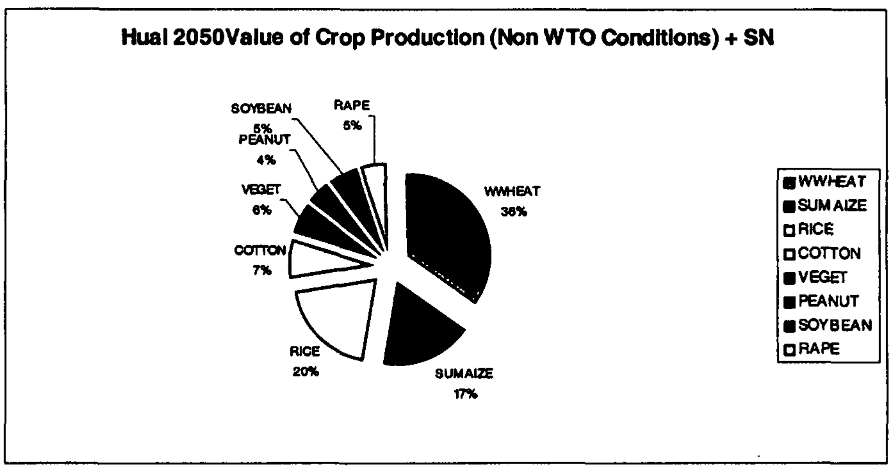
The effect of WTO accession on crop production and prices was projected using 3-HMS (Tables 6.5 to 6.8 MR. Also refer to Table 6.2 below). The results show that WTO accession would accentuate existing trends in decline of prices and crop production in the 3-H basins. Thus, WTO accession would ensure that Chinese agriculture would trend to specialize in production where it has a comparative advantage: mainly labor. See also Figure 6.2.

TABLE 6.2: TOTAL CROP PRODUCTION WITH WTO AND WITHOUT WTO ACCESSION
(Millions of Tons)

		2000	2010	2020	2030	2040	2050
3-H	Non-WTO	122.4	119.0	116.4	115.2	114.5	113.8
	WTO	122.4	116.7	114.8	113.4	112.8	112.1
	% change	0.0	2.0	1.5	1.6	1.5	1.5

FIGURE 6.2: CROP PRODUCTION VALUES UNDER WTO AND NON-WTO CONDITIONS IN HUAI BASIN





In terms of water withdrawals, it is clear that WTO accession would not make such a large difference because production itself would not change significantly. Only the value of the crops would change. This is shown in Table 6.3 below.

TABLE 6.3: CHANGES IN PRESENT VALUE OF CROP PRODUCTION IN THE 3-H BASINS WITH NON-WTO AND WTO ACCESSION

(Y billion)

		2000	2010	2020	2030	2040	2050
3-H Basins	Non-WTO	200.3	199.5	196.2	194.4	193.4	192.4
	WTO	200.3	171.5	169.4	168.0	167.3	166.5
	% Change	0	16	16	16	16	16

D. IMPLICATIONS FOR FOOD SECURITY

A widely accepted definition of household food security is "access to food (and nutrition) required for a healthy and productive life," meaning the ability to grow and/or purchase food as needed. This implies access to a variety of foods (not just food staples) that would provide a balanced nutritious diet. Similarly, national food security means the country has the ability to meet food requirements through production and imports. China is certainly food secure by this broader definition. Over the past decade China's total food trade balance has remained highly positive, although the trade balances of some food categories (animal and vegetable fats and oils) have been continually negative, and the overall trade balance has been positive almost every year. Even considering China's fertilizer imports (China is the world's largest fertilizer importer) as a proxy for food imports, this still leaves an average annual net food export balance.

National food security implies full integration into the international grain markets, which would be automatic when China assumes WTO membership. Furthermore, based on use of general equilibrium (CGE) models, over the next 20 to 25 years worldwide grain production would increase sufficiently to meet all importing country requirements and continue their long-term, real price decline.

Maintaining and improving household food security would depend substantially upon household income levels and whether farmer households are net producers or consumers of grain. Conceptually, lower grain prices imply that households and the nation would improve their capacity to purchase food and thereby improve food security. Farmer households would continue to produce much of their food needs, even in an open domestic and external market environment, but they would allocate more of their productive resources to nonsubsistence, higher-value commodities to improve income.

E. Irrigation with Improved Institutions and Water-Saving Measures

Introduction

The main bulk of Chapter 6 is concerned with improving demand management and use of water-saving technologies to ensure that each unit volume of water supply is utilized as efficiently as possible. The study included evaluation of general conditions of large-scale irrigation districts (Table 6.9 MR).

Based on results generated using the 3-H basins modeling system, the conclusion is that increases in both irrigation area and economic value are likely to result from the implementation of water-saving technology. The key issues related to sustainability in the irrigation subsector are how to: (a) pay for irrigation and drainage improvements and O&M; (b) achieve more efficient management of the irrigation system; (c) increase local participation and "ownership" of irrigation; and (d) design, implement, operate, and maintain irrigation systems to the highest technical, institutional, and financial standards. In addition to improvements in the physical irrigation infrastructure there is a recognized need for irrigation management reforms and current efforts in irrigated agriculture focus on (i) institutional or management reforms, (ii) structural engineering measures, and (iii) nonstructural and nonengineering measures.

Management Reform

There are large potential gains from rehabilitation and completion of irrigation and drainage systems that remain unfinished. Ensuring a more reliable and equitable water supply would reduce the risk of crop failure, increase aggregate agricultural production, and improve rural income distributions. Also, rehabilitation would provide more equitable irrigation water supply to farmers by increasing deliveries to water-deficient areas within schemes, primarily farms located in the lower reaches of tertiary and quaternary canals. Consideration should be given to installation of control structures and water-measuring devices to facilitate trading among members of water user associations or among water user associations.

The need for irrigation management reforms has been strongly supported by MWR. As a result, China has taken a lead in implementing management reform and over the past decade has instituted innovative irrigation management reform programs allowing greater decentralization of decision-making in large-scale irrigation projects in several provinces. Several management models have been tried in large-scale irrigation projects. The responsibility for water resources at the provincial or regional level rests with the water resources bureaus (WRBs). These bureaus has offices in each prefecture and county and water management stations at the township level.

At the provincial level, local governments have supported management reform as they realize greater participation of farmers in the management of irrigation systems is needed if they are to strengthen financial efficiency and overall sustainability of irrigation investments. Management reform models being used are still evolving in China, and are described in general as follows:

- **Contracts**: Management contracts transfer management responsibility to the contractors with the irrigation districts (IDs) retaining property rights for the infrastructure. For a fixed time period (10-30 years) the contractor is given the right to operate and maintain the system. He can: (a) establish irrigation service fees within an agreed range checked by the ID, (b) decide the management principles, and (c) be responsible for profits or losses of the contract. In most cases the contractor is required to invest a specified amount of funds to improve, for example, through lining, the laterals and sublaterals and to deliver a fixed volume of water (or pay a penalty for the difference if he does not meet the stated volume). The contractor hires staff as required and collects a "local" water fee on top of the ID water fee. He also must collect the ID water fees and pass them on to the Irrigation Management Station. IDs operating under this kind of arrangement include (a) the Fen River ID in Shanxi; (b) the Luohuiqu, Jinghuiqu, and Jiaokouchuoqei IDs in Shaanxi; and (c) the Qunan ID in Jiangsu.

- **Leases**: A lease is a slight modification from the contract system with the main difference being that the leased lateral irrigation system infrastructure is usually in much better shape at the time of leasing. Therefore, Management Stations can lease out the right to operate and maintain the system without requiring significant investment, and the expected repayment period is less, with leases tending to be much shorter, 5 to 10 years.

- **Water User Associations (WUAs)**: Water user associations are established to benefit farmers receiving irrigation water from the laterals. The WUA signs a contract with the Irrigation Management Station (usually for 3 to 5 years) that clearly establishes the rights and responsibilities of both parties. In most cases a Representative Council is elected by the members and farmer groups. This is the decision-making organization for the WUA and selects the bosses for managing the irrigation system. Because the leaders are elected by the farmers, this model is most responsive to local needs.

- **Auction Model**: The auction model is used extensively in the Jinghuiqu ID. It is a variation in the contract model where the Irrigation Management Station prequalifies three to four contractors to bid on the O&M responsibility for the lateral canal.

- **Joint Stockholders**: This model converts communal ownership to shares. Portions of the irrigation system are divided into shares and these are sold to farmers, local residents, irrigation section staff and other local officials. Property rights belong to the individuals but the operation of the system is collective.

- **Water Supply Companies** : In contrast to the above five models that are primarily focused on one or two laterals, water supply companies cover a branch or a subbranch and therefore serve all the laterals that take water off that branch, up to 20 laterals. Water Supply Companies (WSCs) have used the Joint Stockholder model in order to raise the larger investments that are required to improve the multiple laterals as well as the branch.

- **Self-Financing Irrigation and Drainage Districts**: The government's strategy is to progress to transform irrigation management agencies into self-financing, independent legal entities. One of several experimental institutions, the self-financing irrigation and drainage district (SIDD) has been successfully piloted for several years and it, or similar institutions, would increasingly be responsible for holistic water management. The structure comprises a water supply company (WSC as described above) and a water user association (WUA as described above). Figure 6.6 MR shows the relations between the WSC and the WUA in the SIDD arrangement for irrigation water supply management as developed in the Tarim basin in Xinjiang province with World Bank assistance. The SIDDs negotiate water use licenses and agreements with prefectures, water resource bureaus, and water management departments and assume sole responsibility for their profits and losses.

- **Overall Evaluation**: It should be noted that institutional reform of irrigation water delivery is already promoting the diversification of clients. WUAs for example would purchase water during the irrigation/growing season but demand would be lower at other times of the year. In some IDs, winter and summer crops may be grown so demand may be maintained all year-round. Thus, depending on the region, climatic factors and type of agriculture, some excess water may be available for sale by contractors who manage the water supply system for irrigation. In such cases, given the continuing need for revenue for O&M of the system, some operators are already selling water to other organizations outside the agricultural sector including hydropower generators, municipalities, and industries/mines. To prevent "overselling" to the detriment of irrigation, a minimum of water must be supplied to irrigation or for conjunctive use and this quantity should be regularly checked by the authorities.

Structural/Engineering Measures

Engineering measures can be divided in (a) water-saving technology focusing on reducing nonbeneficial evapotranspiration and nonbeneficial outflows to the oceans, and (b) supply augmentation. Numerous projects are proposed to increase water supplies and these are discussed in Chapter 4. The large investments into infrastructure required to augment supplies in the 3-H basins, such as the recently completed Xiaolangdi and Wanjiazhai multipurpose projects and the proposed South-North transfers, make water-saving technology an attractive supplementary option (see Annex 6.1, Volume 3). The feasible alternative structural/engineering measures were delineated and evaluated in the Study as discussed in Sections (b) to (d) below.

(a) Comprehensive Agricultural Development (CAD) (Tables 6.10 to 6.12 MR)

CAD, promoted since 1988 by the State Office of Comprehensive Agricultural Development (SOCAD), is a strategic measure which aims to support and protect the development of agriculture by improving (a) agricultural production; (b) farmers' incomes; (c) economic and ecological benefits of agriculture; (d) use of a wider resource base; and (e) minimization of constraints to agricultural development. CAD was authorized in 1988 by the State Council, which decided to implement large-scale agricultural comprehensive development in key areas like the 3-H basins. The CAD initiative stemmed from (i) the fact that the population had been increasing for years while cultivated land area decreased, and (ii) the poor condition of large areas of farmland had reduced yield, particularly related to lack of irrigation and lack of drainage.

The CAD program includes soil improvement and multi-operation and "dragon-head" items, which may be summarized as follows (Tables 6.11 to 6.12 MR):

- Engineering works in water conservancy construction projects, such as small-scale reservoirs, drainage and irrigation canal systems, drainage and irrigation stations, transformer stations, pumped wells, agricultural power lines; underground drainage or irrigation pipelines, and so on (Table 6.11 MR).

- Engineering works in agricultural construction, such as farmland leveling, soil improvement, farmland roads, sunning ground, warehouses, and so on.
- Engineering works in pasture construction, such as grassland improvements, and water storage pits.
- Improvements in agricultural mechanics construction, such as equipment for excavation, leveling, cultivation, sowing, planting, crops gathering, transportation, agricultural products processing, and others.
- Use of advanced and practical technologies for improving agriculture, forestry, animal husbandry, and fisheries.

The CAD program is financed from a farmland occupation tax, submitted to the central government since 1988.

The basic target of the CAD program in the tenth five-year period is to improve 182 million mu of farmland, originally with medium and low yields, by use of water-saving irrigation and by production of higher-quality agricultural products. CAD investment would be approximately Y 168 billion. The financial sources include (a) Y 48 billion from central government's finance, (b) Y 48 billion from local governments' finance, (c) Y 48 billion from bank loans, and (d) Y 24 billion from collectives and farmers themselves.

(b) Water-Saving Technology

Since 1996, the government has renewed interest in water-saving development due to increasing water shortages. In 1996-97, about 50 million mu of water-saving irrigation were developed, including 30 million mu by canal lining, 14 million mu by low-pressure plastic pipes, 6 million mu by sprinklers, drip irrigation, drip under plastic film and micro-sprinkler irrigation. By the end of 1997, irrigated areas receiving water with some form of water-saving technology totaled 200 million mu. The government plans to increase this area to 300 million mu by 2010.

Given that agriculture accounts for some 80 percent of water requirements in China, and that 30 to 40 percent of this water is lost to nonconsumptive uses, there is ample incentive to improve consumption patterns in China. Water-saving incentives would increase with higher prices for irrigation water and this is discussed in the next section under water demand management. Much literature is available in China on water-saving technology and most techniques have been tried since the early 1970s. Field data on effectiveness of water-saving technology are not readily available because over the last 20 to 30 years, the emphasis has been on water supply rather than water conservation. Despite major investments in infrastructure, only about 80 percent of the agricultural water requirements are satisfied and in the last decades in the water-scarce areas of the north including the 3-H basins, agriculture has become the default user where municipal and industry uses are satisfied first. Faced with this declining water supply scenario, management of water for irrigation is beginning to focus again seriously on water-saving technology. However, improving efficiencies of local schemes would result in only modest water savings for the entire water basin. This is because most of the losses from inefficient irrigation schemes return to the hydrologic (surface or groundwater) system and are available to downstream users. The actual water savings (available for incremental use) within a water basin are derived only from reduced amount of nonbeneficial evapotranspiration and nonbeneficial outflow to the ocean. Actual water saving can be generated only through agronomic and irrigation management measures that improve water use efficiency and reduce nonbeneficial evapotranspiration; for example, improved crop genetics, plastic and organic mulching, irrigation scheduling and farm best-management practices. These are described in the following sections.

The benefits of the water-saving development measures described above are tabulated for 1998 and 1999 in Table 6.4 (for details, refer to Annex 6.2, Volume 3). Planned investment for the tenth five-year plan and beyond are shown in Table 6.14 MR (for details, refer to Annex 6.2, Volume 3). In order to increase the use of the water-saving measures/technologies described above to more IDs, a total of Y 25 billion was invested from 1996 to 1998 for water-saving irrigation projects all over China. Some Y 7 billion came from local governments, Y 5.3 billion from loans by the National Agriculture Development Bank and the Chinese Agriculture Bank and Y 12.7 billion was pooled by communities.

TABLE 6.4: WATER-SAVING DEVELOPMENT IN 1998-99
Unit: 10,000 mu

Province	Water-Saving Irrigation Area up to 1998					Water-Saving Irrigation Area up to 1999				
	Canal lining	Pipeline irrigation	Spray irrigation	Micro-irrigation	Sub-total	Canal lining	Pipeline irrigation	Spray irrigation	Micro-irrigation	Sub-total
Total China	13,051	6,814	2,260	171	22,295	14,573	7,451	3,395	309	25,728
3-H	4,342	5,603	1,232	144	11,321	4,907	6,000	1,830	193	12,930
3-H-a	2,858	4,830	936	84	8,708	3,189	5,137	1,318	114	9,757
3-H-b	1,484	773	296	60	2,613	1,718	862	512	80	3,173

(c) Water-Saving Improvements in Large Irrigation Schemes (LISs)

In 1996, there were 220 large irrigation schemes with a total irrigation area of 160 million mu, comprising at least 300,000 mu of effective irrigation area. Both cotton and crops grown in these LISs comprise 20 percent of China's total capacity. These large schemes have required large investments for operation and maintenance which have not always been forthcoming and over the last several decades many have developed problems related to water source, canal lining, drainage, and structures along the canals (Table 6.16 MR). MWR's department of agricultural water was put in charge of this program with responsibilities for progress identification, inspection and appraisal. The initial estimation of funds required came to Y 35 billion over 15 years to rehabilitate 220 selected LISs with issues identified and measures required for rehabilitation (Tables 6.16 and 6.17 MR).

(d) Improved Water Supply Management

On the supply side, there are several approaches for improving supply management including (a) a water licensing system needs to be made fully effective in reducing groundwater extractions to sustainable levels to prevent further environmental and urban infrastructure damage; (b) managed expansion of groundwater capacity in rural areas can promote conjunctive use of surface and ground supplies; (c) in wet years, farmers could rely on surface water and allow groundwater to recharge; in dry years when river flows are low, groundwater could be pumped to maintain minimum irrigation supplies; (d) rehabilitation of the irrigation system can reduce losses and permit more timely water supplies; and (e) treatment, distribution and reuse of urban wastewater can feasibly produce water of sufficient quality for use both in industries and agriculture.

Nonstructural Measures for Agriculture

Demand Management Pricing. Chapter 4 argued for a shift in focus away from planning to reduce water shortages by increasing consumption, to an emphasis on water demand management. This means that, no matter what increases in supply are forthcoming, there would always be shortages, inefficiencies and misallocations unless demand is managed. The most effective tool in demand management is price, but prices need to rise much more in order to recover the full costs of water supply, and restrain demand to manageable levels. The agricultural sector must pay higher prices along with other sector users. This would provide the badly needed funds for system rehabilitation and maintenance, and the market signals on higher prices would help guide the sector toward necessary adjustments. As noted earlier, almost all the IDs price their water below cost recovery and some examples of price cost ratios have been tabulated.

As previously emphasized, the low price of water for agriculture, industry and domestic uses is preventing efficient use of the resource. Pricing is the most efficient demand management tool and while water prices are starting to reflect the true cost of supply for some sectors, this is still not the case for most irrigation districts supplying water for agriculture. The reasons for this are justifiable in some cases but because irrigation is the biggest user of water in the 3-H basins as in other parts of China, pricing water to reflect delivery costs and resource utilization costs would have very significant impacts on overall water resource sustainability. Various procedures and guidelines relating to water charges and the financial viability of water institutions have been issued and used over the past several years. Legally, water charges are to cover all water supply costs, but water charges in many provinces remain below the costs of supply and account for only a fraction of the opportunity cost of water during critical periods. On the other hand, farmers are faced with an increasing number of levies and fees and their capacity to pay is under government review. Irrigation water measurement is essential for implementing a competent charging system and is becoming steadily more widespread. However, in many systems the measurement is undertaken at major offtakes and branches and the farmer pays a flat rate per mu for each type of crop, with the cost calculated according to standard amounts water delivery for each individual irrigated crop. In more sophisticated schemes, water is measured at the field turnout, which permits the farmers to be charged according to actual water use which provides a strong incentive for careful water management.

In general it seems to be accepted that the cost of water for use in irrigating grain crops should be set according to actual cost of water supply. Cost of water for more financially attractive crops would then be set at a level that captured some of the higher profitability of such crops.

Water prices for agriculture varies in different regions in China and for different crops reflecting (a) the unevenness of regional distribution of water resources, (b) the difference in level of economic development between regions, (c) the cost discrepancy between development and utilization of water resources, and (d) uneven government policies in water price formulation and decision-making. The study concludes that price does reflect scarcity and willingness to pay.

Another study for the 3-H basins shows a consistent pattern of water demand response to higher prices, per unit area. Increasing the price per cubic meter beyond, say, Y 0.15/m^3 up to Y 0.40/m^3 would reduce consumption per unit area, provided the price is clearly related to the quantity used by the farmer, and if the price signal is not distorted by other charges lumped on the farmer. For prices up to Y 0.15/m^3, however, the response in water demand may be negligible.

A key aspect that needs to be strengthened in conjunction with water pricing measures is water measurement and volumetric water charging. Although everywhere in China irrigation water charges are stated in terms of cubic meters of water use, in reality there is a major lack of adequate water measurement at the lower end of the irrigation systems and the actual calculation of the water charge is based on the irrigated area and an average water usage rate, rather than on a measured delivery amount. Although there are no accurate data that can be generalized, anecdotal data have shown in China that when transparent water measurement and volumetric charging are introduced in specific areas where there are no major water shortages, in conjunction with water user associations, there is a reduction in the amount of water used.

The study also shows that where irrigation water is the limiting factor, and irrigable or potentially irrigable land is unable to be supplied with water, additional water supply is likely to lead to an increase in the area irrigated. The returns to water use, the returns to irrigation schemes, and the returns to the economy are maximized by practicing deficit irrigation on a larger area, rather than by fully irrigating a smaller area.

In the 3-H basins overall, since there are significant water shortages in all areas and about 15 percent of irrigation areas do not receive water at all, raising the price of irrigation water would probably not reduce the aggregate demand for irrigation water. Nonetheless, it could be very beneficial in that this would (a) encourage more efficient water use and enable a more efficient allocation of water, (b) provide funds to irrigation companies enabling improved maintenance and repairs, and (c) enable more land to be irrigated, and overall could result in increased production. Increased efficiency of water use enables water allocations to irrigation companies to be reduced and diverted to other uses, without necessarily reducing the value of national agricultural production.

F. AGRICULTURAL ACTION PLAN

Introduction

Based on the information given above, an indicative Agricultural Action Plan has been formulated comprising two components: (a) continued/enhanced commitment to the government's existing program, and (b) an integrated comprehensive approach.

Continued/Enhanced Commitment to Existing Program. The present study concludes that the government's current program for comprehensive agriculture development addresses fundamental problems in irrigated agriculture in a realistic way; hence the proposed Agricultural Action Plan recommends accelerated and increased commitments to achieve the goals and objectives of its three main components: (a) CAD, (b) improvements in irrigation water-saving measures, and (c) increased use of LISs (Tables 6.5, 6.6, 6.7). This is expected to result in a 10 percent increase in water use efficiency, including significant increases in grain production (for example, for the Huai basin, average winter wheat production would increase from 1.5 to 1.7 kg/m^3 (Figure 6.9 MR).

TABLE 6.5: ADDITIONAL INVESTMENT TO EXISTING SOCAD, WATER-SAVING AND LIS PROGRAMS PROPOSED BY THE ACTION PLAN
(10^8 Yuan)

	2001-2005	2006-2010	2011-2015	2016-2020	2021-2025	Total
SOCAD	106.0	57.8	49.5	45.1	40.4	298.8
Water Saving	166.6	231.2	211.4	146.3	152.6	908.0
LIS	264.0	292.8	280.9			837.7

TABLE 6.6: RESULTING TOTAL LAND IMPROVEMENT (SOCAD AND WATER-SAVING)
(1,000 ha)

	2000	2001-2005	2006-2010	2011-2015	2016-2020	2021-2025	Total
SOCAD	7,152.7	2,355.7	1,185.1	943.7	751.4	598.3	5,834.2
Water Saving	7,737.0	2,468.0	3,082.4	2,562.7	1,695.8	1,695.1	11,504.0

TABLE 6.7: RESULTING TOTAL LAND IMPROVEMENT (LIS)
(1,000 ha)

	2000			2001-2005		2006-2010		2011-2015		Total	
	Present(1)	Newly(2)	Improvement(3)	Newly	Improvement	Newly	Improvement	Newly	Improvement	Newly	Improvement
LIS	5,199.7	331.9	871.1	207.4	1,299.9	239.9	1,039.9	416.9	780.0	864.20	3,119.82

Note:
(1) Present: Existing large Scheme Irrigation Area in 2000;
(2) Newly: Large Scheme Irrigation Newly Increase Area From 1996 To 2000;
(3) Improvement: Large Scheme Improvement Irrigation Area From 1996 To 2000.

The improvements noted above would result from improved on-farm works efficiency including (a) land leveling, (b) use of standardized farm sizes, (c) partial irrigation for dry crops, (d) modified rice irrigation, (e) modified agricultural cropping patterns, (f) soil and soil moisture improvements, (g) sprinkler and micro-irrigation, and (h) canal system improvements.

These measures would be carried out as part of an "integrated comprehensive approach" as described below.

Integrated Comprehensive Approach

The proposed Integrated Comprehensive Approach is different from the present National Irrigated Agriculture Water-Saving Program, which mainly focuses on engineering measures to save water. The Integrated Approach embodies three sets of measures, namely (a) physical improvements to irrigation and drainage systems and on-farm facilities, (b) agronomic measures, and (c) irrigation management measures. These are to be implemented together with the needed water pricing adjustments. Experience in China and elsewhere has proven that all of these measures can make valuable contributions to achieving more efficient irrigation practices.

The physical improvements, each described in detail, include (a) improved canal lining, (b) improved surface irrigation techniques, (c) alternative irrigation techniques, (d) high-rate surge inflow systems, (e) conjunctive use of surface water and groundwater, (f) precision land leveling, and (g) input substitution (substitution of capital and technology for land and water).

Agronomic measures, described in detail, include (a) improved cropping patterns that make more efficient use of water in terms of realizing higher market yields, and (b) a variety of other measures including nontillage in the dry season, deep plowing in the rainy season, soil fertility improvements, organic and plastic mulching, seed improvements and development of drought-resistant varieties, balanced fertilization, improvements in planting cultivation techniques, changes in cropping patterns, and forestry shelter belts around fields to slow wind velocity and reduce evaporation.

Improved irrigation management measures include two types: (a) irrigation and drainage system management improvement, and (b) on-farm irrigation management improvements. Irrigation management improvements include water measurement, volumetric water price and institutional development. On-farm irrigation management improvements include soil moisture control and management through irrigation scheduling with the help of improved irrigation methods.

As noted earlier, setting water prices to offset water costs is absolutely essential for China's water utilization future, including the increase of irrigation water costs to appropriate levels.

The present study applied the Integrated Approach to each 3-H basin under different P75 scenarios as shown in Table 6.25 MR. This included preparation of a tabulation that gives an overall evaluation of the proposed Action Plan (Table 6.25 MR).

7. CLEAN WATER FOR ALL

A. INTRODUCTION

The current water quality situation in the 3-H basins was reviewed in the study and it was concluded that although some progress has been made in controlling pollution from urban, industrial and rural sources, many sources of pollution remain uncontrolled. The result is that during the past several decades, along with increasing population and industry, water quality has been declining in almost all rivers in the 3-H basins. This chapter reviews current attempts to control pollution and proposes an action plan to improve the effectiveness of the current government strategy to achieve the designed goal of enough water of adequate quality to meet all important beneficial water uses.

B. CURRENT WATER POLLUTION CONTROL IN 3-H BASINS

Water Polluting Wastes

The control of wastewater generate by people and industries in the 3-H basins is primarily aimed at reducing water pollution and improving public health. This is a complex process in the 3-H basins as elsewhere, utilizing structural and nonstructural components that are described below.

Structural control of water pollution depends on facilities for management of sanitary and industrial wastewaters, as well as management of solid wastes, in urban and rural areas.

Management of sanitary wastewaters (excreta and kitchen wastes) in urban areas is usually accomplished by providing a municipal sewerage system, including collecting sewers, interceptors and pumping plants, a treatment plant, and facilities for final disposal of treated wastewater and digested sludge, which serves homes and buildings that are connected to the system. Homes and buildings that are not connected utilize on-site individual building disposal units, such as septic tanks, with final disposal by leaching into the ground through the use of pits.

Municipal solid wastes are managed by the municipality's solid waste collection and disposal system. Uncollected solid wastes are commonly flushed by surface runoff into drainage channels, then into streams. Water quality evaluations in river basins often overlook the role of solid wastes, which can be very significant.

Industries in urbanizing areas may utilize on-site treatment systems for managing their sanitary and industrial wastewaters, and/or discharge the wastewaters into the municipal sewerage systems. Similarly they may manage their own solid wastes or deliver them to the municipality for treatment and disposal.

Rural towns often have no public sewerage system and management of excreta and solid wastes is usually left to those in charge of individual homes and buildings.

The primary pollution in wastewaters produced by people is organic matter (expressed as BOD or COD), which is biologically degradable, and the treatment afforded by municipal WWTPs is essentially to remove this BOD including removal of settleable solids and floatables (such as oils, and grease).

The primary pollution in wastewaters produced by people is organic matter (expressed as BOD or COD), which is biologically degradable, and the treatment afforded by municipal WWTPs is essentially to remove this BOD, including removal of settleable solids and floatables (such as oils and grease, and so on).

The wastewaters from industry include degradable organics, but may also contain substances that cannot be received or treated by municipal WWTPs, including toxics, explosives, and corrosives. Industries should remove these materials by in-plant treatment prior to discharge of wastewaters to the environment or to municipal sewers.

Because of economy of scale; it is commonly advantageous to both the municipality and industry for the industry to discharge its wastewaters (without the unacceptable substances) to municipal sewers, with the municipal WWTP removing BOD or COD from both types of wastewater with very significant savings to both, especially where the industrial wastewater contains large amounts of degradable organics.

In order for the municipality to be able to receive industrial waste inflows to the advantage of both the municipality and industry, the municipality must establish a permit system that requires the industry to remove objectionable materials before discharge to the municipal system (or discharge directly to environment) and that including includes effective monitoring. It would also include provisions for payment by the industry to the municipality for the service rendered.

With respect to the first paragraph in this section on control of water pollution wastes, although sizable investments are often made for building and operating municipal sewerage systems, the municipality gives little attention to the functioning of the unconnected homes and buildings that use on-site units. These units often fail to function properly, resulting in overflows of the wastes into the drainage system, which may often be enough to negate much of the water pollution improvements that the WWTP is supposed to make. A competent municipal system therefore includes provisions for appropriate management of on-site units. (In the United States this is a function carried out by local health departments.)

Situation in 3-H Basins

Water pollution control in the 3-H basins is only very partially effective. The municipal sewerage systems often serve only the affluent portions of the city, and the WWTPs are often limited to primary treatment (removal of settleables and floatables), which removes about one-third of the BOD and COD. Industrial wastes are only partially controlled in many areas, and many rural towns lack any meaningful structural investments in waste management. In 1997 investment in municipal sewerage facilities amounted to only 0.22 percent of GDP. The present study included collection and collation of information on existing municipal WWTP systems in the 3-H basins (Table 7.1 MR).

The main report notes that recent State Council Circulars (July 18 and November 7, 2000) indicate that the government is serious about improving the rate of wastewater treatment in China. MOC, SEPA and MOST (Ministry of Science and Technology) jointly issued a document on "Technical Policy on Urban Wastewater Treatment and Pollution Control". It is stated in this national policy paper that up to 2010, the wastewater treatment rate in all cities should not be lower than 60 percent, and for key cities not lower than 70 percent. For cities, secondary treatment facilities must be built and for enclosed or semi-enclosed water bodies, enhanced secondary treatment with phosphorus and nitrogen removal facilities should be provided. For cities directly under the administration of central government, provincial capital cities, cities separately listed in the national plan and the key tourist cities, the wastewater treatment rate should not be lower than 70 percent. From now on, at the same time cities plan construction of new water supply facilities, they should also plan to build corresponding wastewater treatment facilities. For water-short regions, at the same time urban wastewater treatment facility construction is planned, wastewater reuse facilities should also be provided.

Detailed information on industrial wastewater production is given in Volume 3, Annex 7.4 which shows that currently the paper industry produces by far the largest COD load. Other industries of concern are food, pharmaceuticals, chemicals and tanning. Those industries, however, are dwarfed by the paper industry. This is a reflection of the manufacturing process, including age of equipment and the raw materials, used for making paper and pulp in China. Ownership, such as private or state, and size of the enterprise have a lot to do with the end-of-pipe treatment and cleaner production used in all industry categories. The WPM-DSS proposes that management of both community and industrial wastewater in both urban and rural areas must be significantly improved in the next ten years. At the present time, industrial WWTPs do exist to some extent. The model reflects this because the SEPA survey (on which the WPM-DSS model is based) sampled effluent industries discharging over 100 m^3/day. Unfortunately many of these industries were designed without attention to waste management, hence the need to replace or modify the WWTPs to utilize cheaper production technologies, together with provision for adequate end-of-pipe treatment for wastewater discharged to the environment or municipal sewers. There is evidence to suggest however that industry COD production intensity (COD kg/Y 10,000) has decreased over the last decade because of (a) modernizing the production process and (b) internal recycling of wastewater, which is driven by water scarcity and not so much by penalties from regulatory authorities. In addition to the serious problem of discharge of untreated wastewater from large industries, even less attention has been given to the smaller industries including TVEs discharging less than 100 m^3/day, which number in the thousands. Also, little if any attention has been given to organic waste discharges from animal husbandry operations, which contribute a sizable portion of the BOD and COD reaching the rivers (even though such wastes could readily be treated at the animal farm sites by simple ponding which could reduce the BOD and COD up to 90 percent).

This chapter summarizes the components of the Chinese institutional regulatory system for the management of wastewaters (Table 7.2 MR). This system appears to be patterned after Western practices (which achieve the desired control), including the use of emission and ambient standards and the use of the EIA process, but the overall control program leaves much to be desired for achieving effective control for a number of reasons including the following:

- Insufficient attention to monitoring and enforcement of the applicable governmental laws and regulations, including ineffective use of the permit system for industries; hence ineffective monitoring and control of industrial wastes, due primarily to limited budgets and staffing of the provincial and local EPBs that are charged with carrying out these controls, especially inattention to TVEs, smaller industries of under 100 m^3/day discharge, and animal farms. Experience everywhere in the Western world (for example, the United States) has shown clearly that without effective monitoring and enforcement, no system of governmental regulations, no matter how comprehensive, would mean very much. The saying in California is "no effective monitoring and enforcement, no effective compliance." It should be noted here that, although effective monitoring and enforcement is routine in the industrial countries because this is the salient element of control, to this date not a single developing country has been able to devise and implement effective monitoring and enforcement mechanics for environmental pollution control. It is timely now for China to face up to this issue.

- The wastewater discharge standards set by SEPA for wastewater management appear to be more or less emulations of practices in affluent industrial countries. To a considerable extent, they are not realistic and appropriate for use in much of China. If standards are appropriate they can be meaningfully applied by waste producers; otherwise they are counterproductive and evaded. Similarly the existing system of ambient standards for river water quality classifications appears inappropriate and should be modified to suit the current situation on water and water pollution management in China.

- Lack of coordination of river water quality monitoring carried out independently by MWR and SEPA, resulting in serious gaps in data acquisition and in redundancy wastage.

The modeling program of the present study (Figure 8.1 MR), described in Volume 3 Annex 7.1, indicates that under the existing situation in the 3-H basins, water pollution in the rivers (and shallow groundwaters) is already unacceptably severe and with increasing growth of people and industry the pollution can only get worse. Under the current government program, pollution load reductions are likely to be insufficient to improve water quality to restore beneficial uses of water bodies, even to prevent them from getting worse. The major measures that are needed for meeting the desired water sector management goals include structural, nonstructural and institutional measures (Table 7.4 and 7.5 MR).

C. The Need for Modeling with a Knowledge-Based System

Generally, a model can potentially forecast the impact of proposed management scenarios prior to implementation, offering guidance to planning and saving planning agencies from making costly mistakes. However, choosing a model can be difficult. This is because (a) the algorithms used do not always represent the chemical, physical or biological system being modeled since they may have been derived from site-specific information that is not necessarily transferable; (b) the input data required to drive the model may not be available or reliable; (c) the level of uncertainty associated with the modeling process is often restricted to sensitivity analysis without considering overall uncertainty inherent in items (a) and (b) above; (d) the modeling process and output of the model may require too much foreign expert involvement, leaving the local agency without "ownership" of the recommended management strategy.

One type of modeling approach that serves equally well as a predictive technique and that can avoid the potential failures of the conventional models described above is the "knowledge-based" approach (KBA). According to Ongley et al. (1999)[8], this type of approach acknowledges uncertainty by relying on locally available data and expertise and creates models that recognize uncertainty from the beginning. In addition, KBAs recognize that policy decisions are driven by confident, affordable and realistic management solutions that would cause a desirable shift of water quality from class V to class IV, for example, with minimum uncertainty. In addition, through ownership of the model development process, local agencies gain improved confidence in the proposed management scenarios.

Following discussions with MWR, a simple spreadsheet pollution load forecast model based on the KBA as described above was judged more appropriate than commercially available water quality models such as MIKE or SWMM and AQUALM because (i) it provided greater accessibility to the model and allowed future modification, (ii) it assisted with data in disparate form, (iii) it reflected current practices and data types in China, and (iv) it allowed integration of investment with future scenario analysis. The model needed to be capable of (a) tracking gross water usage by sector, (b) evaluating water demand strategies, (c) calculating gross waste production in terms of COD and volume by sector, (d) calculating waste discharge and loads to rivers with provision for various waste treatment and reuse scenarios, (e) calculating investment cost accumulation for municipal/industrial waste treatment and collection system, and (f) summarizing results at a city; control unit, subarea or level-2 basin degree of detail. The WPM-DSS spreadsheet model is presented in Volume 3, Annex

---

[8] E. Ongley and W. Booty; 1999. "Pollution Remediation Planning in Developing Countries: Conventional Modeling Versus Knowledge Based Prediction," *Water International*, **24**, 31-38.

7.1. The model provides a systematic compilation of water use data consistent with basinwide water assessments, calculates COD loads and wastewater quantities for major sources. The model was run by CRAES, the World Bank and GIWHP in a "forward" usage where pollution from urban and rural industry and municipal and livestock sources were subjected to intervention (called Programs 1, 2 and 3) from WWTP, reuse and pollution prevention programs and the resulting water quality improvements were determined.

D. ACTION PLAN PRIORITIZATION

The construction of pollution prevention infrastructure is one of the components of the proposed action plan. But as noted above, pollution is not the only issue facing the 3-H basins. As pollution levels increase, the resource available for water supplies decreases also. Water supply companies have to find cleaner intakes farther away from the pollution discharge sources, which are usually located around the towns and cities. Alternatively, groundwater has been increasingly relied on in the last decades to supplement declining surface water availability. In addition, heavily polluting cities upstream from intakes for irrigation and urban uses impact much more on the public health of downstream citizens. Thus, pollution is linked to water shortages and declining groundwater tables; and in order to maximize the effect of pollution abatement measures in the shortest time frame at least cost, there is a need to acknowledge these links and propose a priority list of cities that overall have the worse environmental problems; that is, not just pollution problems.

The WPM-DSS produced a list of cities with high COD and toxic pollution generation and further prioritizing of these cities was done by selecting those with the highest loads. Overall priority for the action plan was determined by scoring cities on the basis of (a) public health, (b) environment, and (c) sustainable water resource use, with public health protection being the most important in the hierarchy of needs. The priorities and assigned weights are shown in Table 7.1 below and the overall selection of priority cities are shown in Table 7.2.

E. PROJECTED LOAD GENERATIONS UNDER THE "BUSINESS AS USUAL" SCENARIO

The *base case* or *business as usual* scenario, also called Program 1, represents our understanding of the current situation with respect to pollution management in the Hai and Huai basins and projected trend of government programs and aspects of economic growth that impact on wastewater production and pollution loads as measured by COD. In the case of large industry, indications are that trends are favorable from an environmental perspective. Industries have already begun to reduce their COD intensity[9] due to modernizing of manufacturing processes and internal reuse of wastewater encouraged to a great extent by water scarcity, in addition to favorable reaction to regulatory enforcement. This is shown in Figure 7.2 below with pollution data derived from SEPA and statistical data on industrial GDP.

[9] COD intensity is COD kg/10,000 Yuan of production.

FIGURE 7.1: WATER POLLUTION MANAGEMENT MODEL DECISION SUPPORT SYSTEM (WPM-DSS)

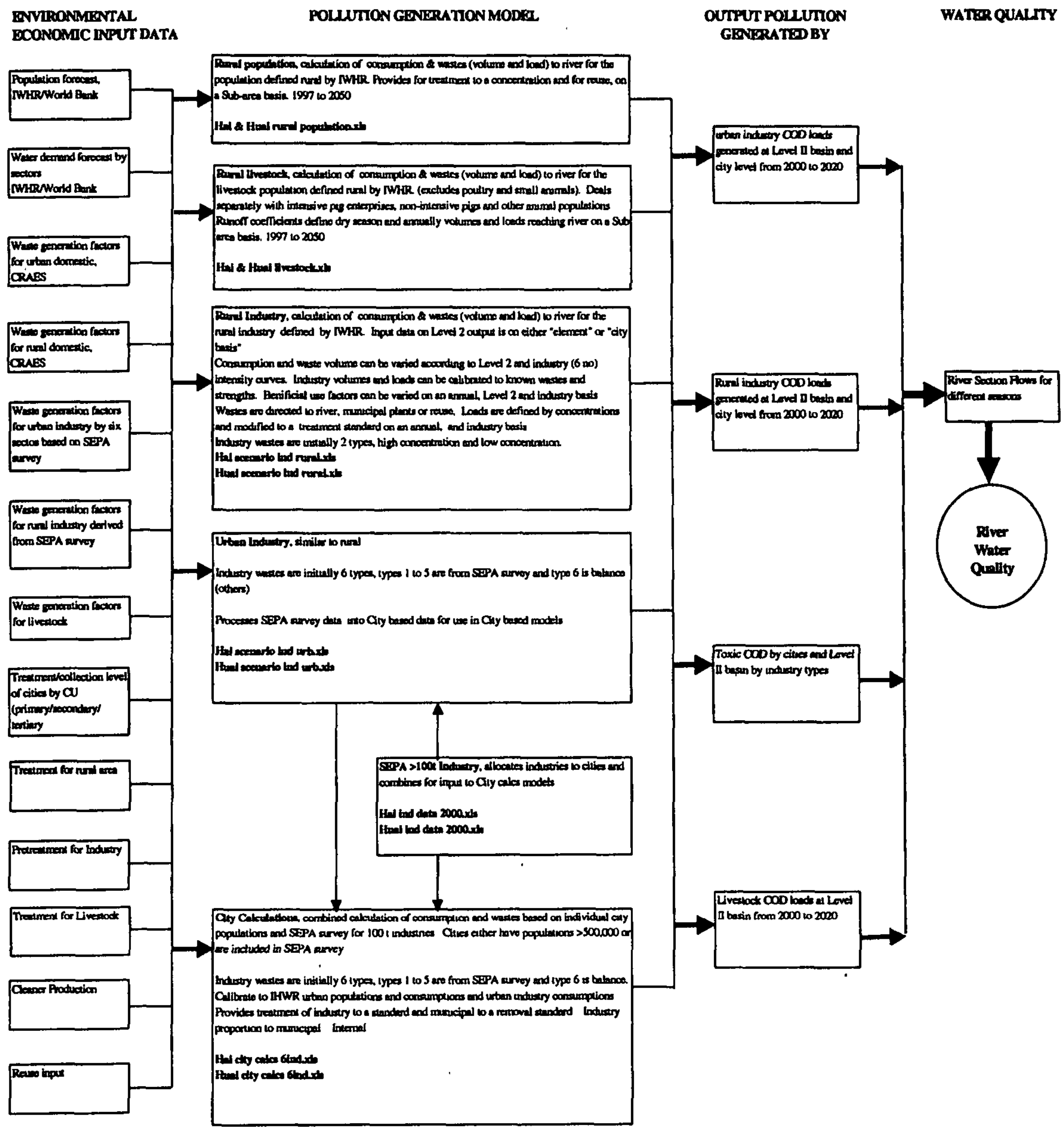


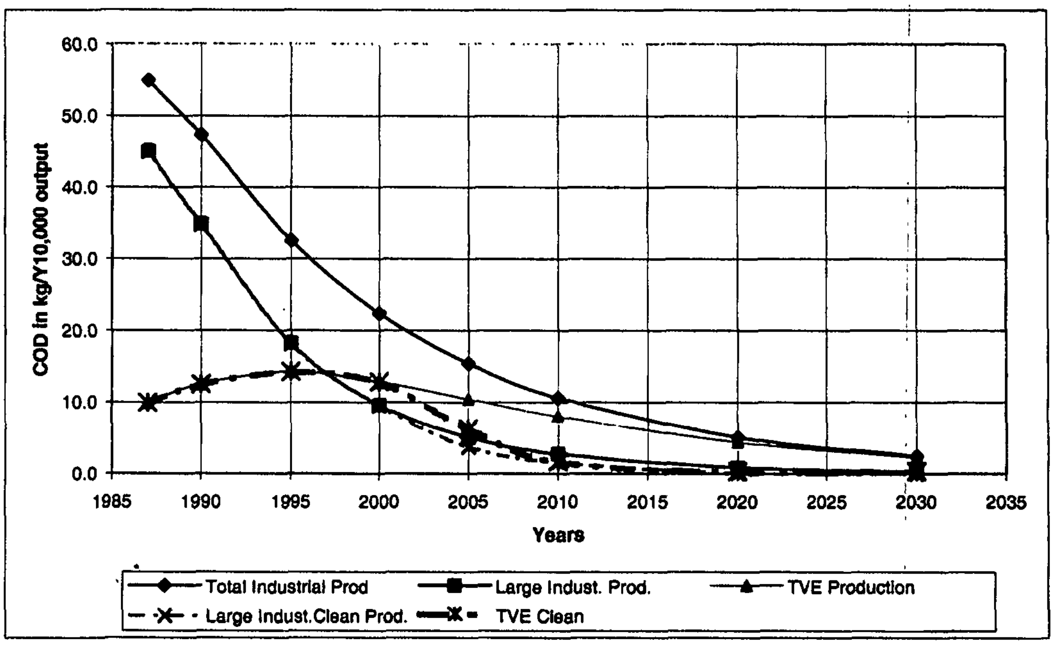
TABLE 7.1: PRIORITIZING CRITERIA USED TO SELECT CITIES/REGIONS FOR THE ACTION PLAN

Issues	Priorities	Weight
Environment / Public Health	Cities with most toxic waste discharge	10
Environment / Public Health	Cities with highest COD load	7
Public health	Cities located upstream of water supply intakes	6
Resource / Public Health	Cities with highest degree of water shortage	5
Public health	Cities located upstream of irrigation intakes	4
Resource / Environment	Cities with most unsustainable groundwater pumping	4
Resource/Environment	Cities with highest potential for artificial recharge	3

TABLE 7.2: HAI AND HUAI BASINS OVERALL PRIORITY CITIES

Cities in Hai Basin	Beijing	Tangshan	Zhangjiakou	Changzhi	Chengde	Xinzhou	Anyang	Shijiazhuang	Xinxiang	Tianjin
	Jiaozuo	Handan	Datong	Xingtai	Baoding	Puyang	Binzhou	Cangzhou	Dezhou	Yangquan
	Qinhuangdao	Liaocheng	Shuozhou	Hengshui	Hebi	Langfang	Jinan			
Cities in Huai Basin	Jining	Linyi	Zhumadian	Suzhou	Xuzhou	Heze	Pingdingshan	Bengbu	Kaifeng	Shangqiu
	Huaiyin	Fuyang	Lianyungang	Yancheng	Zhengzhou	Zibo	Zhoukou	Zaozhuang	Taizhou	Yangzhou
	Liuan	Xuchang	Luohe	Xinyang	Huaian	Taian	Huainan	Huaibei	Suqian	Rizhao
	Chuzhou	Nanyang	Qingdao							

FIGURE 7.2: COD INTENSITY REDUCTION.



In the case of livestock and urban and rural municipal sources, future trends may not be favorable. Thus the "base case" scenario or the "business as usual" scenario reflects a mixture of favorable and unfavorable trends. The input data are compiled from available information for the four models including livestock, rural municipal, rural domestic and urban industrial and municipal. The conclusion is that overall water quality should improve as a result of (a) increased monitoring and enforcement of pollution from large industry by the government, (b) changes to large industry manufacturing processes resulting from modernization of equipment, (c) increased treatment of wastewater from large industry, and (d) increased incidence of reuse of wastewater by large industry. However, other sources of pollution such as livestock are predicted to continue to grow despite sector restructuring resulting from globalization and other economic trends. Urban and rural municipal sources would also increasingly contribute to COD pollution loads in the Hai and the Huai basins with existing treatment levels.

However, under the current government program, pollution load reductions are likely to be insufficient to improve water quality to restore beneficial uses of water bodies. Maps A7-1 to A7-6 in Annex 7.3 of Volume 3 summarize WPM-DSS modeling results presented in ArcView GIS for major cities and for basins level II for 2020 under the "base case" scenario or government program. The figures show the level of pollution likely to results under the current government program in 2020.

F. Options for Additional Pollution Loads Reductions

Introduction

The following sections discuss alternative structural options available to the government to reduce pollution loads in the Hai and Huai basins and their forecasted impact on load and water quality along with implementation timeframes for key programs. Augmenting current government programs and economic activities that benefit the environment can be achieved in a large number of combinations of activities in many locations and sectors. The limited resources available, however, require prioritizing, so the WPM-DSS has been designed to distill key elements of a rational achievable program that could lead to dramatic reductions in pollution loads in the Hai and Huai basins within a realistic timeframe and at realistic cost. The rationale for these elements has been discussed in Chapters 3, 7, 8, and 9, and in their annexes in Volume 3. Table 7.3 summarizes indicative programs (called Programs 1, 2 and 3), which can be seen as markers in a continuum of possible action programs. Thus with the help of the WPM-DSS, Chinese experts can explore the effects of tailored programs that suit economic or regional constraints. Figures 7.2 and 7.3 MR show the effects of the different programs on COD loads in the Hai and Huai basins as described in this chapter below. The base case—"business as usual"—is also shown.

Structural Pollution Control Measures for Urban Areas

Structural options available to reduce industry pollution loads include (a) industrial wastewater treatment, (b) cleaner production technology, and (c) the reuse of treated wastewater. These options have been discussed in more detail in other chapters of the report (Table 7.3). Industrial wastewater treatment is projected to increase as noted above but under the accelerated intervention of Programs 1 and 2, this level of treatment should increase more dramatically to achieve significant improvement in water quality, and the WPM-DSS input data should reflect this improvement by assigning 80 and 95 percent proportion of wastewater volume treatment in 2010 and 2020, respectively, in the Huai basin and 90 and 100 percent in the Hai basin. The difference is due to the more critical water pollution status in the Hai basin.

Reduction of urban industrial wastewater volumes under Programs 2 and 3 should result in 90 and 80 percent of volumes of wastewater being generated for the Hai and Huai basins in 2010 and 2020, respectively, compared with 2000 volumes. Similarly, Programs 2 and 3 should accelerate wastewater strength reduction in 2010 and 2020 to 30 and 20 percent, respectively, compared with 50 and 40 percent for the same year under the current "business as usual" scenario or Program 1. Programs 2 and 3 also indicate that 20 and 30 percent of wastewater should be reused in 2010 and 2020.

TABLE 7.3: POSSIBLE INTERVENTION PROGRAMS TO REDUCE COD POLLUTION LOADS IN THE HAI AND HUAI BASINS

	(A) Urban Industry + Municipal (6 scenarios; see Tables 7A.2 & 7A.3 for Hai, Tables 7B.2 & 7B.3 for Huai in Annex 7.2, Volume 3)	(B) Rural Industry (4 scenarios; see Table 7A.4 for Hai and Table 7B.4 for Huai in Annex 7.2, Volume 3)	(C) Rural Domestic (2 scenarios; see Table 7A.5 for Hai and Table 7B.5 for Huai in Annex 7.2, Volume 3)	(D) Livestock (4 scenarios; see Table 7A.6 for Hai and Table 7B.6 for Huai in Annex 7.2, Volume 3)
1	Base case or current government program	Base case or current government program: some treatment and some attention to PPP	Base case or current government program: Scenario 1: Reuse = 10%, pit latrines treat to 180 mg/L	Base case or current government program: Scenario 1: 6% weighed annual runoff coefficient for intensive pigs and 10% for nonpigs.
2	Treatment	Intervention focusing on treatment with some PPP	Scenario 2: Reuse = 10%, pit latrines treat to 80 mg/L	Scenario 2: 50% reduction of runoff in Beijing, Hebei, and Shandong (for the Hai), and Henan & Shandong (for the Huai)
3	RevE-3: Cleaner production only (PPP)	Scenario 3: Intervention focusing on PPP		Scenario 3: 50% reduction of runoff in all provinces
4	RevE-4: Treatment + PPP	Scenario 4: Treatment + PPP		Scenario 4: 75% reduction of runoff in 2010 and 90% in 2020 for all provinces
5	RevE-5: Treatment + reuse only			
6	RevE-6: Treatment + PPP + reuse			

Notes

(a) Program 1 consists of A1+B1+C1+D1, Program 2 = A4+B4+C2+D2, and Program 3 = A6+B4+C2+D4.

(b) Program 1 is the current government program, also known as the "base case scenario" or the "business as usual" scenario. It represents our understanding of government commitment to improve water quality through structural programs. Nonstructural programs also exist although they are not modeled but rather discussed and assessed in the last part of Chapter 7. The effects of the government program are modeled using the WPM-DSS for the present and for future years to 2020. The model is described in detail in Volume 3, Annex 7.1.

(c) Program 3 is the Recommended Action Plan. It includes structural and nonstructural investments believed to comprise the optimal investment program.

(d) Program 2 is an intermediary program consisting essentially of similar components as program 3, except for reuse.

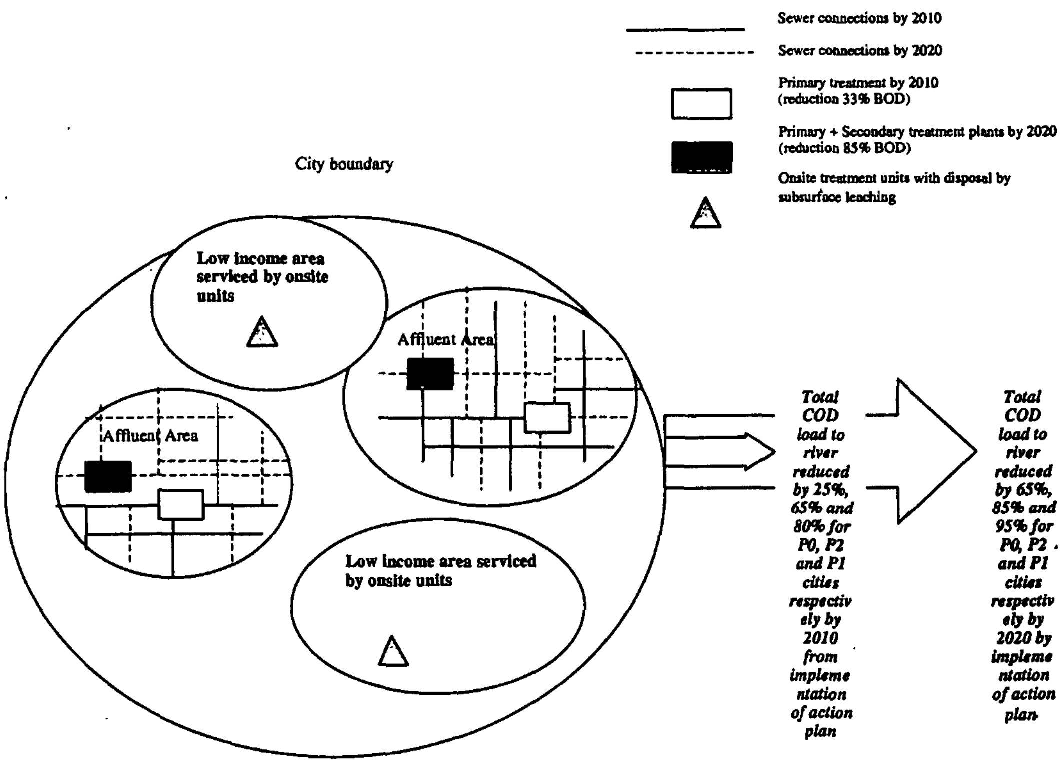
The most polluting industries in terms of COD were identified in Chapter 3 and are included in the WPM-DSS. They include paper-making, brewing and distillation, and chemical, pharmaceuticals and food processing. In addition, the Chapter 3 discussion on priority cities (P1, P2, P0)[10] above identified toxic waste industries including steel and metallurgy, leather and tanning, and textiles. Programs 2 and 3 propose different intervention scenarios with a mix of wastewater treatment, pollution prevention and reuse to address pollution, applicable to all types of industries. Programs 2 and 3 differentiate between industries in terms of required treatment levels, requiring the paper industry to lower effluent COD by 90 percent and toxic industries by 30 to 50 percent by 2020. Other industries are equally targeted but to different levels, reflecting their COD contents and their anticipated capacity to invest in treatment technology to meet the requirements of stricter environmental control, as shown in Volume 3, Annex 7.2, Tables A7.2-A2 and A7.2-B2. Further discussions of large and small industry are presented in Volume 3, Annex 7.4. Further explanation of the various program alternatives of Table 7.3 are given in the Chapter 7 text with details given in Volume 3, Annexes 7.2 and 7.4. This includes results for toxic industries separately, as well as for total industry, because of the serious impact on the environment and public health that result from these types of industries.

---

[10] P1: High first-level priority cities; P2: second-level priority cities; P0: nonpriority cities.

Urban domestic wastewater for programs 2 and 3 are shown in Tables A7.2A-3 and A7.2B-3 in the Annex 7.2, Volume 3. Cities are typically composed of affluent areas and low-income areas. Treatment and associated collection systems would be proposed initially to service affluent areas with appropriate leaching systems for low-income areas. The combined effect of these programs requires that P0 cities should have a combination of primary and secondary treatment combined with a level of collection system in affluent areas and leaching systems in low-income areas, which results in 25 and 65 percent of municipal COD removal by 2010 and 2020, respectively. Similarly, P2 cities should have primary and secondary treatment causing 65 and 80 percent municipal COD removal by 2010 and 2020, respectively. Higher removal rates in P2 cities would be achieved by more treatment plants and higher levels of connections. P1 cities should have secondary treatment with 80 and 95 percent removal by 2010 and 2020, respectively. Similarly, higher reductions of municipal COD should be achieved by more secondary treatment plants and higher levels of connection, in addition to higher efficiencies of operation. The rationale here is that since P1 cities were identified as top priority cities[11] with P2 and P0 ranking next, they should have an accelerated and expanded program to reduce COD loads. See Figure 7.3.

FIGURE 7.3: URBAN MUNICIPAL ACTION PLAN



COD pollution from domestic sources would be larger than industry in 2010 and 2020 under the base case scenario, so Program 3 reduces this growth by allocating resources to boost treatment capacity, especially in P1 cities because of environmental and public issues. Treating industrial and municipal wastewater in combined systems should offer large cost savings; this is investigated in Chapter 8 and below in the section on costing of the priority program.

---

11 Based on a number of key criteria as explained in the section on locating priority regions in this Chapter.

Structural Pollution Control for Rural Industry

Rural industry's contribution to the total basin load in both the Hai and Huai would continue to grow. In 2020 load from rural industry is projected to account for 18 and 22 percent of the total load in the Huai and the Hai basins, respectively, under the base case scenario. According to Program 3, this contribution should decrease by about 60 percent by 2020 for the Hai and Huai Basins. This is achieved with an ambitious program of end-of-pipe treatment, together with use of clean technology, which would reduce the paper industry wastewater concentration to 20 and 12 percent of its original strength by 2010 and 2020, respectively, and reduce nonpaper industry wastewater concentration to 45 and 30 percent of original strength in the same timeframe.

As explained in Chapter 3, rural industry restructuring resulting from economic changes, combined with tighter regulation, would be the main causes of change.

Structural Pollution Control for Rural Towns

Program 3 proposes to promote the use of improved on-site excreta management units for rural homes and buildings using community programs specially designed for urban low-income communities, so that functioning of the on-site units would be much more effective without the escape of excreta from the on-site unit into the drainage system.

Pollution Control for Livestock

The basic intervention scenario for livestock consists of stabilization ponds installed in practically all the many livestock operations to produce a large reduction in direct COD runoff to the river. This simple technology can reduce COD by as much as 80 to 90 percent. Initial limited adoption rates, however, may reduce this reduction level to 50 percent. With continued community programs to improve the design and operation and with more widespread adoption, load reductions can be increased to 75 percent by 2010 and eventually to 90 percent by 2020. This is modeled as Program 3.

In the base case scenario, Shandong and Henan are the largest producers of livestock COD, so the first scenario investigates COD load reduction from intervention in only those two provinces, leaving the others without intervention (Program 1). The next scenario investigates the effect of all provinces adopting the intervention program (Program 2), and the last scenario investigates a more widespread program where 75 percent of runoff is reduced in 2010 and 90 percent in 2020 (Program 3).

Projected Pollution Levels Under Proposed Action Plan for Hai and Huai Basins

The results of Programs 2 and 3 are shown in full in Annex 7.2, Volume 3. Under Program 3, total basin COD load is reduced from some 6.9 million tons in 2000 to just under 1.9 million tons by 2020 for the Huai basin and from some 5.2 million tons in 2000 to just over 1.2 million tons in 2020 for the Hai basin.

Urban Industrial and Domestic Sources. Current government programs (Program 1) combined with market forces should reduce annual loads for P1, P2 and P0 cities (a) by increasing the level of treatment, (b) through cleaner production caused by modernization of manufacturing processes and (c) through increased reuse (both internal and external) due to water scarcity and increased prices of water and wastewater services and tighter pollution discharge control. This encouraging trend, however, is not enough to improve overall water quality to the desired degree because the combined annual COD loads from urban centers as well as rural sources would continue to exceed the environment's assimilative capacity. Program 3 investigated the effects of additional intervention for urban municipal and industry sources as described in the previous sections. The proposed action plan for urban systems is described more fully in Chapter 8 and consists of combined treatment of sanitary sewage discharged into municipal treatment plants along with degradable COD from industry to provide economy of scale. Revenue from industries greatly help finance WWTPs because the latter can remove BOD much more cheaply than industry could with its own in-plant treatment. Figures 7.4 and 7.5 show the level of COD and toxic COD generation after the implementation of the action plan (compare with Figures 3.8 and 3.9). Volume 3, Annexes 7.2 and 7.3 give supporting details.

Livestock. As previously noted, the action plan for livestock industry calls for the implementation of stabilization ponds to gain large reductions in COD loads discharged to the environment.

Rural Industries, including TVEs. Reductions in loads would occur from industry restructuring as noted above in the base case scenario, and Program 3 proposes to accelerate this trend. This would be achieved by a combination of appropriate treatment and pollution prevention programs for those rural industries capable of affording such technology and those financed by government programs. The program would also requires the termination of some TVEs that simply cannot compete on an environmentally sound basis, namely those that use and discharge toxic substances that cannot be removed by small-scale industries because the treatment required can be afforded only by large-scale industries because of their economies of scale. The initial step would be to require registration of all TVEs to improve knowledge of operators and their location. The first part of the action plan addressing rural point sources should categorize TVEs on the basis of pollution control costs, to show clearly which TVEs would likely not be able to afford to furnish the needed environmental protection.

The present SEPA regulation calls for all TVEs to comply with waste discharge standards "by year 2000," which as noted earlier is an unrealistic and unachievable goal. Reasons for polluters' inability to meet the standards set by SEPA, as explained earlier, are that they are derived mostly from industrial countries and thus do not reflect the level of affordability of a developing country such as China, because the treatment technology required to meet these standards is beyond the current financing capability of even some large operators such as SOEs, let alone small operators such as TVEs. The second part of the action plan on rural point sources is thus a review of water quality standards and strengthening of monitoring and enforcement procedures appropriate for the rural sector. This in fact forms part of the second element of the general water pollution control action plan described in the introduction of this chapter.

Although the legislation makes the local government responsible for environmental quality improvements and reduction of discharge through administration of the law, there is a fundamental lack of knowledge about planning, design, operation, and maintenance of TVEs appropriate for developing countries. Despite calls by the government for institutes and universities to help in these matters, little has been achieved to date. Third then, the action plan calls for the preparation of a manual of guidelines on planning, design, operation and monitoring of production TVEs appropriate for developing countries. This would require the adaptation of similar manuals produced for industrial countries including attention to technical design criteria, costs for installation and for O&M, financing and cost recovery, and for environmental monitoring, for each and every type of TVE to be considered, for a range of production sizes covering smaller family to medium-scale operations, including production technologies, using appropriate environmental standards.

Figures 7.6 and 7.7 show total COD loads for 2000, 2010 and 2020 for programs 1, 2 and 3.

Water Quality Improvement Under the Action Plan (Program 3)

Using the procedure described above, Chapter 7 projects the ambient water quality levels to be achieved for the rivers in the Hai and Huai basins under the action plan as shown in Maps 7.1 and

7.2. The most striking benefit from implementation of Program 3 is the disappearance of Class V and V+ water bodies.

G. Coastal Zone Water Quality

The 3-H basins' rivers spill into the Huanghai Sea and the Bohai Sea. As a result of pollution generated in the basins and the fact that the rivers drain to these seas, both seas are moderately to highly polluted. According to a 1999 CEY survey, 70 percent of sampled points were classified class III or above, with inorganic nitrogen and phosphate and oil being the most common pollutants. As noted in the Environmental Sector Update Report (WB, 2000), the incidence of red tides caused by algal blooms (resulting from excess nutrients entering the sea over a short period of time) has increased dramatically in the 1990s when 380 incidences were reported compared to 74 in the 1980s and 9 in the 1970s.

The current study has calculated COD load generations for 2000 and 2020 under the base case (business as usual) and the action plan (treatment, pollution prevention and reuse in urban areas; treatment and pollution prevention for rural industry; reuse and latrines for rural domestic sources; and settling ponds for livestock operations). The effect of the implementation of the action plan pollution program (program 3) is to reduce loads generated within the Hai and Huai basins. As discussed above, the freshwater quality improvements resulting from the implementation of this program show that for an average year, water quality would move up by one class, for example, from class IV to III by 2020, which means that COD would reduce from 20 mg/liter to 15 mg/liter.

Flows available for the sea were shown in Table 4.27 MR. Without measures implemented in the action plan, water to the sea in 2020 would be minimized and concentrations of pollutants would be high. There is a need to dilute these concentrations as well as reduce the loads generated in order to minimize the pollution impacts to the sea. The estimated combined effect of the flow augmentation and pollution reduction components of the action plan on COD loads to the sea is shown in Table 7.4 below.

Table 7.4: COD Loads to the Sea from the Hai and Huai Basins
('000 tons/year)

	Base 2000	Base 2020	P3 2020
Hai Basin			
II-1	116	71	27
II-2	95	76	47
II-3	679	402	121
II-4	93	844	24
Total	982	633	220
Huai Basin			
III-4	525	446	117
III-6	197	141	117
III-7	192	152	113
Total	914	739	347

FIGURE 7.4: 2020 COD POLLUTION LOADS FOR PRIORITY CITIES IN THE HAI BASIN UNDER PROGRAM 3 OF THE ACTION PLAN
(tons/day)

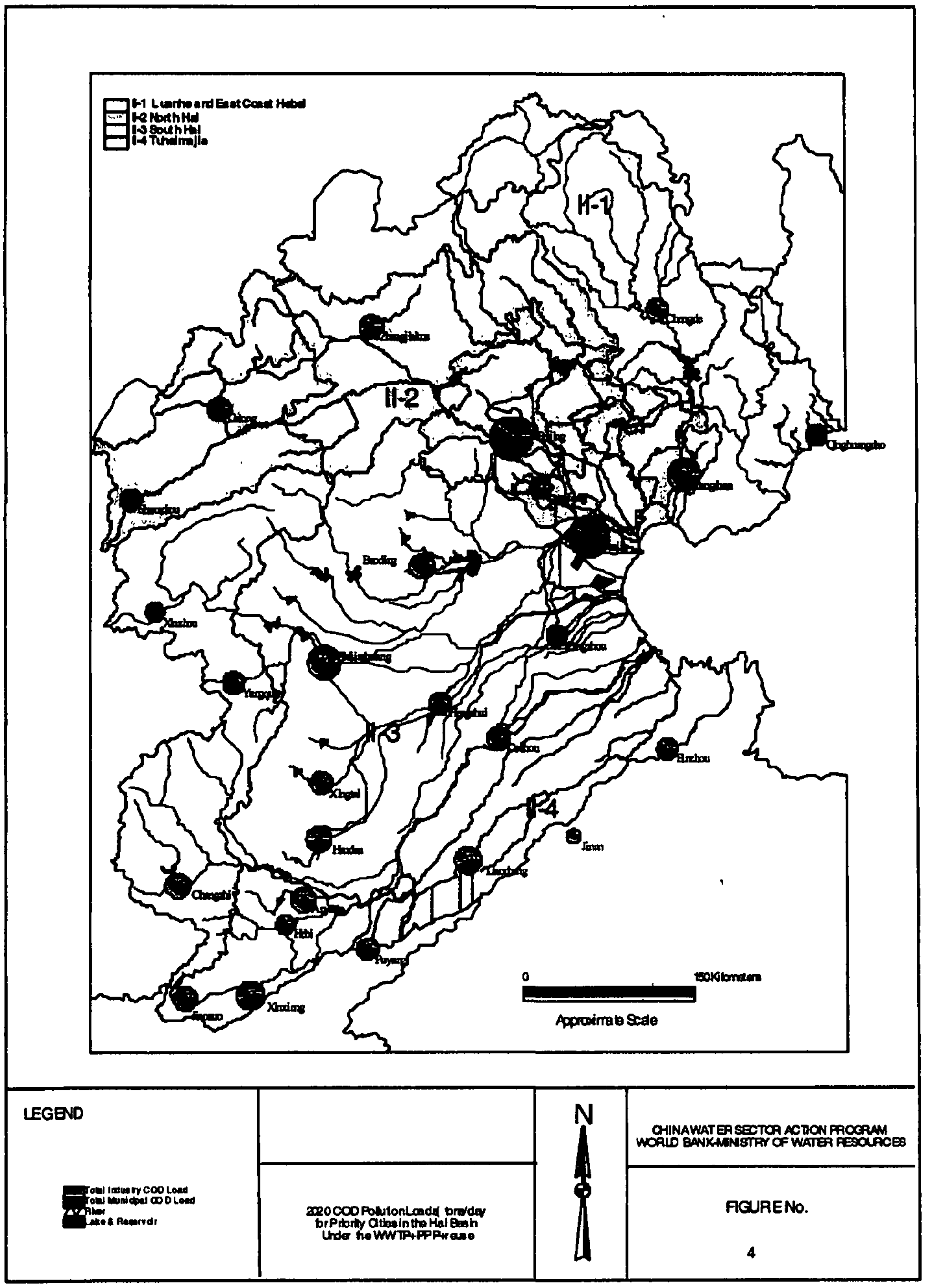


FIGURE 7.5: 2020 TOXIC COD POLLUTION LOADS FOR PRIORITY CITIES IN THE HAI BASIN UNDER PROGRAM 3 OF THE ACTION PLAN
(tons/day)

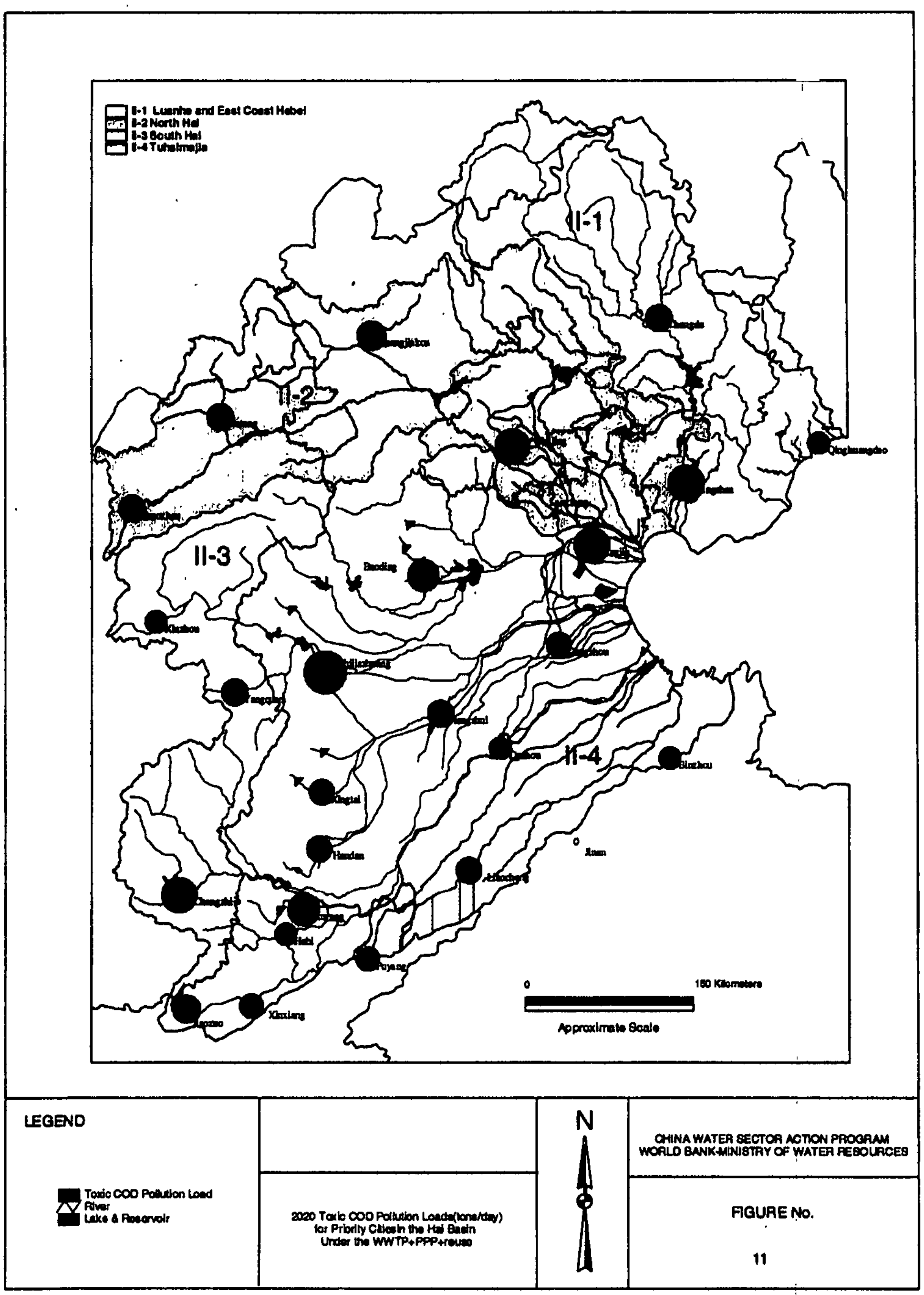
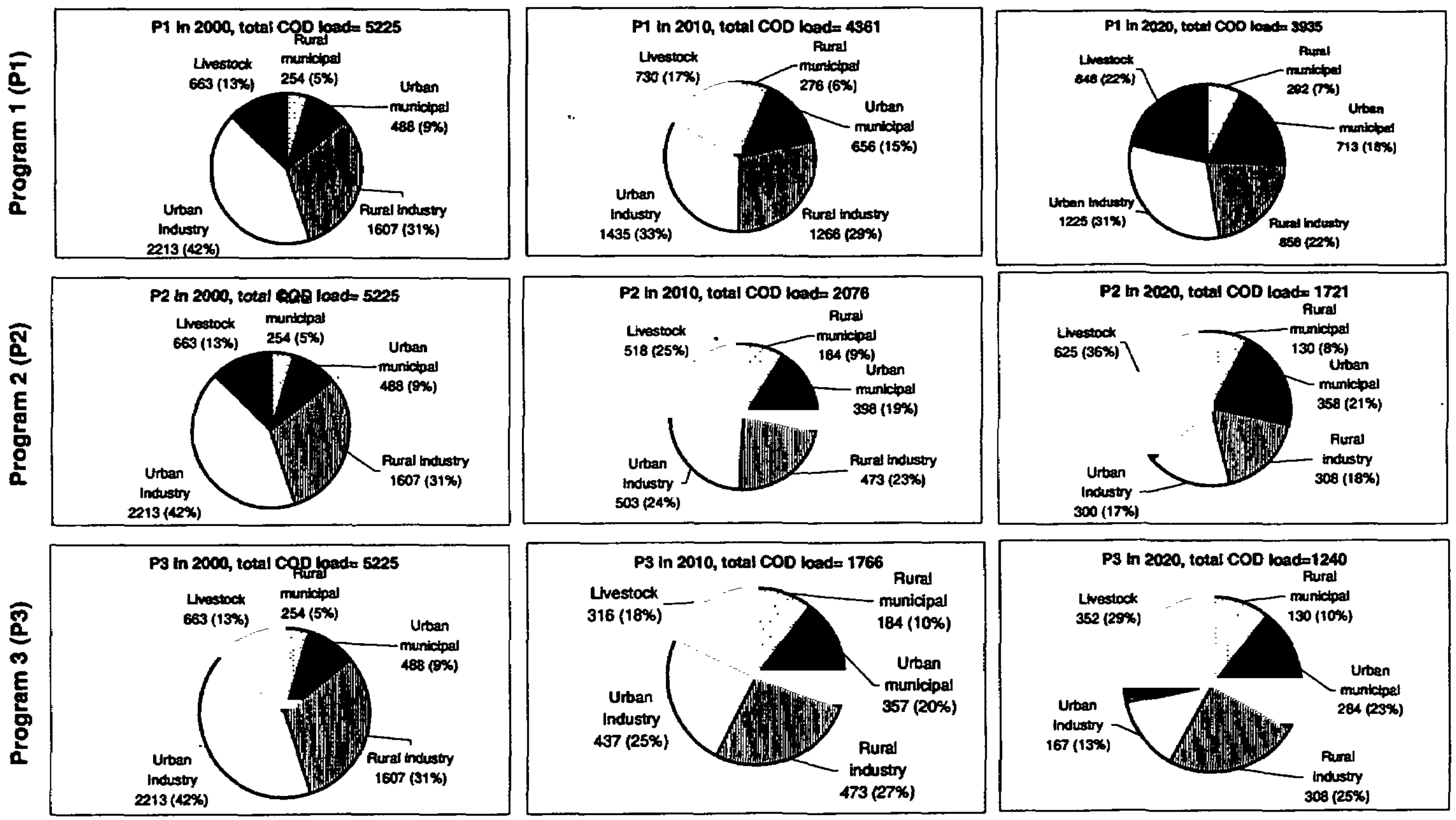
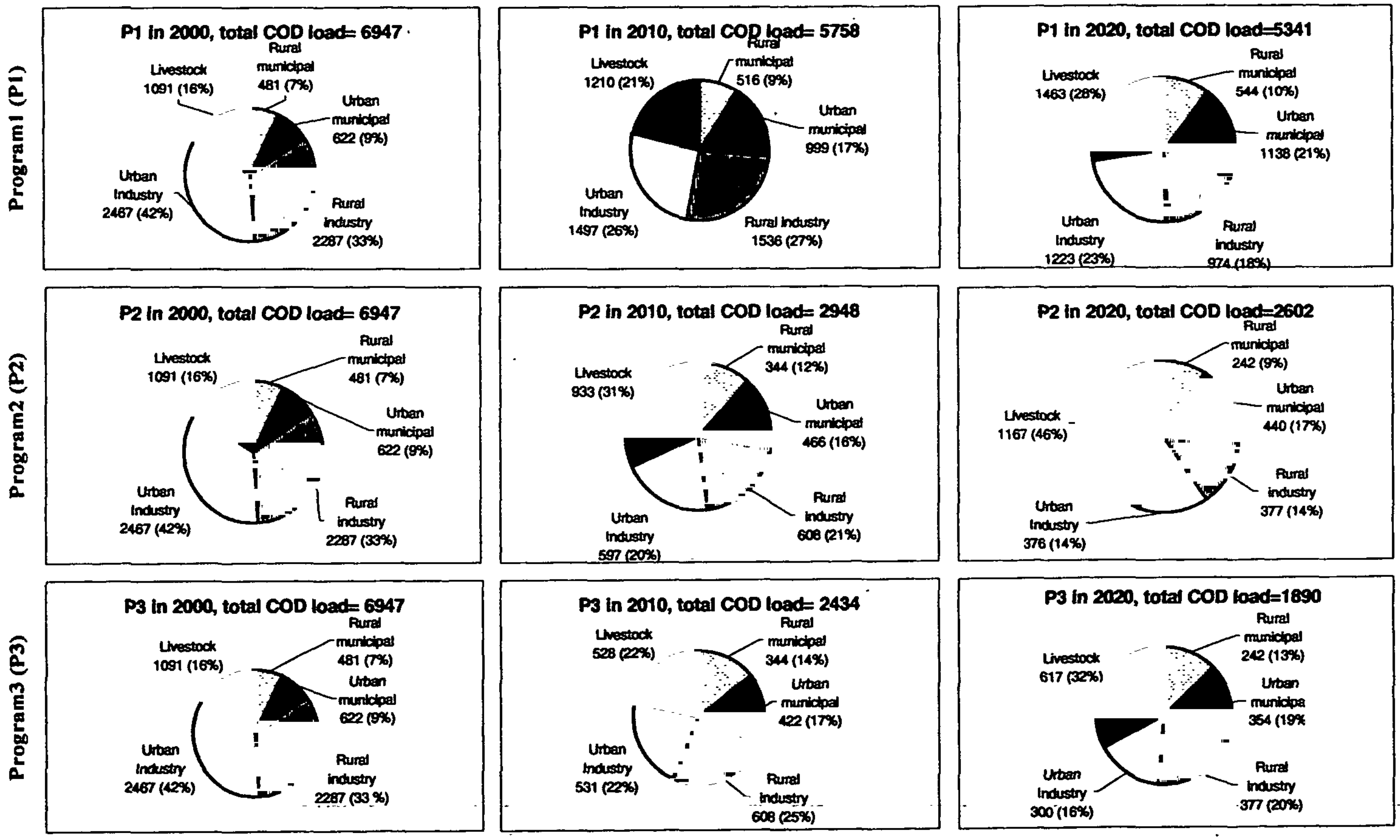


FIGURE 7.6: PROPORTION OF COD LOAD FROM MAJOR POLLUTION SOURCES OF VARIOUS PROGRAMS IN HAI BASIN
(1,000 tons/year)



P1: Business as usual for urban industry & municipal + some treatment & some PPP for rural industry + reuse=0.1 & septic tanks treat to 180 mg/l for rural municipal + 0% reduction in COD load for livestock; all livestock data came from IWHR without poultry which is consistence with water demand data (same as following);
P2: WWTP & PPP for urban industry & municipal + remediation focusing on treatment & PPP for rural industry + reuse=0.1 & septic tanks treat to 80 mg/l for rural municipal + 50% reduction in Hebei, Beijing & Shandong for livestock;
P3: WWTP + PPP+ reuse for urban industry & municipal + remediation forcusing on treatment & PPP for rural industry + reuse=0.1 & septic tanks treat to 80 mg/l for rural municipal + 75% reduction in 2010 & 90% reduction in 2020 in all provinces for livestock.

FIGURE 7.7: PROPORTION OF COD LOAD FROM MAJOR POLLUTION SOURCES OF VARIOUS PROGRAMS IN HUAI BASIN
(1,000 tons/year)



P1: Business as usual for urban industry & municipal + some treatment & some PPP for rural industry + reuse=0.1 & septic tanks treat to 180 mg/l for rural municipal + 0% reduction in COD load for livestock; all livestock data came from IWHR without poultry which is consistence with water demand data (same as following);
P2: WWTP & PPP for urban industry & municipal + remediation focusing on treatment & PPP for rural industry + reuse=0.1 & septic tanks treat to 80 mg/l for rural municipal + 50% reduction in Hebei, Beijing & Shandong for livestock;
P3: WWTP + PPP+ reuse for urban industry & municipal + remediation forcusing on treatment & PPP for rural industry + reuse=0.1 & septic tanks treat to 80 mg/l for rural municipal + 75% reduction in 2010 & 90% reduction in 2020 in all provinces for livestock.

It can be seen from Table 7.4 that loads would be substantially reduced from the implementation of the action plan. Once flow augmentation measures are implemented, there would be a need for corresponding waste generation reduction program as advocated in the proposed pollution action plan.

H. Cost of Government Program (Base Case) and Action Plan (Program 3)

Structural Components

Summary of Findings. As noted earlier, the structural component of the action plan addressing water pollution focuses on the use of both clean production technology together with wastewater treatment to reduce COD loads and improve water quality in water bodies in the 3-H basins. Projected load reductions to 2020 for major pollution sources have been estimated in the previous section, which would result from the ongoing government program and the proposed action plan. In this section, costs for the implementation of the action plan have been calculated for (a) urban industry (divided into paper and nonpaper), (b) urban municipal, (c) rural industry (TVEs), (d) rural livestock, and (e) rural domestic. In addition, the costs of the action plan for the urban component (i.e., urban industry and urban municipal) have also been calculated for P1 and P2 cities. The costs were based on the target 2020 COD loads and allocated back to the 10th, 11th, 12th, and 13th Five-Year Plans according to estimated proportions shown in the cost tables. These proportions were weighted qualitatively to allow sufficient funding within each planning period to produce the proposed load reductions. The total costs for each pollution source (a) through (e) above are based on "unit" costs derived from a study of current treatment technology in China for different classes of pollution sources (Table 7.9 MR).

Cost Determinations. This chapter discusses preparation details of the cost estimates for the components of the base case and the action plan, namely (a) urban industry, (b) urban municipal, (c) rural industry, (d) rural towns, and (e) rural livestock (see Tables 7.5 and 7.6). The cost data are summarized by sectors for both the base case and the action plan, and the total, as shown in Chapter 11.

Nonstructural Components

The nonstructural component is an equally important aspect of the overall plan for pollution control. This includes two basic subcomponents: the government's environment regulatory system (Table 7.2 MR) and the wider reforms undertaken by the government to promote China's transition to a socialist market economy.

The present study included a detailed review and evaluation of all ongoing governmental regulatory nonstructural requirements on water pollution control, including preparation of recommendations for improving and strengthening each of these various measures to meet action plan needs (Table 7.14 MR), including (a) use of the permit system, (b) use of the EIA process to bolster the permit system, (c) use of appropriate emission and ambient standard, (d) effective monitoring and enforcement, (e) practical methods for collecting revenues from pollutant producers, and (f) various other related measures.

The reform program includes sectoral changes for a shift away from "dirty industries," such as coal mining, building materials, transport equipment, chemicals and metals. Generally, factories would become larger and thus benefit from lower abatement costs, newer technology, and economies of scale not generally available to older and smaller SOEs. As government reforms take effect, an increasing share of industrial pollution would move to large non-SOEs and the marginal abatement cost for industry would decrease significantly. Similarly, rural industries and livestock operation would be subject to increasing international competition, which would restructure these many small industries into fewer bigger ones with more economies of scale in pollution abatement. Program 3 identifies areas where additional strengthening with structural measures would help reduce loads from each main pollution sources. This program assumes that nonstructural control measures would be applied in parallel to ensure sustainability of the structural program.

Summarized Recommendations. Table 7.14 MR summarizes further improvements in the regulatory system needed to ensure that the structural program is viable.

Summarized Costs. Presented in Tables 7.5 and 7.6 and Chapter 11.

TABLE 7.5: HAI BASIN STRUCTURAL POLLUTION CONTROL INVESTMENT (2000-2020) (Y'000)

Urban Industry	Government Program and Action Plan							
Pollution Control Measure	Municipal Treatment		Sewerage	PPP		Pretreatment		
Industry	Paper	Nonpaper		Paper	Nonpaper	Paper	Nonpaper	
Luanhe & East Coast Hebei	498,881	153,735	652,616	2,159,105	542,322	498,881	25,027	
North Haihe	75,872	343,502	419,374	341,261	1,240,222	75,872	55,919	
South Haihe	1,364,219	1,611,084	2,975,303	5,818,208	4,313,606	1,364,219	262,270	
Tuhaimajia	930,366	157,486	1,087,852	3,680,768	421,399	930,366	25,637	
Hai Basin	**2,869,339**	**2,265,806**	**5,135,145**	**11,999,341**	**6,517,548**	**2,869,339**	**368,852**	
Subtotal	32,025,370							

Urban Municipal	Government Program and Action Plan combined	
Pollution Control Measure	Treatment	Sewerage
Luanhe & East Coast Hebei	1,825,211	1,825,211
North Haihe	7,011,252	7,011,252
South Haihe	13,243,576	13,243,576
Tuhaimajia	653,710	653,710
Hai Basin	**22,733,749**	**22,733,749**
Subtotal	45,467,497	

Rural Industry	Government Program and Action Plan		
Pollution Control Measure	Treatment	Sewerage	PPP
Luanhe & East Coast Hebei	222,926	111,463	1,164,921
North Haihe	398,902	199,451	2,291,734
South Haihe	1,803,126	901,563	11,098,436
Tuhaimajia	224,916	112,458	1,102,865
Hai Basin	**2,649,869**	**1,324,934**	**15,657,956**
Subtotal	19,632,759		

Rural Municipal	Government Program and Action Plan combined
Pollution Control Measure	Treatment
Luanhe & East Coast Hebei	1,572,120
North Haihe	2,596,000
South Haihe	10,572,540
Tuhaimajia	2,402,620
Hai Basin	**17,143,280**
Subtotal	17,143,280

Livestock	Government Program and Action Plan combined	
Pollution Control Measure	Treatment	Sewerage
Luanhe & East Coast Hebei	357,342	178,671
North Haihe	625,476	312,738
South Haihe	1,589,788	794,894
Tuhaimajia	631,021	315,511
Hai Basin	**3,203,627**	**1,601,814**
Subtotal	4,805,441	
Hai Basin Total	119,074,347	

TABLE 7.6: HUAI BASIN STRUCTURAL POLLUTION CONTROL INVESTMENT (2000-2020) (Y'000)

		Action Plan + Government Program						
	Pollution Control Measure	Municipal Treatment		Sewerage	PPP		Pretreatment	
	Industry	Paper	Nonpaper		Paper	Nonpaper	Paper	Nonpaper
Urban Industry	Upstream of Wangjiaba	124,214	47,806	172,020	498,103	184,559	110,152	10,494
	Wangjiaba to Bengbu	749,609	813,895	1,563,503	3,202,944	2,603,280	664,747	178,660
	Bengbu to Hongze lake	279,342	337,194	616,535	1,170,866	971,632	247,718	74,018
	Lower Huaihe, Hongze lake to Huang Sea	209,856	326,557	536,413	895,448	1,155,400	186,099	71,683
	Nansi Lake	676,957	610,168	1,287,125	2,876,918	1,867,327	600,320	133,939
	Lower Yishusi	376,662	379,919	756,580	1,567,133	1,063,124	334,021	83,397
	Shandong peninsula	55,351	419,039	474,390	242,711	1,635,550	49,085	91,984
	Huai Basin	**2,471,990**	**2,934,577**	**5,406,567**	**10,454,122**	**9,480,871**	**2,192,142**	**644,176**
	Subtotal	**33,584,445**						

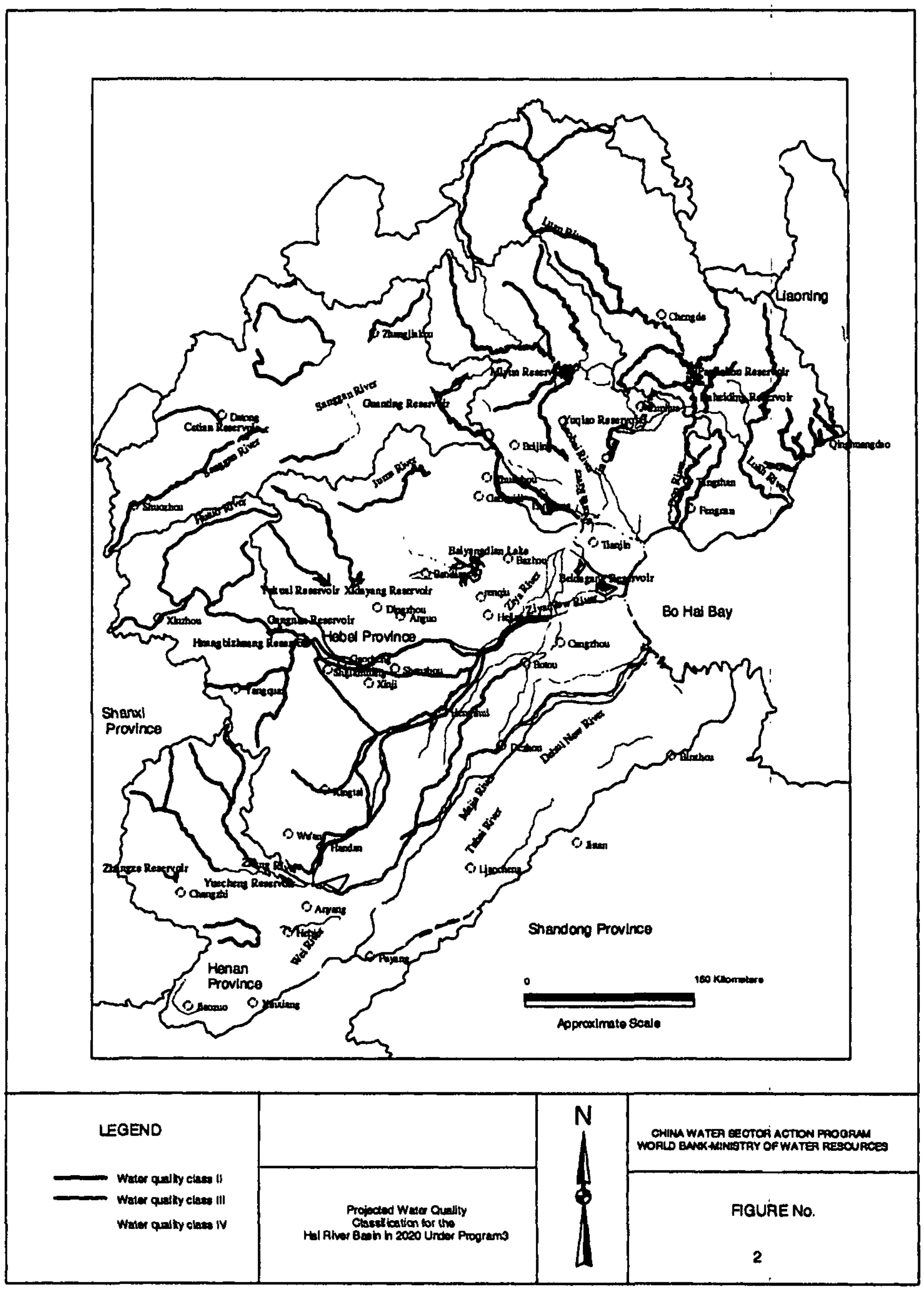
		Government Program and Action Plan combined	
	Pollution Control Measure	Treatment	Sewerage
Urban Municipal	Upstream of Wangjiaba	1,390,820	1,390,820
	Wangjiaba to Bengbu	9,706,529	9,706,529
	Bengbu to Hongze lake	2,291,173	2,291,173
	Lower Huaihe, Hongze lake to Huang Sea	1,515,681	'1,515,681
	Nansi Lake	2,881,335	2,881,335
	Lower Yishusi	1,861,277	1,861,277
	Shandong peninsula	2,722,260	2,722,260
	Huai Basin	**22,369,074**	**22,369,074**
	Subtotal	**44,738,148**	

		Government Program and Action Plan		
	Pollution Control Measure	Treatment	Sewerage	PPP
Rural Industry	Upstream of Wangjiaba	204,735	102,367	1,383,919
	Wangjiaba to Bengbu	1,144,630	572,315	9,602,330
	Bengbu to Hongze lake	458,651	229,326	4,675,220
	Lower Huaihe, Hongze lake to Huang Sea	318,719	159,360	3,311,456
	Nansi Lake	348,576	174,288	3,709,807
	Lower Yishusi	233,606	116,803	2,466,095
	Shandong peninsula	204,501	102,250	1,626,448
	Huai Basin	**2,913,418**	**1,456,709**	**26,775,275**
	Subtotal	**31,145,402**		

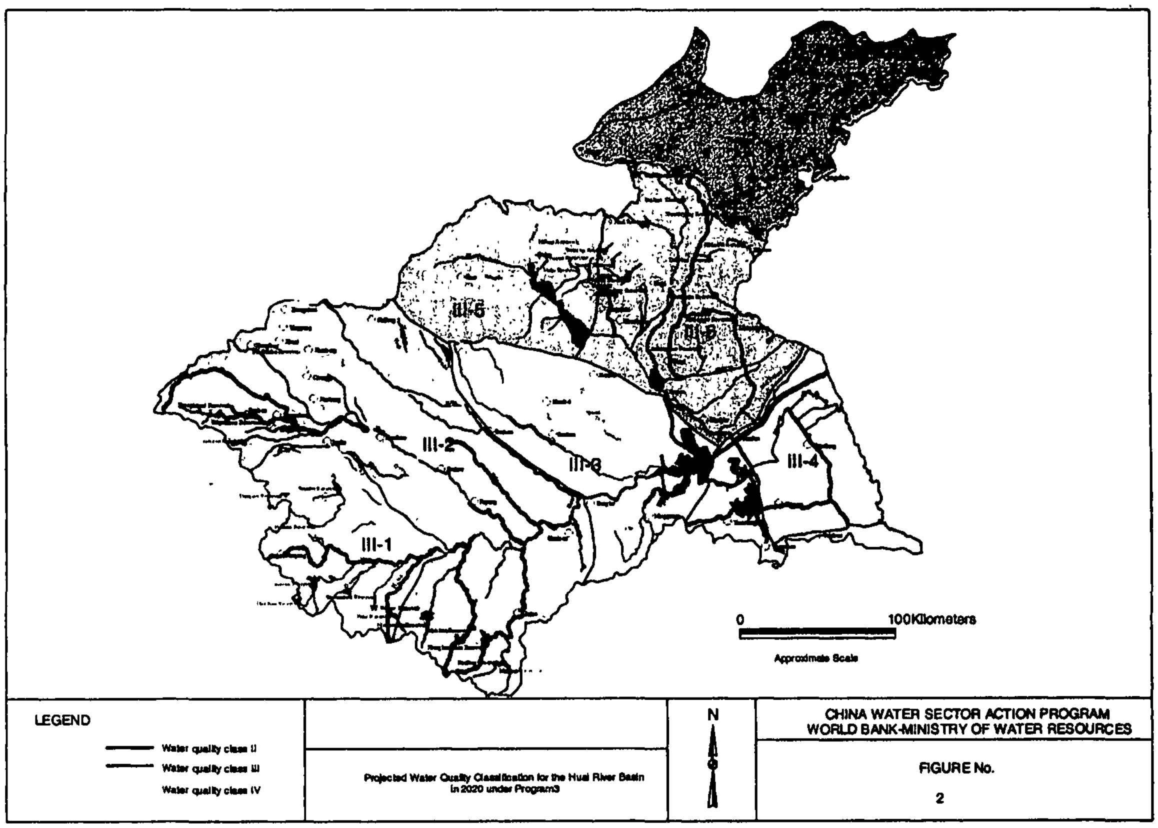
		Government Program and Action Plan combined
	Pollution Control Measure	Treatment
Rural Municipal	Upstream of Wangjiaba	2,426,380
	Wangjiaba to Bengbu	10,228,240
	Bengbu to Hongze lake	3,388,220
	Lower Huaihe, Hongze lake to Huang Sea	2,942,500
	Nansi Lake	4,702,500
	Lower Yishusi	3,949,440
	Shandong peninsula	4,336,200
	Huai Basin	**31,973,480**
	Subtotal	**31,973,480**

		Government Program and Action Plan combined	
	Pollution Control Measure	Treatment	Sewerage
Livestock	Upstream of Wangjiaba	393,758	196,879
	Wangjiaba to Bengbu	1,817,617	908,808
	Bengbu to Hongze lake	587,984	293,992
	Lower Huaihe, Hongze lake to Huang Sea	482,346	241,173
	Nansi Lake	1,053,047	526,523
	Lower Yishusi	632,998	316,499
	Shandong peninsula	562,242	281,121
	Huai Basin	**5,529,990**	**2,764,995**
	Subtotal	**8,294,985**	
	Huai Basin Total	149,736,459.	

MAP 7.1: PROJECTED WATER QUALITY CLASSIFICATION FOR THE HAI RIVER BASIN IN 2020 UNDER PROGRAM 3



MAP 7.2: PROJECTED WATER QUALITY CLASSIFICATION FOR THE HUAI RIVER BASIN IN 2020 UNDER PROGRAM 3



8. WASTEWATER REUSE

A. INTRODUCTION

Reuse of treated municipal wastewater for irrigation has been common practice in the industrialized countries ever since the beginning of wastewater management in the developed countries. This reuse was hardly planned, though. The common situation was to locate the WWTP in the rural area outside the city, and the farmers around made free use of this water for irrigation, subject to controls imposed by the health departments. This situation began to change significantly in the semiarid regions of the southwestern United States, especially Southern California, following World War II, because these areas were becoming increasingly dependent upon importing water from outside sources and because costs for this importation had steadily increased. It was realized in the early 1950s that expensive importation costs could be partially reduced by reusing treated wastewaters, especially for irrigation. These were through planned reuse schemes that are now commonly used in these semiarid and arid areas for irrigation, industrial water supply and recharging of groundwater aquifers, again subject to health department controls. Usually the "20/30" BOD/Suspended Solids effluents produced by the municipal WWTPs have been well-suited for such reuse. This includes reuse by industry for cooling tower purposes and, with some extra treatment, by the industry for plant processing purposes. Similarly many industries in these areas themselves reuse some of their own wastewaters following appropriate treatment.

The reuse practices noted above are governed in the developed countries areas by use of the governmental permit system whereby each industry and each municipality must obtain a permit for its wastewater management operations, including reuse, which specifies the treatment levels required for reuse and the monitoring programs to be carried by the industries and municipalities.

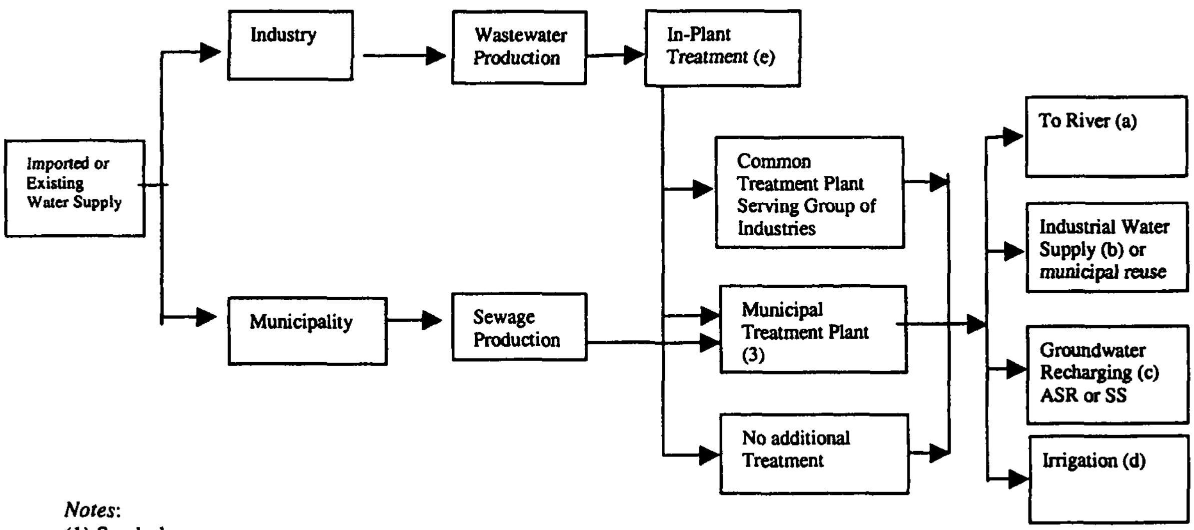
Many areas in the 3-H basins are now facing severe water shortages, hence their interest in making effective reuse of treated wastewaters, following the developed countries' practices with modifications to suit conditions in developing countries, conditions including the use of appropriate water quality standards. This chapter (Chapter 8 MR) evaluates these potentials for the 3-H basins.

It is important to note here that use of the permit system, including provisions for competent monitoring and enforcement, is an essential aspect of reuse projects in developed countries, but, as noted earlier, China thus far has not been able to impose such effective monitoring. If pollution control (including reuse) is to be successful in the 3-H basins, the permit system, including effective monitoring and enforcement, would be essential. This includes requiring industries to treat their own wastes to remove toxic and other objectionable constituents before discharging them to municipal sewerage systems.

The action plan proposed in the present study for wastewater management, including reuse, would require pioneering efforts by the governmental regulatory agencies to get this done. It is feasible for them to do this if they really have the will to do so. Among other things, this would require reorientation of the existing water quality standards and regulations to be realistic for such reuse purposes.

Figure 8.1 is a schematic drawing of an integrated water management system as proposed for the Wanjiazhai Project for optimal integrated water importation-use-reuse-waste management and water pollution control. It shows that there are two essential components in integrated water management systems to maximize the efficient use of raw water supply for water-short cities. The first essential component is the need to combine the treatment of industrial wastewater and municipal wastewater so as to (a) benefit from economies of scale from the joint treatment, which significantly reduces the cost to both industries and municipalities, and (b) collect the maximum volume of wastewater which, when treated, would become suitable raw water supply for the city's industry and irrigators. This component requires not only suitable infrastructure, such as collection sewers, interceptors, and treatment and disposal systems, but also appropriate institutional mechanisms. The second component is the very important permit system, which includes ordinances for regulating sanitary and industrial waste discharges.

FIGURE 8.1: SCHEMATIC DRAWING OF INTEGRATED WATER USE AND REUSE MANAGEMENT SYSTEM



Notes:

(1) Symbols:

(a) Treatment to meet prescribed standard. The "20/30 BOD/Suspended Solids is recommended (US Standard is 20/30).

(b) Any additional treatment needs furnished by industry.

(c) Water pumped from aquifer useful for all purposes including drinking water supply.

(d) No additional treatment needed.

(e) In-plant treatment, pursuant to permit system, removes all toxics and other objectionable substances which cannot be removed by conventional sewage treatment plants.

(2) All technologies noted above are already well developed and commonly used in Southern California and other arid regions of the southwestern United States, wherever water is precious or expensive. All are affordable even in developing countries where water is precious and expensive. Although these technologies are not well known in China, it is timely and feasible now to begin using them in parched regions of the country, beginning with WWTPs. Shanxi Province has already carried out some measures and seems ready and willing to utilize them with maximum effectiveness.

(3) This is the same treatment plant where industry is authorized to use the municipal sewage system.

Source: Wanjiazhai Project for Optimal Integrated Water Importation/Use/Reuse/ Waste Management/Water Pollution Control at Taiyuan, China, Daniel Gunaratnam, Dr. H.F. Ludwig, July 1997.

B. SITUATION IN CHINA AND THE 3-H BASINS

Many cities in the 3-H basins and in China in general do not have sewers, and where sewers do exist, they often discharge untreated wastewater to the nearest drainage channels or watercourse. Collecting the wastewaters for treatment is a formidable and expensive task. But formal reclamation cannot begin until collecting sewers, interceptors and facilities for delivering the untreated flows to the treatment plants, and final disposal facilities are built.

Because alternative sources of water are generally not available for irrigation of high-value market crops near cities, the common practice is to use raw wastewater directly or to withdraw water from nearby streams that are often heavily polluted with raw wastewater. The consequent contamination of foodstuffs to be eaten raw maintains a high level of enteric disease in the area, not to mention unknown long-term consequences from toxic substances in the municipal sewage derived from industries and also from homes. Thus, improving the protection of public health, as well as the provision of additional water supply, present important incentives to the establishment of agricultural reuse projects near cities.

Water reuse for agricultural purposes is widely practiced in China, where wastewater is applied either without treatment or with only partial treatment, especially by irrigators who withdraw water previously used by upstream consumers. These are informal reuse schemes where the lack of treatment causes public health problems. Hence, the target for China is to bring all treatment and reuse schemes under a permit system of control so that both public health protection and water reuse objectives would be realized.

As explained in Chapter 3, many Chinese industries have inadequate wastewater treatment systems, but in severely water-short cities in north China, like Taiyuan and Changzi, the industries now furnish their own treatment as needed for their own reuse. The Wanjiazhai Water Transfer Project, involving World Bank financing, is designed to help alleviate the extremely severe water shortage problem at Taiyuan by water importation, but the overall project also emphasizes maximum feasible wastewater reuse for both irrigation and industry in order to decrease dependence on the very expensive imported water. This same principle is applied to the 3-H basins under the recommended action plan.

C. POTENTIAL WASTEWATER REUSE APPLICATIONS

Table 8.1 summarizes potential reuse opportunities for the 3-H basins. Some important aspects of Table 8.1 are as follows:

Groundwater Recharge: There appear to be two potentials that merit evaluation, namely (a) recharging to establish groundwater mounds to prevent water quality degradation from saline water intrusion and (b) surface spreading for shallow aquifer recharge. The potential for these practices, however, may be quite limited, given the many competing uses for the limited quantity of treated effluent water available. Another potential is for such recharging using surface water runoff during flood periods.

River Flow Augmentation: Ecological values in the river systems in the 3-H basins have been substantially altered or lost as a result of pollution and reduction of flow volume in the lower reaches. It seems that all available water, including recycled wastewater, would be required for human needs in both urban and rural pursuits. Consequently, at least in the foreseeable future, any wastewater discharged to the river system would be mostly extracted for human purposes, and "low flow augmentation" should be viewed in this context. It seems doubtful that the use of fresh water for low flow augmentation would be feasible in China, especially in north China where water shortages are severe.

Agricultural Reuse: A serious issue with the reuse of wastewater for agriculture relates to the quality of the water. Current water quality standards for agricultural use (Table 8.2 MR) seem hardly related to the reality of the situation in all water-shortage areas, including all of north China, where priority for use of water is given to the urban-industrial sectors, such that farmers commonly use very polluted river water or even raw sewage and feel "lucky" to get this. The most important water quality parameter for irrigation is the amount of coliforms, then followed by others such as total dissolved solids (TDS) and toxins such as cadmium. Apart from the very severe public health risks from this practice, the pollutants in the wastewater may adversely affect the soil fertility quality over a long period of time.

TABLE 8.1: CATEGORIES OF MUNICIPAL WASTEWATER REUSE AND POTENTIAL ISSUES/ CONSTRAINTS IN INDUSTRIALIZED COUNTRIES (ICs) COMPARED TO CHINA AND OTHER SIMILAR DEVELOPING COUNTRIES

Wastewater reuse categories	Issues and constraints in ICs	Issues and constraints in China
1. Agricultural irrigation Crop irrigation Commercial nurseries	1.1 Surface water and groundwater pollution if not controlled properly. 1.2 Marketability of crops and public acceptance. 1.3 Effect of water quality, particularly salts, on soils and crops. 1.4 Public health concerns related to pathogens (bacteria, viruses, and parasites).	1.1 Pollution of groundwater (GW) already happening because of irrigation with untreated wastewater, so any treatment prior to reuse is an improvement to GW pollution situation. 1.2 Crops are already marketed, sold, or accepted by the community with raw wastewater irrigation, so initial treatment can only improve this situation. 1.3 As above. 1.4 As above
2. Landscape irrigation Parks School yards Freeway medians Urban greenbelts and trees Residential	2.1 Use for control of area, including buffer zone. 2.2 May result in higher user costs.	2.1 In China, land is too scarce to allow use of buffer zones; in addition, land use planning policies are not as developed as in ICs. 2.2 Higher user cost is a real issue in China, since normal water supplies are highly subsidized by the government. Cost recovery issues of reuse schemes need to be addressed.
3. Industrial recycling and reuse Cooling water Boiler feed Process water Heavy construction	Constituents in reclaimed wastewater relating to scaling, corrosion, biological growth and fouling. Public health concerns.	The reclaimed water sent to industry is raw water supply for industry. Industry must further treat it to meet its particular needs. This is true even when industry uses the municipal water supply as its raw water. Industry often has to treat this to adapt it for the industry's operations. 3.2 Controlled by chlorination.
4. Groundwater recharge by spreading on areas with permeable soils 4.1 With treated wastewater 4.2 With flood runoff	 4.1.1 Buildup of TDS by continuous recycling. 4.1.2 Toxicity in wastewater used for spreading. 4.1.3 Pathogens not of concern because filtration in soil removes these. 4.2.1 May need to remove suspended solids from floodwater.	 4.1.1 Same as for ICs, except lower TDS standards may be needed. 4.1.2 Same as for ICs, except lower toxicity standards may be needed. 4.1.3 Same as ICs. 4.2.1 Same as for ICs.
5. Groundwater quality protection by establishing salinity intrusion barrier mounds	5.1 To protect salinity intrusion in groundwater. 5.2 Wastewater used for irrigation must have tertiary treatment to have very low turbidity.	5.1 Same as for ICs. 5.2 Same as for ICs.
6. Recreational and environmental uses, lakes, and ponds, marsh enhancement, augmentation of stream flow, fisheries	Health concerns on bacteria and viruses. Eutrophication caused by nitrogen (N) and phosphorus (P) in receiving water. Toxicity to aquatic life.	Same as for 5.1 above. Eutrophication is an environmental problem considered not quite as urgent as the public health and economic aspects, although the two are, of course, related. In any case, the implementation of wastewater treatment and reuse schemes in conjunction with improved water resource management through institutional reform of operation of water distribution and allocation at the provincial level should improve water quality and flows in rivers, which would reduce risk of eutrophication. 6.3 Limited aquatic life remains in rivers and lakes in the 3-H basins. All fish stocks are bred in aquaculture ponds. Wastewater from ponds contains high ammonia levels that need to be treated prior to discharge to rivers. In addition, fish kills occur frequently because of uncontrolled flooding with highly polluted floodwaters in the floodplain areas of the provinces. (Most fish ponds are situated in naturally occurring lowlands that were initially wetlands). Thus, treatment would improve this situation.

Wastewater reuse categories	Issues and constraints in ICs	Issues and constraints in China
7. Nonpotable urban uses Fire protection Air conditioning Toilet flushing	Public health concerns on pathogens transmitted by aerosols. Effects of water quality on scaling, corrosion, biological growth and fouling. Cross-connection.	Same as for 5.1 above. Same as for 3.1 above. Same as for ICs.
8. Augmenting urban water supply Potable reuse by spreading to augment groundwater	8.1.1 Problems of increasing TDS because of continuous recycling. 8.1.2 Problems of toxics in wastewater. 8.1.3 No problem with pathogens (all removed by filtration through soils).	8.1.1 Same as for ICs. 8.1.2 Same as for ICs. 8.1.3 Same as for ICs.
Potable reuse by blending in freshwater reservoir (now in experimental stage in the United States)	8.2.1. Problems of cross-connection. 8.2.2 Concern about disease hazards.	8.2.1 Not recommended for China. 8.2.2 Same as for ICs.
Dual piping systems—one for drinking and one for other uses	8.3 Cross-connection hazard.	8.3 Not recommended for China (too many cross-connection hazards).

Source: Adapted from Tchobanoglous G. "Appropriate Technologies for Wastewater Treatment & Reuse" in *WaterTech*, 1996 and modified by H.F. Ludwig and J. Foerster.

Municipal Reuse: The primary reuse potential is for irrigation of municipal landscape areas (parks, gardens, road strips) and for maintenance of ponds in parks for environmental aesthetics. For these reasons, reuses requiring dual reticulation networks are generally not considered appropriate for use in China. Suggested appropriate water quality requirements for such reuse are proposed (Table 8.3 MR).

Industrial Reuse: The reuse of industrial wastewater is a pivotal part of the plans for the reduction of environmental pollution in the 3-H basins. Moreover, reuse would play an important role in augmenting raw water supply for many water-short cities in north China. Maximizing the reuse of waters within individual industries and the reuse of wastewater discharged by industry to municipal sewers are the targets.

Available Reuse Quantities: The experience in the United States indicates that up to 30 percent of municipal wastewater can be effectively reused. Projected estimates of future wastewater reuse have been made for major cities in the Hai and Huai basins (Tables 8.4 and 8.5 MR). The wastewater would be available predominantly at centralized municipal WWTPs, which treat combined domestic and industrial wastes. The costs associated with the reuse of this water would include the cost of conveying the wastewater to the point of use.

D. Regulations for Reuse

As noted earlier, the permit system would require industries to remove toxins and objectionable constituents before discharging to municipal sewers (or to the environment). Table 8.6 MR presents a set of requirements on such control of industrial wastewater discharges considered to be appropriate for use in China and the 3-H basins. These requirements were derived by modifying U.S. practices to obtain guidelines that are practicable for use in developing countries, including China. These requirements are the basis for municipal ordinances for protecting municipal waterways from industrial pollutants. The required monitoring is done mostly by the wastewater discharging agencies, with the EPBs in the role of surveillance of the monitoring to ensure that its quality meets permit provisions.

As noted earlier, such requirements and ordinances would be meaningful for use in China and the 3-H basins only if the governmental agencies (national, provincial, municipal) are willing to accept that effective monitoring and enforcement are essential, and willing to implement a competent monitoring and enforcement program. With some guidance from Western experts on this subject, China can readily establish an appropriate monitoring and enforcement system if willing to do so. Monitoring costs are borne mostly by fees paid by the wastewater-discharging agencies pursuant to permit provisions. The key aspect is that the monitoring be technically competent in order to produce the firm reliable data needed for purposes of enforcement.

A salient nonstructural component of the action plan recommended by the present study is establishment of a meaningful monitoring and enforcement system, including use of the permit system by the municipalities and use of the courts for enforcement. This should include observation study visits in the United States, for example, with one of the California State Water Quality Control Boards operating in Southern California (the State system comprises nine regional boards, one for each of the State's nine river basins).

9. GROUNDWATER

A. Introduction

Falling groundwater levels are an extremely serious problem in China's water-short regions, including the 3-H basins, and groundwater pollution is also becoming a serious problem.

To alleviate this problem, the management gap that needs to be filled consists of establishing a system that can assess the problem on a basinwide basis (along with assessment of the surface water problem), which can determine how the limited groundwater (GW) can best be allocated for meeting both basinwide and local needs, and which can utilize the permit system for controlling extraction to match the allocation strategy. This chapter evaluates the situation in the 3-H basins and proposes an appropriate action plan, including the potential for GW recharging.

B. Action Plan for Competent Groundwater Management

The first step for improved groundwater management is to redefine the current area unit for GW investigation and management because it often does not coincide with provincial boundaries, or hydrologic basins at Level I or even Level II. This area is called the Groundwater Management Unit (GMU). The GMU must have the following characteristics:

(a) It must be large scale, to allow community participation in the decision-making process.

(b) It must be an aquifer system that functions as a single system (with interconnection flows between aquifer portions) when subject to pumping withdrawals.

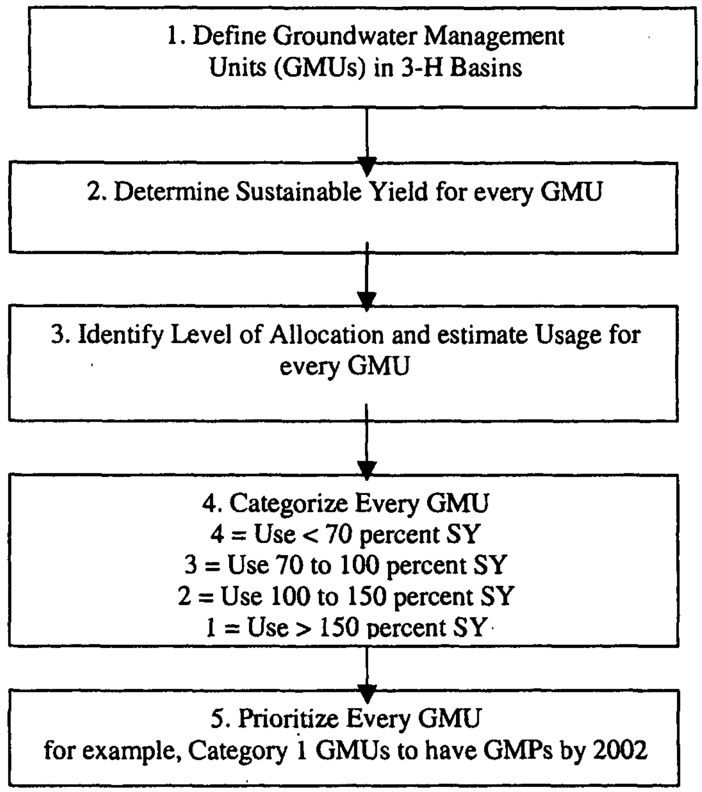
In most cases, the GMU would cover one aquifer only. There can be multiple GMUs overlying each other if there are multiple aquifers that behave essentially independently. For the Hai river basin, some 10 to 100 GMUs would be identified. The GMU boundaries can be chosen based on hydrogeological, geographic (for example, roads), or administrative (for example, county) criteria. The GMU boundary should normally include the recharge area, so that protection of the recharge area is included in the overall GW management plan.

This first step also requires the definition of sustainable yield for each GMU. This can be done by numerical modeling using Modflow, (MODular three dimensional finite-difference groundwater FLOW model) for example. For the present study, "sustainability" implies use of a resource in such a way that does not preclude the same level of use for future generations. However, because groundwater has often been overexploited for several decades, it is impossible to return to earlier levels of access. Hence, the aim of the groundwater management plans should be to (a) stop further overexploitation, (b) control pollution to prevent loss of GW quality, and (c) recharge the aquifers where this is feasible.

The specific groundwater management plan is to be devised for each GMU to take into account the local groundwater problems and needs of the community in line with national groundwater management principles. Then the GMUs should be prioritized based on the ratio of current usage to sustainable yield (SY). For example, GMUs with usage per SY ratio of > 1.5 should be classified as heavily overexploited, and their groundwater management plans should be implemented as matters of urgency.

The above steps are summarized as follows:

FIGURE 9.1: STEPS OF GW MANAGEMENT UNITS FOUNDATION



Groundwater extraction licensing requirements should be based on the sustainable yield assessment, and the licensing should be carried out by only one agency if the licensing system is to be effective. Three levels of management are needed to implement these reforms: (a) national-level planning and coordination (by MWR), (b) river basin management, and (c) GMU scale "day-to-day" management, controlled at the provincial level.

Drilling of water supply wells should be carried out by licensed drillers to ensure efficient well construction. In addition, well design should be undertaken by qualified groundwater engineers.

An absolutely fundamental need for effective groundwater management is a comprehensive, publicly accessible, groundwater database (GDB). The complete lack of such a GDB has prevented formulation and implementation of competent GW management throughout China. Such GDBs have been established in every country that has achieved competent management of GW resources. The GDB should be a coordinated operation with the national level on overall policies, with the river basin agency applying the policies to suit basin needs, and with maintenance by the provinces.

Many of the 3-H basins' GW aquifers have become seriously polluted over the past several decades, especially the shallower aquifers, resulting in their abandonment; hence more pressures on deep aquifers. It is important to note that even in the United States, the seriousness of this problem has been recognized only in the last two decades, with the realization that, once the aquifers are polluted with nondegradable toxics, resources may actually be lost permanently, unless the toxics are removed by "remediation" measures being developed and used in the U.S. "Superfund" program, which are extremely costly and not affordable in developing countries. The message for the developing countries, including China and the 3-H basins, is clear: pollution discharges must be controlled to prevent such degradation from occurring.

Users of GW must pay for the costs of such use, the same as for users of surface waters. This is of critical importance in severe water-short areas like Taiyuan, where pricing policy must be established to promote optimal differential use of surface waters, GWs, reused waters and imported waters.

C. ACTION PLAN FOR WASTEWATER REUSE

As noted earlier, many parts of the 3-H basins are now at the stage of very serious water shortage that requires maximum feasible reuse of water used by municipalities and industries, by modifying the basic concept of wastewater treatment with disposal to nearby receiving water bodies, so that disposal is by means of reuse of the treated effluent for municipal and industrial purposes whenever this is economically attractive and feasible. There are many artificial recharge schemes currently operating in China (Table 9.4 MR), and the purpose of the present study has been to explore the potential for more systematic use of this alternative.

The present study included fairly comprehensive preliminary evaluation of the potentials for using the municipal wastewater following treatment for alleviating GW degradation problems, including potentials for recharging aquifers by spreading the wastewaters on selected areas with suitable permeability and by creating GW mounds to protect aquifers from salinization by the intrusion of seawater or of nearby saline aquifers. The engineering technology for such use of treated effluents has been well developed in the southwestern United States and furnishes the information needed for competent design of such systems in China.

The study evaluated these potentials for some 33 selected 3-H cities with serious GW degradation problems and concluded that from the hydrogeological point of view, there are many feasible artificial recharge options. The study identified 11 high priority cities where feasibility studies should be undertaken, including consideration of the availability of treated wastewater for this purpose in competition with other uses. Areas in the Hai and Huai that are potentially suitable for artificial recharge have been delineated, as shown in Figure 9.1, included here. The hydrogeological characteristics of these recharge schemes are described in detail in Annex 9.1, Volume 3. These include permeability, hydraulic conductivity grain size, and porosity. The estimated volumes required to address the most severe groundwater problems in the 3-H basins are presented in Table 9.1 at the Basin II level, in Table 9.2 for individual cities (for water supply augmentation), and Table 9.3 for groundwater issues.

Another potential that could be feasible is the use of floodwater runoff for artificial recharging, and further evaluation of this potential is recommended. In California, use of untreated floodwaters for artificial recharge is a sizable business. Potentials for such recharge between levees for the Hai and Yellow river basins where GW is heavily overexploited have been estimated for areas (Table 9.9 MR).

The overall conclusion of the study is that the volumes of treated wastewater available for GW recharge in the 3-H basins are quite small compared to the huge magnitude of the GW overextraction problem. Moreover, it seems that only a small proportion of the wastewater might be available for artificial recharge. Deciding priorities for use of treated wastewater should be within the context of an overall water management strategy. Nonetheless it is possible that there could be enough wastewater available to help resolve critical GW overexploitation, in particularly in local areas, particularly in cities where overexploitation is most critical (Table 9.8 MR).

TABLE 9.1: VOLUMES OF WATER REQUIRED TO ADDRESS GROUNDWATER PROBLEMS IN 3-H

River basin	No.	Subarea	Area (km^2)	Groundwater problems	Volume (Mcm)	Time to solve problems	Possible options
Hai	2-1	Luanhe and east Hebei coastal area	54,530	Seawater intrusion Surface collapses	256	10 years	Decrease GW extraction Artificial recharge
	2-2	Hai river north system	83,119	Land subsidence Continuous drawdown of groundwater levels	2,440	20 years	Decrease GW extraction Artificial recharge
	2-3	Hai river south system	148,669	Land subsidence Continuous drawdown of groundwater levels	6,162	20 years	Decrease GW extraction Artificial recharge
	2-4	Tuhai and Majia river system	31,843	Continuous drawdown of groundwater levels	1,218	20 years	Decrease GW extraction Artificial recharge
	2	Basin total	318,161		10,076		Decrease GW extraction Artificial recharge
Huai	3-2	Between Wang and Beng area	91,860	Continuous drawdown of groundwater level	148	10 years	Decrease GW extract
	3-7	Shandong peninsula	60,370	Seawater intrusion	100	10 years	Artificial recharge
	3	Basin total	331,620		248		
Total			**1,448,842**		**11,143**	**20 years**	

TABLE 9.2: VOLUMES OF WATER REQUIRED FOR WATER SUPPLY PROBLEMS IN SOME CITIES

Basin	City	Problems	WW produced[a] (Mcm/yr)	Water needed (Mcm/yr)	Time to solve problems	Possible options
Hai	Beijing	Continuous drawdown of groundwater levels	360	565	10 years	Decrease GW extraction, artificial recharge
	Tianjin	Land subsidence; continuous drawdown of groundwater levels	140	158	20 years	Decrease GW extraction, artificial recharge, interbasin transfer
	Shijiazhuang	Continuous drawdown of groundwater levels	262	36	20 years	Decrease GW extraction, artificial recharge
	Tangshan	Surface collapses in karst area	372	10	20 years	Decrease GW extraction, artificial recharge
	Qinhuangdao	Seawater intrusion; surface collapses	26	122	20 years	Decrease GW extraction, artificial recharge
	Xingtai	Continuous drawdown of groundwater levels	79	26	20 years	Interbasin transfer
	Cangzhou	Land subsidence; continuous drawdown of groundwater levels		77	20 years	Decrease GW extraction, interbasin transfer
	Dezhou	Land subsidence; continuous drawdown of groundwater levels	71	37	20 years	Decrease GW extraction, interbasin transfer
	Anyang	Continuous drawdown of groundwater levels	115	57	20 years	Artificial recharge and interbasin transfer
	Datong	Continuous drawdown of groundwater levels	40	94	20 years	Interbasin transfer
	Puyang	Continuous drawdown of groundwater levels	15	50	20 years	Artificial recharge and interbasin transfer
Huai	Zhengzhou	Continuous drawdown of groundwater levels	41	293	10 years	Artificial recharge
	Xianyang	Continuous drawdown of groundwater levels; land fissures and subsidence	47	202	20 years	Interbasin transfer, artificial recharge
	Qingdao	Seawater intrusion		80	10 years	Artificial recharge and interbasin transfer
Yellow	Taiyuan	Continuous drawdown of groundwater levels		16	20 years	Interbasin transfer
	Xian	Continuous drawdown of groundwater levels; land fissure and subsidence		135	20 years	Interbasin transfer
	Lanzhou	Groundwater pollution		160	20 years	Interbasin transfer, artificial recharge
	Luoyang			35	20 years	Artificial recharge
Cities in 3-H Basin Total			**NA**	**2,493**		

[a] Data from Water Pollution substudy for the Hai/Huai basins. Data not available for Yellow.

Note: The volume data are from: Yellow River Water Resources Commission (1997), Haihe River Water Resources Commission (1997) and Huaihe River Water Resources Commission (1996).

TABLE 9.3: GROUNDWATER QUALITY ASSESSMENT FOR SOME PROVINCES IN THE 3-BASINS
(Percent)

Province/city	Class I	Class II	Class III	Class IV	Class V
Beijing	2	50	0	45	3
Tianjin	0	14	0	21	65
Hebei	4	27	0	35	34
Henan	9	40	0	36	15
Shanxi	3	28	16	49	3
Inner Mongolia	0	29	24	12	25
Ningxia	0	0	0	0	100
Gansu	0	0	42	33	25
Qinghai	0	0	0	0	100

Source: Department of Hydrology, Ministry of Water Resources, *Water Quality Assessment of China*, 1997.

The salient technical parameters for using wastewater effluents for recharging use the following:

- The level of wastewater treatment for recharging by surface spreading would be either primary or secondary depending on location. For creating GW protection mounds, tertiary treatment is required.
- Locations where coarse sediments outcrop around the western rim of the north China plain are the most attractive locations for shallow artificial recharge.
- The recommended GW Action Plan for GW is given in detail in Section D of Chapter 9, included here. This includes very substantial changes in GW management from its present quite inadequate level to a meaningful level, and recommendations for GW aquifer recharging and protection from saline intrusion.
- The level of wastewater treatment for recharging by surface spreading would be either primary or secondary depending on location. To create GW protection mounds, tertiary treatment is required.
- Locations where coarse sediments outcrop around the western rim of the north China plain are the most attractive locations for shallow artificial recharge.

The recommended GW Action Plan is given in detail in Section D of this chapter, included here. This includes very substantial changes in GW management from its present quite highly inadequate level to a meaningful level, and recommendations for GW aquifer recharging and protection from saline intrusion.

10. INSTITUTIONAL MANAGEMENT

A. INTRODUCTION

Previous chapters have reviewed the many complex problems of water resource management in China, which has long focused on flood control and irrigation, but in the past half-century the problems of urban and industrial water supply, water pollution control, and protection of aquatic ecological resources have also become major issues. Historically flooding has been the major unresolved problem, but nowadays there is increasing realization that water shortages in northern China, including in the 3-H basins, appear to be an equally severe problem in limiting the sustainability of continuing growth. Spectacular floods have given the impression that China has ample water, but the "unseen" reality is that the water availability in China on a per capita basis is only one quarter of the world average. In the 3-H basins it is only $1/20^{th}$ of the world average, and proper use of this precious limited resource is of the highest level of importance.

The government now recognizes the great importance of making the best possible use of the available water in nonflood periods, as well as the continuing importance of better flood management, and moreover that to achieve this would require a marked change in the existing institutional pattern relating to water resource management, which is now highly fragmented between national, basin and provincial local interests and agencies, to establish a new institutional system that recognizes that the salient approach must be based on planning where the entire river basin is the controlling, unit, with the national and provincial local governments working in coordination to achieve optional water utilization within the basin, including both surface waters and groundwaters.

Chapter 10 evaluates this situation as applied to the 3-H basins (and other river basins) in China, including consideration of (a) water resource allocation, regulation and enforcement; (b) demand management, financing, and incentives; and (c) service delivery organizations. The chapter then makes recommendations on the needed institutional changes.

B. WATER RESOURCE MANAGEMENT IN CHINA

The 3-H basins have reached a limit to the volume of water that can be delivered to consumers. With limited additional supplies, incremental increases can only push available resources by 19.7 Bcm to about 148 Bcm by 2050. In comparison, demand is projected to continue to increase from the present 169 Bcm to 204 Bcm, even with a 3.9 percent to 2 percent annual increase in price included in the calculations from the present and continuing to 2050. Thus, water shortages are not only projected to continue—confirming that the limits on the natural resource use in the 3-H basins have long been reached—but are forecasted to intensify, warning that competing demands on access to the available resources would become more acute. Since the traditional approaches to increasing supply from within the 3-H basins is no longer an option, many Chinese planners are rightly turning their attention to other methods of meeting supplies.

C. BASIC INSTITUTIONAL ISSUES

Governance Issues

MWR has the primary responsibility for overall management and development of the nation's water resources and is well-skilled and qualified to address the myriad problems. However, in an operational sense, its specific functionaries for flood protection and water management are implemented through the seven established River Basin Commissions, and the ministry's authority is limited in many critical areas, given the high degree of autonomy of China's provinces and overlapping jurisdiction of other ministries and agencies, particularly in the areas of urban water supply, groundwater management, pollution control, and operation of reservoirs for hydropower. The result is that the current water management system is somewhat confused, not cohesive, and fraught with opportunities for overallocation, which has been confirmed by grossly depleted groundwater resources.

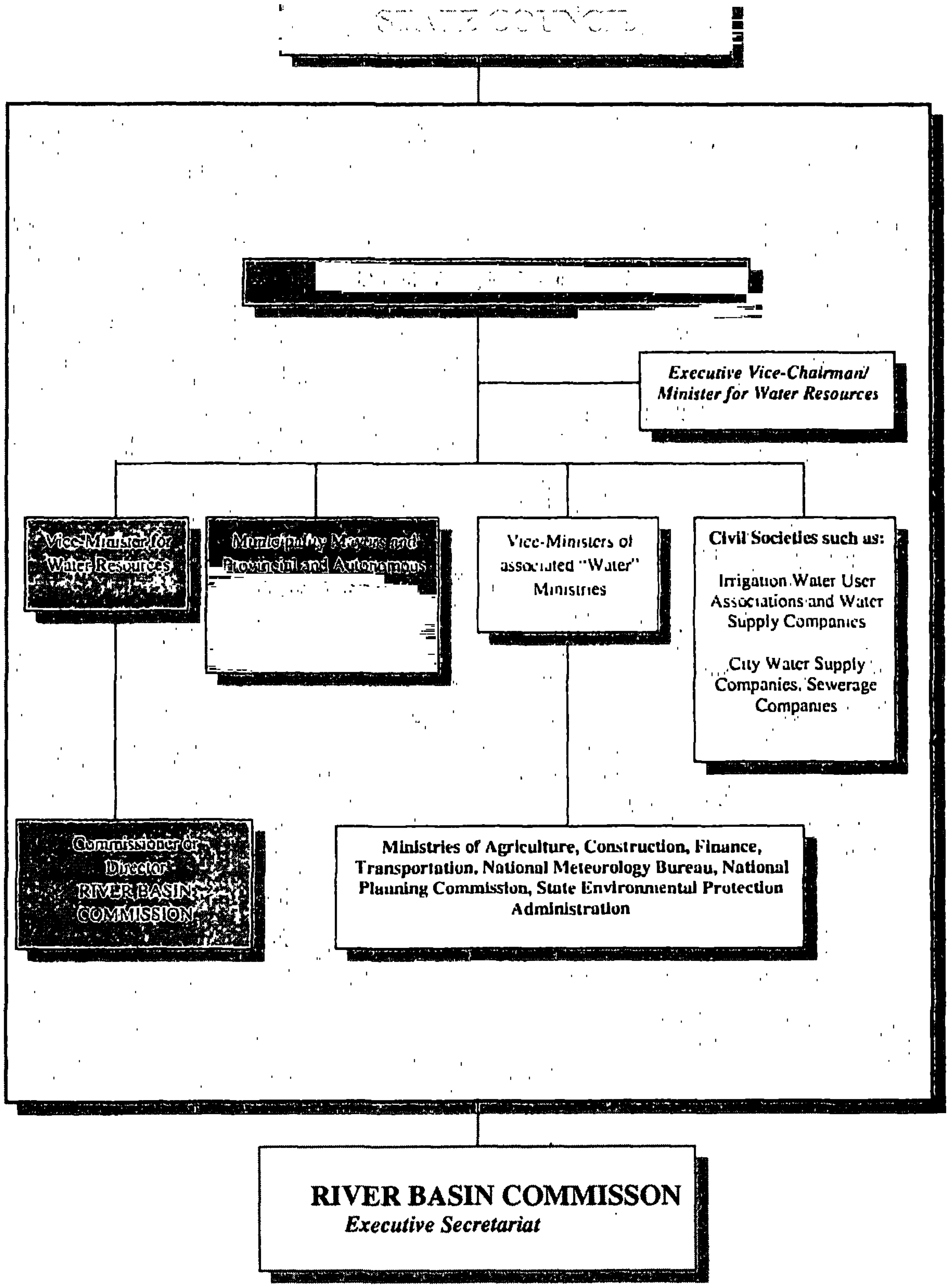
The River Basin Commissions are, in general, weak compared with the economic and political strength of the provinces. Institutional fragmentation from the central government downward explains a large part of this, since it does not allow planning and day-to-day operational management to be put into effect over the entire river basin. It is suggested, therefore, that the provinces' preeminence over natural resource management and development within their borders, subject to "technical" oversight by the respective river basin commissions, should be formally recognized and, in particular, their responsibility for the management and use of their respective shares of interprovincial surface and groundwaters. At the river basin level, the institutional challenge is to bring the provinces together with the key "water" agencies, so that they all have a direct role in governance to ensure sustainable development of the river basin as a whole.

D. Water Supply Allocations

Allocations Distribution of Allocations

In the 3-H basins, it is clear that future water allocations cannot meet demands. Hence, there would be required adjustments whereby priorities for water use would tend to be governed by productivity values, including increasing influence of free-market forces. The likely result is increasing water use for urban and industrial needs with irrigation allocations suffering continuing reductions.

However, three-fourths of China's population is rural and depends on agriculture for two-thirds of their incomes. Protecting and increasing these incomes and maintaining growth in agricultural production is a national concern, and one that depends in part on more and better irrigation. The indication is that the most feasible approach would be through rehabilitating and completing surface irrigation and drainage systems, including the installation of control structures and water-measuring devices to improve efficiency. Rehabilitation should be undertaken where economic benefits justify the investment, particularly if it provides a more reliable and equitable supply of irrigation water to farmers and increases deliveries to water-deficient areas within the scheme, typically located in the lower laterals and sublaterals. Investments in improving and extending these existing systems would likely provide better returns than new construction.


Executive Vice-Chairman/ Minister for Water Resources
Vice-Minister for Water Resources
Municipality Mayors and Provincial and Autonomous
Vice-Ministers of associated "Water" Ministries
Civil Societies such as:
Irrigation Water User Associations and Water Supply Companies
City Water Supply Companies, Sewerage Companies
Commissioner or Director RIVER BASIN COMMISSION
Ministries of Agriculture, Construction, Finance, Transportation, National Meteorology Bureau, National Planning Commission, State Environmental Protection Administration
RIVER BASIN COMMISSON
Executive Secretariat

Interprovincial Allocation and Related Agreements

The only formal allocation of a major river system in China, apart for from the Tarim River, is that for the Yellow River, which provides for the allocation of mean annual flows between 12 provinces, municipalities and autonomous regions. In addition, there are numerous local agreements relating to specific tributaries and watercourses that affect more than one province.

Numerous problems have arisen in the Yellow River basin with existing basin allocations, which include (a) excessive withdrawals in the upper reaches, (b) disputes as to whether the allocations refers to consumptive use or gross withdrawals, (c) failure to clarify how shares are to be adjusted in response to variable river flows, and (d) how to manage flows in recent years that have fallen well short of the mean assumed. To manage these problems, the provinces need to know what resources are at their disposal if they are to have preeminent responsibility for resource planning and management.

E. Basin Management Functions of River Basin Councils

In view of the forgoing, it is recommended the River Basin Councils be charged with the responsibility for (a) determining water resource allocations (surface and groundwater) for the various municipalities, provinces and autonomous regions; (b) development of broad policies and programs promoting sustainable water resource management, and particularly with respect to (i) flood control and drought relief, (ii) groundwater management, (iii) water resource protection and pollution control, and (iv) promotion of increased water use (especially irrigation) efficiency through demand management mechanisms and community-farmer education; and (c) preparation and supervision of comprehensive basin development and operating plans, which would be essential to the preparation of provincial plans, but would not dictate how the provinces should utilize their water allocations.

F. Groundwater Management

As noted in Chapter 9, groundwater management areas (GMAs) need to be defined and groundwater management plans (GMPs) drawn up for those aquifers that are overdeveloped. Three levels of management are needed to implement these reforms, including (a) national-level planning and coordination (by MWR), (b) river basin-level allocation linked to provincial licensing of groundwater use (by RBCNs), and (c) GMA-scale "day-to-day" management, controlled at the provincial level.

The new management structure would plan and implement needed reforms for the salient issues, which include management of licensing, databases, interbasin groundwater issues, groundwater investigation, and setting GMA boundaries. Details are given in Chapter 9, Section C.

G. Regulation and Enforcement

The water use permit system is the primary instrument for regulating water quantity, and for administering the discharge permit system for regulating pollution discharges and water quality.

Water Use Permits. The water permit system was authorized in 1988 and became operative in 1993. Each province has since adopted its own regulations, and permits now covers approximately 85 percent of water withdrawals in the country. Permits are issued to utilities, irrigation companies, and industries that take water directly from the water system rather than to end-users. In principle, permits cover both groundwater and surface water (excluding specified small users), but it has proved more difficult to extend coverage to dispersed wells than to identifiable river offtakes. The permit system has been developed remarkably quickly, although problems have inevitably arisen, including (a) monitoring and enforcement problems; (b) insufficient objective data on which to base allowed quotas; (c) ambiguities on rights and allocations at times of shortage; and (d) overlapping responsibilities between the provinces, the local departments, groundwater agencies and the RBCNs.

Pollution Discharge Permits. The discharge permit system dates from the 1984 Water Pollution Law although, as in the case of water permits, implementation was delayed until implementing regulations had been adopted. Similar problems have arisen to those faced in implementing the water permit system. Moreover, as its name implies, a discharge permit controls specific point sources, and is only indirectly related to total loads and ambient water standards. The permit system is only one aspect of management to achieve desired ambient quality levels in designated river reaches. The other aspect, which is to set ambient quality levels that can be reached by feasible pollution control measures, is lacking. Instead, the river classifications are set more or less arbitrarily. Hence, the classifications may be quite unrealistic.

While the discharge permit system for controlling waste discharges is sound in principle, its application in China (as in other developing countries) has been limited because the EPBs have not had sufficient resources for monitoring and enforcement. As noted earlier, in areas of critical water shortages, China must face up to this issue and install appropriate monitoring and enforcement procedures.

In addition, where water shortages are very severe, as in Taiyuan, where very expensive water must be imported to help balance supply and demand, it would be necessary to combine the two permit systems to use a system covering all agencies that either supply or use water. The Taiyuan experience clearly illustrates this need.

H. ENVIRONMENTAL STANDARDS FOR WATER QUALITY

As noted in Chapter 7, in order to achieve cost-effectiveness in managing pollution in the 3-H basins, design of the pollution control facilities needs to be based on economically acceptable, as well as environmentally acceptable, criteria or standards, including both ambient standards (river water quality use classifications) and emission or discharge standards. Experience in practically all developing countries over the past several decades has shown that environmental standards promulgated by national environmental agencies are often not met or cannot be met, because the standards often attempt to match those set by the affluent industrialized countries. As a consequence, some of the ongoing major MWR water resource development projects, such as the Xiaolangdi Dam project in the Yellow River basin, utilize standards for the management of wastes that are practicable and affordable under the circumstances.

The recommendation here is that it seems very timely now to formulate and carry out a study to review and evaluate the ongoing situation on water quality standards as applied to the 3-H basins, so as to achieve a better balance between goals and actual results. Such balance is sorely needed because of the large wastage that can accrue in investing in systems for achieving goals that are not realistic. Of special importance is the need to reevaluate the river water quality classification system prepared by SEPA, to ensure that this is consistent with the current status of applicable technology, particularly as related to the minimum quality standards for river water suitable for raw water supply for municipal systems. A great deal of research and development has been carried out in the industrialized countries over the past 50 years on how to improve performance of the rapid sand filtration systems (RSFSs), which are commonly used for treating raw waters to produce an effluent of drinking water quality, especially on the use of new flocculation agents used in the RSFSs. As a result, it is now feasible to produce high-quality drinking water using raw water of much lower quality than, say, in 1950.

Another aspect of the study would be to modify emission and effluent standards so that they would be realistic and appropriate as the bases for design of facilities and systems. The suggestion here is to consider the existing standards as goals and to set "working level standards" (WLSs) applicable to the existing status of economic development for, say, a period of 10 years, to be revised every new decade, that is, set the WLSs at levels representing the maximum standards that can reasonably be met at the time, which could be accepted by industry in a constructive manner, so that the industry would be prompted to comply rather than evade them.

On this same point, it should be noted that experience in the industrialized countries where effective river pollution control has been accomplished shows clearly that small-scale, polluting-type industries, including many TVEs and straw-type paper mill plants, would never be able to afford appropriate wastewater treatment. Hence, they must be phased out over an acceptable period of time with appropriate government programs in place to absorb the displaced work force. This would form part of the feasibility study for all programs in pollution abatement in the same way that resettlement is an important component of flood control or dam construction projects.

Emission and discharge standards applicable to industrial wastewater discharges should be expressed in weight units (weight of pollution per a selected unit of plant production) rather than in concentrations of discharge volume. The U.S. Environmental Protection Agency made this change in the 1970s, in recognition that concentration units cannot be depended upon to achieve control. It is timely now for China and SEPA to do the same. Such weight units eliminate the industrial practice of wasting large amounts of water to dilute wastewater effluents so that they would meet concentration standards with no or lesser treatment.

It would be very helpful if the Action Plan program could include translation of the latest volume of the U.S. *Standard Methods for Examination of Water and Wastewaters*, which is a virtual up-to-date textbook on the current status of water quality technology, and copies of this could be made available to those who need it.

To sum up, the proposed study would reevaluate the entire subject of water quality standards applicable to industrial and municipal wastewaters in China, including emission and ambient standards and including the river water quality classification system. These revised standards would come up with a new set of regulatory requirements, which would be constructive and suitable as the basis for design of community water supply and sewerage systems and of industrial wastewater management systems.

I. Environmental Monitoring and Enforcement

As noted earlier, it is essential that China now face up to the essential need for competent monitoring and enforcement of pollution discharges, to ensure compliance with the permit system's requirements. And, in critical water-short areas like Taiyuan, where very expensive water is to be imported, the permit system and associated monitoring and enforcement should cover water suppliers as well as users.

Initial efforts at pollution discharge monitoring should focus on the large heavy industries with the largest potentials for pollution, which would yield the highest results from the investment and yield guidelines for proceeding with other industries.

All monitoring programs should be reviewed periodically (say, annually) to eliminate wastage and to cover all needs in order to obtain reliable information at least cost. Monitoring should not measure "everything" designated in prescribed monitoring manuals, but should be limited to obtaining data that is actually useful or necessary for control purposes.

There is need for improved coordination between the water quality monitoring programs to be carried out by MWR and by SEPA to eliminate overlapping and to fill gaps.

There is a need to evaluate the adequacy of enforcement applied by the regulatory agencies (EPBs and SEPA) and the effectiveness of such enforcement in obtaining (a) compliance by pollution discharging enterprises, and (b) compliance with monitoring to be carried out by the discharger (as specified in the project environmental impact assessment and the discharge permit). Such evaluation should also include meaningful penalty measures for persistent noncompliance, and how to improve use of the enforcement power of the regulatory agencies.

J. Economic Regulation

There is need to review the current system of levies applied for industries in the priority cities (which are likely to be representative of those in the whole of China), so this system would give optimal support and be consistent with the proposed action plan. Economic regulation deals with enterprises, and financial matters, and in particular the need to protect society from monopolistic abuse. Potential tasks include (a) definition of service obligations and service standards, (b) determination and supervision of water tariffs, (c) approval of investment plans, (d) standardization of accounting systems, (e) the overseeing of financial planning, (f) the overseeing of civil service structure, (g) enforcement of regulatory requirements, and (h) resolution of disputes involving water entities. The primary task is to set prices in such a way that efficient and viable water services are provided.

Section C in this chapter reviews and evaluates this problem with suggestions on how existing practices in China can be improved to support the recommended action plan.

K. Demand Management: Financing and Price Incentives

Introduction

Appropriate charging for both surface and groundwater, in all its uses, is the single most effective method to overcome many of the problems of water shortage and water pollution in the 3-H basins. Water permit systems and water-saving activities are much more effective when supported by appropriate water charges and prices.

The salient issues are covered in Section D in this chapter.

Components of Water Pricing

Resource Charges. China is one of the few countries that has included a resource charge in the water laws and regulations, but it has been linked to resource administration costs rather than to opportunity and externality costs. It is thus regarded more as a cost recovery instrument comparable to a service charge than as an economic incentive mechanism. Likewise, pollution charges from point sources are related to cost of administration.

Charges for resource use and water discharge can have an important role in promoting sustainable and optimal water use, and can powerfully reinforce the implementation of the permit systems provided (a) the charge is delinked from the costs of resource administration (which should be a regular item in the national and/or provincial budget), and (b) the level of the charge is varied to reflect specific conditions and to be increasingly adjusted to reflect scarcity and externality effects associated with the resource concerned.

Details on the implementation of the proposed revised system, which involves many complexities, all feasible, are given in the full report.

Service Charges. Charging urban and industrial consumers for water at levels that more closely approach marginal costs can be a powerful determinant of water demand. However, present charges are usually much below full cost recovery levels, and hence need to be increased fairly sharply in the short term if full cost recovery is to be achieved. And since costs typically increase in real terms over time, charges would need to rise continuously if full cost recovery is to be sustained.

For water prices to be effective in improving efficiency, water services need to be charged on a volumetric basis, and all users must be required to pay. Water charges should not be lumped with other charges, nor should water charges be subsidized. The structure should also be simple. Structures vary greatly around the world, and include rising block tariffs, falling block tariffs, and quota allocations with penalties for excessive use. However, it is increasingly being realized that a uniform tariff rate is the simplest, fairest and most effective structure; and that water tariffs are an inappropriate vehicle for welfare assistance. Where water is scarce and incomes are low, as in the 3-H basins, uniform volumetric tariff rates are almost certainly the most sensible structure to adopt.

Irrigation. In contrast to urban and industrial uses, any realistic irrigation water charge is so far below the theoretical equilibrium price, and the irrigated area is so extensive, that the irrigation sector would in practice take any water that remains after satisfying priority industrial, urban and other demands. Even so, an increase in irrigation water charges could potentially contribute to increased economic returns per unit of irrigation water, for example, by promoting reductions in field applications, changes in cropping patterns, extensions of actual irrigated areas and/or farm restructuring (Chapter 5). Higher water charges would also help cover O&M costs and some capital costs, and thus help promote the sustainability of irrigation schemes. The report gives suggestions on how to proceed to implement this policy. The study conclusion is that farmers are willing to pay higher rates and to adjust practices to make more efficient use of water.

Water Markets. Tradable water rights and discharge permits would inevitably have a role to play in the conservation and allocation of water use. Water markets have the great advantage over administrative charges in that they arise out of the mutual interests of willing buyers and willing sellers. There are many examples of water markets, for example, between farmers along a watercourse and for tanker water in cities poorly served by reticulation, already in use in China, which are short-term "spot" markets readily managed at the local level.

Long-term markets involving tradable water rights and/or pollution permits are more difficult to introduce. Nevertheless, some more longer-term exchanges have occurred in the 3-H basins, despite the fact that they appear to be disallowed under the regulations governing the existing permit systems. For instance, the city of Qingdao is reported to have purchased the water rights of local farmers at rates favorable to both the city and the farmers. The potential for integrating exchangeable and saleable rights within the permit systems is an area that should receive further study, within the context of the evolving "socialist market" system.

L. ORGANIZATIONAL ISSUES AND SERVICE DELIVERY

Organizational issues have been referred to in earlier sections of this chapter. In particular, independence has been advocated for resource management and regulatory agencies, and financial autonomy has been assumed in respect to most bulk water and service delivery entities. These suggestions are consistent with present policies of decentralization, as expressed in legislation.

It is recommended that resource management and regulation should be consolidated at the level of the province for all water resources lying within a province's borders. Hence, the provinces would need to strengthen their policy-making and planning functions, and all water sector policies and programs would need to be coordinated within the framework of a provincial water resource plan consistent with water allocations and broad planning at the river basin level.

Multipurpose Bulk Water Facilities

Construction and operation of multipurpose facilities are, as at present, often best left to single-purpose subsector entities that have predominant interest in the facility concerned, for instance, in system irrigation reservoirs that also provide domestic supplies, city reservoirs that have environmental or recreational benefits, and hydroelectric dams that also serve other requirements downstream. This recognizes that operations are so closely integrated with the primary purpose that it would make little sense to separate operational responsibility from the user entity.

If a multipurpose facility, however, serves a number of clearly identified users on a sizable scale, there may be strong justification for a separate multipurpose or bulk wholesaling entity to clarify accountabilities.

Service Delivery

The scope of a service entity needs to reflect the subsector concerned, taking into account economies of scale and other factors. Irrespective of size, services are typically provided in a hydraulically defined or geographically defined area. Thus, urban water supply and sanitation may be provided for a city or town, irrigation within a command area, flood protection for an area threatened by a river, and electricity within a power grid.

Organizational structure is best addressed at a subsector level but five main types of service delivery entity can be described: (a) department service provision, (b) government or publicly owned utilities, (c) public-private partnerships, (d) privately aimed facilities, and (e) customer-owned facilities.

Many irrigation and urban water supply services in China are provided by publicly, or communally owned, autonomous entities. With the move to a socialist market economy, numerous models are being piloted with the aim of increasing efficiency and customer satisfaction, and reducing the financial burden on government. They include models for water user associations and independent water supply corporations for main system operation. Which model is appropriate depends on subsector and location-specific factors. The key issues are local control, and that water use, water price and collected fees are transparent. In introducing reforms, however, there is a need to guard against three real dangers, each of which threatens to undermine the success of reform programs. They include (a) failure to provide service entities with true autonomy, (b) failure to clarify ownership and risk, and (c) failure to address all service requirements in an integrated and balanced manner.

Wastewater Utility Reform

Newly formed wastewater companies in the implementation of their institutional and financial reform programs have largely focused on those reform elements in which implementation can be achieved within the companies' existing scope of authority. This includes fixed asset transfers, the assumption of direct operations of some assets, the development of plans and policies for taking over remaining assets, and the implementation of enterprise accounting systems. However, achieving progress in core elements of the reform programs also requires approvals by the municipal governments on such items as financial autonomy, tariff policy and operationalizing of the companies including enterprise accounting, billing and collection, operational status of the wastewater companies, fixed assets transfers and sludge management.

M. RECOMMENDATIONS

Recommendations for Immediate Implementation

The recommendations in this chapter, for immediate consideration, as an essential part of the recommended action plan, are summarizes briefly as follows:

- Establish high-level River Basin Coordinating Councils in each of the 3-H basins.

- The River Basin Councils are to be charged with, and given the necessary legislative support for: (a) determining water resource allocations (surface and groundwater) for the provinces, (b) developing policies and programs that promote sustainable water resource management, particularly with respect to flood control and drought relief, groundwater management, water resource protection and pollution control, promotion of increased water use (especially irrigation) efficiency, and comprehensive basin development planning.

- The established River Basin Commissions are to be confirmed by law as the primary water resource management agencies in the basins (and with specific flood control responsibilities) to ensure enforcement of council decisions on the allocations, policies, and programs in consultation with the municipal, provincial, and autonomous region governments, and to be strengthened with the appropriate expertise, where necessary, to provide the administrative and technical secretariat support for the respective River Basin Councils.

- Strategic planning methodology is to be adopted by the River Basin Councils to determine the policy, program and project priorities required to accelerate the basins toward achievement of sustainable development.

- Provincial Water Resources Coordinating Committees are to be established, as necessary, on similar lines to the river basin councils.

- Within the provinces and at the major water service entity level, the recommended institutional arrangements proposed for managing and utilizing the water to be delivered by the Wanjiazhai water transfer project, now under construction for the provision of urban and industrial water supplies in the city of Taiyuan in Shanxi Province, are to be adopted as the model for use elsewhere in the 3-H basins, and indeed throughout China.

- Legislative amendments and institutional restructures be undertaken so that approval to extract both surface and groundwater rests with a single agency (presumably MWR) working in coordination with the river basin agencies and the provincial, prefecture and county water departments and bureaus. This is very urgent.

- With respect to the irrigation sector, institutional reform to transfer management authority from the government be actively promoted by establishment of WUAs, WSCs, and SIDDs.

- With respect to the urban-industry sectors, provisions are to be made (a) for effective use of the permit system for regulating all water "handlers," including suppliers and users, including integration of water use and pollution control permits in critically water-short areas, (b) conducting an in-depth study on current practices in China on setting of environmental standards in the water sector, and revision of existing standards to be appropriate for Action Plan purposes, (c) recognition of the fundamental importance of competent environmental monitoring and enforcement in the water sector, and establishment of this system as promptly as possible, including at the national level, coordination of SEPA and MWR monitoring to be an integrated comprehensive cost-effective program, and (d) efforts be made to encourage greater adoption of a range of water use efficiency suggestions, and in particular reuse of municipal wastewater around the major urban areas for irrigated agriculture, using the Australian "Filter" technology.

Additional Recommendations

The following additional recommendations need to be authorized and implemented as integral parts of the overall action plan.

- With respect to flood control arrangements, consideration be given to establishing a division within the group to provide emergency assistance to the central government and local governments during flood (and drought) events.
- With respect to demand management, water charges are to be instituted for all uses and users where practical (on a metered volumetric basis) and supported by necessary regulations.
- A community awareness and education program is to be initiated, confirming the seriousness of the resource situation, the necessity to save water, and the means by which this may be achieved.

11. PROPOSED ACTION PLANS

A. INTRODUCTION

The action plan summarized in this chapter proposes a set of integrated measures to be adopted by riparian states in the 3-H basins, the Ministry of Water Resources and the World Bank. The recommendations include structural changes, policy/nonstructural changes and institutional changes which, if applied in the proposed timeframe and with sufficient degree of political and financial commitment, would ensure that water resources do not impede China's development but rather play an increasingly vital and supportive role in the development of China's economy and society. The main components of the proposed action plan are in the areas of (a) water resource development, (b) flood protection, (c) agriculture, (d) water pollution, (e) wastewater reuse, (f) groundwater, and (g) institutional management. The main aspects of these components are described in this introduction and more specific actions for each component are presented in sections B to H below. The last section in this chapter presents the summarized total investment program for the action plan.

Water Scarcity and Water Resources: The current level of shortages is caused by excessive demand for water and limited supplies at the basin level. The proposed action plan recommends two key measures for demand management because water resources are unable to cope with augmented new supplies from within the 3-H basins if sustainable water balances are to be maintained. These measures are (a) price increases for all sectors and (b) increased efficiency. According to the analysis carried in this study, demand management alone would not be able to reduce demands for water to meet current supply levels and so the action plan recommends two measures to augment supplies. These are (i) increased wastewater reuse and (ii) construction of the South-North transfer.

Flood Protection: The study describes how losses due to flood damage are increasing despite massive efforts and resources being expended on flood protection. The action plan recommends more emphasis on the development of a systematic methodology focusing on flood protection areas with defined flood protection levels to focus on the protection of key assets. Flood protection is a highly visible activity to the public and is easily targeted for short-term political gains but the costs to society of inappropriate flood protection are also highly visible and damaging. In addition, the action plan proposes a series of strategic projects in the 3-H basins in parallel with existing recommendations by Chinese planners. These strategic projects are in the areas of (a) reservoir construction, (b) upgrading of flood capacity, (c) risk assessment, (d) upgrading of flood forecasting and warning systems, (e) infrastructure construction for safe evacuation in detention basins, (f) the development of hydrodynamic models for flood damage assessment.

Agriculture: The changes occurring in China's economy would continue to reduce the relative importance of the agricultural sector's contribution to GDP. However, agriculture itself would continue to grow over the coming decades and would also undergo a shift from grain production to higher-valued cash crops. The percentage income of farmers derived from agriculture would remain steady at about a third of total income and for many farmers in inland provinces, agriculture would continue to be an important source of revenue and security. The action plan recognizes the important social and political (including food security) implications of maintaining adequate water supplies to rural areas for agriculture. At the same time, the cost to the government of supplying large volumes of water to low value-adding agricultural activity is no longer sustainable. Thus the action plan focuses on structural and nonstructural components. The action plan recognizes the need to increase participatory mechanisms and continue management reforms in order to develop innovative models for irrigation districts management including leases, water user associations, contracts, auctions, joint stockholders, water supply companies and self-financed irrigation and drainage districts. Structural components run in parallel with existing Chinese government programs, namely the comprehensive agricultural development program, the large irrigation district program and the water-saving program. These are solely focused on demand management, increased efficiency of water use and appropriate pricing reviews and no supply augmentation is proposed for agriculture. The exception might be indirect water supply derived from wastewater reuse schemes where some water might be available for market gardens in the peri-urban areas around cities once priority shortages for industry and urban life have been satisfied. In addition, increased return flows from additional water supply to priority uses would also benefit irrigation.

Water Pollution: Surface and groundwater quality has been declining for the last several decades to alarming states in much of the 3-H basins. The action plan recognizes that water pollution is not only a threat to public health and the environment but also diminishes the total resource available for specific beneficial uses and these effects combine to seriously impede China's development. The action plan recommends structural, nonstructural and institutional investments and programs to enhance existing government efforts designed to improve declining current water quality trends. Structural options available to reduce industry pollution loads include (a) industrial wastewater treatment, (b) cleaner production technology, and (c) reuse of treated wastewater. Reuse of wastewater features as part of the water resources action plan that highlights the integrated nature of the recommendations. Pollution from urban municipal sources would be addressed by constructing municipal wastewater treatment plants with the required pipe network to allow industry to discharge its wastewater into the municipal systems thus reducing the costs significantly to industry and the community. In the less affluent areas of the cities and for rural populations, programs of well-engineered pit latrines should be developed. Small industry collectively represents a significant proportion of the pollution load and the action plan recommends gradual phasing out of those industries not able to afford treatment or cleaner production for pollution control. Livestock would continue to grow in the 3-H basins because of growing domestic demand and because of China's imminent entry into the WTO which would strengthen industries where China has comparative advantages. Pollution from livestock is already significant and the action plan recommends stabilization ponds and a manual of guidelines for appropriate design and construction.

The nonstructural part of the action plan for water pollution is equally ambitious. The main components of include (a) review of water quality, effluent and laboratory analytical methods standards, (b) review of the monitoring program by MWR and SEPA including opportunities for combining these for increased benefits and reduced costs, (c) review of the regulatory system with a view to develop a mass-based system, (d) inclusion of environmental impact assessment process for small industry planning, (e) review of the pollution permit allocation system and its management at the EPB level.

Wastewater Reuse: As prices for water increase, the value of wastewater would also increase, permitting the development of wastewater reuse schemes. The action plan recommends that options for reuse of wastewater for agricultural, municipal and industrial purposes be investigated. While such practice is already established for agriculture, formal schemes would reduce public health threats. Treatment for municipal reuse would need greater degree of treatment while treatment at common industrial treatment plants, combined municipal treatment plants or in-plant treatment would supply raw water for industry to be further treated according to individual requirements. The development of appropriate institutional and legal mechanisms would be required including local ordinances for combined treatment systems.

Groundwater: The alarming decline in shallow and deep water tables in many parts of the 3-H basins is symptomatic of excessive withdrawals that are in turn due to (a) excessive pollution of alternative sources of water, (b) general water scarcity situation, (c) lack of demand management (low prices for the resource), and (d) ineffective or nonexistent regulatory mechanisms to control withdrawals. The key actions required by the action plan are (i) definition of groundwater management units with determination of sustainable yields, (ii) preparation of groundwater management plans, (iii) allocation licensing linked to the sustainable yield and undertaken by one department only, (iv) licensing of well construction drillers, (v) development of a national groundwater database, and (vi) preparation of groundwater pollution strategy.

Institutional Management: The role that institutions play in the management of water resources is critical and paramount for the success of the proposed action plan. In addition to those noted in previous sections, a number of key recommendations must be implemented to facilitate other components of the action plan. These include (a) the establishment of high-level River Basin Coordinating Committees or Councils in each of the 3-H Basins, (b) the RBCMs be charged with determining water resource allocations and developing water resource policies, (c) RBCMs be given the necessary legal muscle and be confirmed by law, (d) the strategic planning methodology be adopted by the RBCMs, (e) provincial water resource coordinating committees be established at the next administrative level including for the management of water resources at the local levels, (f) ensuring that only one agency be charged with permits for resource extraction, for example MWR, (g) transferring management of irrigation districts to local institutions following a consultative process, and (h) reviewing water charges for all sectors.

The following table summarizes the needed investment required to implement the action plan described above.

TABLE 11.1: ESTIMATION ON THE NEEDED INVESTMENT FOR IMPLEMENTATION OF THE ACTION PLAN
(Constant Billion Yuan)

		2000-2005	2006-2010	2011-2015	2016-2020	2021-2025	Total
		Water Supply New & Rehabilitation					
Hai	Urban	2.8	4.1	4.2	2.8	1.6	15.5
	Rural	0.8	1.2	1.1	0.8	0.0	4.0
	Environmental	0.1	0.2	0.1	0.1	0.0	0.5
	Subtotal	3.7	5.5	5.5	3.7	1.6	20.0
Huai	Urban	3.9	5.8	5.3	3.5	1.1	19.6
	Rural	1.0	1.4	1.6	1.1	0.2	5.3
	Environmental	0.8	1.3	1.3	0.9	0.1	4.4
	Subtotal	5.7	8.5	8.2	5.5	1.4	29.3
Yellow	Urban	2.6	4.0	3.7	2.5	1.1	14.0
	Rural	0.5	0.7	0.8	0.6	0.2	2.8
	Environmental	0.4	0.7	0.7	0.5	0.0	2.3
	Subtotal	3.6	5.4	5.3	3.5	1.4	19.1
	3H Total	**12.9**	**19.4**	**19.0**	**12.7**	**4.4**	**68.4**
	S-N Transfer	**122.5**	**122.5**				**245.0**
	Total	**135.4**	**141.9**	**19.0**	**12.7**	**4.4**	**313.4**
		Water Pollution Control and Reuse					
		2000-2005	**2006-2010**	**2011-2015**	**2016-2020**	**2021-2025**	**Total**
Hai	Urban Industry	6.4	9.6	8.0	8.0	2.0	34.0
	Urban Municipal	9.1	13.6	11.4	11.4	2.8	48.3
	Rural Industry	3.9	5.9	4.9	4.9	1.2	20.9
	Rural Municipal	3.4	5.1	4.3	4.3	1.1	18.2
	Livestock	1.0	1.4	1.2	1.2	0.3	5.1
	Total	23.8	35.7	29.8	29.8	7.4	126.5
Huai	Urban Industry	6.7	10.1	8.4	8.4	2.1	35.7
	Urban Municipal	8.9	13.4	11.2	11.2	2.8	47.5
	Rural Industry	6.2	9.3	7.8	7.8	1.9	33.1
	Rural Municipal	6.4	9.6	8.0	8.0	2.0	34.0
	Livestock	1.7	2.5	2.1	2.1	0.5	8.8
	Total	29.9	44.9	37.4	37.4	9.4	159.1
Hai + Huai	**Total**	**53.8**	**80.6**	**67.2**	**67.2**	**16.8**	**285.6**
		Irrigation Efficiency Improvement					
		2001-2005	**2006-2010**	**2011-2015**	**2016-2020**	**2021-2025**	**Total**
Hai	SOCAD	3.2	1.7	1.5	1.4	1.2	9.0
	Water Saving	5.1	9.0	7.4	5.0	5.2	31.7
	LIS	7.8	5.4	4.1	0.1	0.0	17.4
	Total	16.1	16.1	13.0	6.5	6.5	58.1
Huai	SOCAD	4.3	2.5	2.2	2.0	1.8	12.7
	Water Saving	6.6	8.9	8.6	5.9	6.1	36.0
	LIS	6.1	12.5	14.0	0.3	0.0	32.9
	Total	17.0	23.9	24.7	8.2	7.9	81.6
Yellow	SOCAD	3.1	1.5	1.3	1.2	1.1	8.2
	Water Saving	5.0	5.3	5.2	3.7	3.9	23.1
	LIS	12.5	11.4	10.0	0.3	0.0	34.2
	Total	20.6	18.2	16.5	5.2	5.0	65.4
	3H Total	**53.7**	**58.2**	**54.2**	**19.8**	**19.3**	**205.2**
		Groundwater Recharge and Rehabilitation					
		2001-2005	**2006-2010**	**2011-2015**	**2016-2020**	**2021-2025**	**Total**
Hai	GMU establishment	2.0	2.0	2.0			6.0
	Database	1.0	1.0				2.0
	Recharge Basin	5.0	10.0	10.0	10.0		35.0
	Injection wells	5.0	5.0	5.0	5.0		20.0
	Well rehabilitation	2.0	2.0	2.0	2.0		8.0
	Total	15.0	20.0	19.0	17.0		71.0
Huai	GMU establishment	2.0	2.0				4.0
	Database	1.0	1.0				2.0
	Recharge Basin	5.0	5.0	5.0			15.0
	Injection wells	5.0	5.0	5.0			15.0
	Total	13.0	13.0	10.0	0.0		36.0

		Groundwater Recharge and Rehabilitation					
		2001-2005	2006-2010	2011-2015	2016-2020	2021-2025	**Total**
Yellow	GMU establishment	3.0	2.0				5.0
	Database	1.0	1.0				2.0
	Recharge Basin	5.0	10.0	10.0	5.0		30.0
	Injection wells	2.0	2.0	2.0	2.0		8.0
	Total	11.0	15.0	12.0	7.0		45.0
	3H Total	**39.0**	**48.0**	**41.0**	**24.0**		**152.0**
		Flood Control					
		2001-2005	2006-2010	2011-2015	2016-2020	2021-2025	**Total**
Hai	Dam safety	2.0	2.0	2.0	2.0	2.0	10.0
	New dam	3.0	3.0	0.0	0.0	0.0	6.0
	Detention basin	5.0	5.0	4.0	3.0		17.0
	Levee strengthening	10.0	16.0	5.0	5.0		36.0
	Water cost improvement	10.0	8.0	8.0			26.0
	Flood protection area (FPA) establishment	1.0	0.5	0.5			2.0
	Flood forecasting	1.0	1.0				2.0
	Flood database	0.5	0.5				1.0
	Disaster prevention	0.5	0.5				1.0
	Training	0.5	0.5	0.5			1.5
	Total	33.5	37.0	20.0	10.0	2.0	102.5
Huai	Dam safety	3.0	2.0	2.0	2.0	2.0	11.0
	New dam	4.0	2.0				6.0
	Detention basin	4.0	3.0	1.0			8.0
	Levee strengthening	10.0	17.0	5.0	2.0		34.0
	Water cost improvement	15.0	16.0	5.0	5.0	5.0	46.0
	Flood protection area (FPA) establishment	1.0	0.5	0.5			2.0
	Flood forecasting	1.0	1.0				2.0
	Flood database	0.5	0.5				1.0
	Disaster prevention	0.5	0.5				1.0
	Training	0.5	0.5				1.0
	Total	39.5	43.0	13.5	9.0	7.0	112.0
Yellow	Dam safety	3.0	2.0	2.0	2.0	2.0	11.0
	New dam	4.0	5.0	4.0			13.0
	Detention basin	7.0	5.0	4.0	3.0		19.0
	Levee strengthening	20.0	37.0	5.0	5.0		67.0
	Water cost improvement	20.0	27.0	10.0	5.0		62.0
	Flood protection area (FPA) establishment	1.0	0.5	0.5			2.0
	Flood forecasting	1.0	1.0				2.0
	Flood database	0.5	0.5				1.0
	Disaster prevention	0.5	0.5				1.0
	Training	0.5	0.5				1.0
	Total	57.5	79.0	25.5	15.0	2.0	179.0
	3H total	**130.5**	**159.0**	**59.0**	**34.0**	**11.0**	**393.5**
3H Total Investment		**412.4**	**487.7**	**240.4**	**157.7**	**51.5**	**1349.7**

The following tables summarize each component of the action plan.

B. Summary of Action Plan for Water Resources

Problems/Issues	Proposed Action Plan
Price: Water prices charged to different categories of consumers are too low and promote wasteful consumption. North China consumers use a very high volume of water by world standards while the per capita resource availability is one of the lowest being a mere 1/20th the world average. Some areas in north China have raised prices marginally but other sources with lower prices are available and so consumers shift to cheaper supplies (for example groundwater). This practice has created unsustainable levels of groundwater usage.	Prices of water need to be raised across all sources (surface and groundwater) according to the proposed schedule presented below which has been calculated based on extensive analysis presented in this report. Average Tariff (Y/m^3) Low / Mean / High 2000: 0.9 / 1.1 / 2.9 2010: 1.4 / 1.9 / 4.8 2020: 1.7 / 2.3 / 5.9 2030: 2.1 / 2.8 / 7.2 2040: 2.8 / 3.7 / 9.6 2050: 3.6 / 4.7 / 12.3
Wastewater Reuse: The main issues preventing more widespread wastewater reuse in north China include: Low level of treatment currently practical; Lack of institutional mechanisms; Low prices for water supply as described above; Lack of infrastructure; Inappropriate standards there are discussed fully in the section on wastewater reuse	The proposed action plan required that wastewater reuse rate increase to 165 percent by increasing the rate of treatment, developing institutional mechanisms needed to support this practice, raising the price of water, developing infrastructure and raising water reuse standards. These proposed actions are described in the Chapter on wastewater reuse and reuse action plan.
Water Supply Efficiency: Water supply to agriculture would not increase and so water saving/water supply efficiency improvement is the major component of agriculture and water resource action plan.	The action plan proposes to increase water supply efficiency to about 18 percent with (a) physical improvements; (b) agronomic measures; (c) irrigation management measures complementing existing SOCAD, LIS and water-saving government programs. These are discussed in the section on agriculture/irrigation. The action plan recognizes that these measures would lower irrigation shortages by 19 percent, or 30 percent overall. All water saved would be available as additional supply for agriculture and so the shortage reduction benefits overall would amount to only about 12 percent of overall benefits to be gained from the entire action plan proposed in this water resource section. The cost of implementation account roughly for 50 percent of total action plan implementation costs.
South-North Transfer Despite possible/feasible price increases, efficiency gains and reuse improvements, the 3-H would continue to be short of water as demonstrated in Chapter 4. Therefore it can be concluded that proposed demand management programs and supply enhancement by reuse would not be sufficient to bring supply closer to demand. The only feasible additions are provided by the proposed action plan: one that has already been extensively investigated by the Chinese government is the South-North Transfer whereby water would be transferred from the Yangtze River to the Hai and Huai basins.	The action plan recommends further investigations of the South-North transfer. Preliminary costs are estimated at Y 174.2 billion (Y 43.2 billion for the eastern route and Y 131 billion for the middle route) representing almost 30 percent of total action plan costs. Shortage reduction resulting from the South-North Transfer are approximately 45 percent of total but account for about 53 percent of the total Y 233 billion of expected benefits while costing about 30 percent of the total Y 217 billion in implementation costs for the total entire action plan.

C. SUMMARY OF ACTION PLAN FOR FLOOD CONTROL

Basin	Problem/Issue	Proposed Action	Description/Action
Hai	1. There is considerable flooding along the southern border of the Hai River basin, with inundation commencing on the Wei floodplain. The detention basins of Liang-xiangpo, Changhongqu and Baisipo are required to be used every two to three years. This is clearly too frequent and needs to be reduced. It is suggested to upgrade these detention basins but the proposal to construct a dam upstream may mean that this is not necessary.	Reservoir Construction	It is proposed to construct the Panshitou Reservoir on the Qi river to be used for flood storage. Storage capacity would be 6.20 x10^8 m^3. This would seem to be a very worthwhile project. It may provide some water resource storage and can be used to reduce the dependency on the use of the detention basins in the area. It may also reduce the flows in the Wei and thereby reduce flooding in the downstream areas. While the dam would be in Henan Province the downstream benefits would also accrue to Hebei and Shandong Provinces where there is considerable flood damage each year.
	2. Beijing suffers considerable flooding and drainage problems and, as the nation's capital, should have a very high level of protection.	Reservoir Construction	It is proposed to construct a reservoir on Yonding River upstream of Beijing called Chengxiazhuang Reservoir. It would have a capacity 0.63 x10^8 m^3. However in terms of cost per stored cubic meter, it is far more expensive than Panshitou Reservoir. It is recommended that further work be undertaken to determine a cost-effective site for a dam. If constructed it would reduce the flooding in Beijing, reduce the need to use the Yongding detention storage, and reduce the need to transfer water to the Daqing system. If this dam is found not to be cost-effective, then another scheme needs to be designed in order to protect Beijing from flooding.
	3. The flood carrying capacity of rivers, channels and estuaries close to the cities of Beijing and Tianjin needs to be improved desirably.	Upgrading flood capacity	Rivers such as New Yongding, Jiyun, Duliu, New Zhangwei, Feng, Beiyun and the Hai Rivers should be upgraded by dredging and/or raising levees to ensure that the floods can be safely carried to the sea and protect Beijing and Tianjin.
	4. Four major storages, Yuecheng, Huangbizheung, Gangnan and Xidayang, have very low safe ARIs.	Risk Assessment	These dams should have risk assessment to determine if the ARI of the safe flood should be increased.
	5. There are a number of other river systems that have been upgraded but may not now have the design capacity due to sedimentation.	Assessment	They should be assessed to determine if they should be rehabilitated to their old standard.
	6. Improvements are required for all aspects of the flood forecasting and flood warning system for the Hai River Basin.	Upgrading flood forecasting and warning system	This includes expansion of the instrument monitoring network, updated data transmission technology, forecasting techniques and telecommunications for issuing warnings and maintaining contact during flood emergencies.
	7. Safety of the detention areas needs to be improved.	Roads construction	Construct roads with elevations above the flood level that can be used for evacuation and temporary sanctuary during floods. The roads should be at least 20 meters wide to accommodate people sheltering from floods.
	Low flood modeling capacity	Development of hydrodynamic model	Development of a hydrodynamic flood model for the major rivers that would provide information to determine which rivers should be upgraded and which reservoirs should be built.
Yellow	Undoubtedly the biggest problem in the Yellow River is the sediment because it reduces the capacity of the channels and rivers to convey flood waters		The ideal solution would be revegetation of the catchment but this would take too long and may not be practical. The proposed solution is the construction of dams with the main purpose of collecting silt. These dams seem to be required and are described below along with other priority projects.

Basin	Problem/Issue	Proposed Action	Description/Action
			Construction of the Qikou water conservancy project is one of the major projects on the Yellow River. The dam site is located on the middle reaches of the Yellow River in Shanxi province. The project would trap large amounts of silt. The dam is designed as an earthfill dam having a maximum height of 143.5m. The project would have a small design discharge and large storage capacity. Its main task is to retain 14.4 billion tons of silt and also reduce 2.44 billion tons of sand that is accumulated in the Xiaobei main river course. The project is aimed at removing the need to continue to raise levees in the lower areas of the Yellow River to counter the aggrading of the channel bed. In addition power supply would be guaranteed for agriculture and industry along the river banks within Shanxi and Shaanxi provinces. While this project seems to be very valuable in maintaining flood capacity, careful consideration would need to be made as to the effects of sediment deficit downstream of the dam. The river would erode until a stable sediment balance is reestablished. This may provide problems of erosion near the dam and deposition continuing downstream. The Guxian water conservancy project is also one of the primary projects on the Yellow River stem. The dam site is located on the middle reaches of the Yellow River in Xiangnin of Shanxi province and Yichuang of Shaanxi province. The total storage capacity is 160 x 108 m^3 and the sediment-retaining capacity is 11.35 Bcm. The dam has a maximum height of 186m and is designed as an earth-rockfill dam. Its main task is to control flooding and silt and to regulate runoff. It would retain 16 billion tons of silt. After completion of the Guxian and Qikou reservoirs the lower reach levees of the Yellow River would not need to be raised. Dongping Lake reservoir should be upgraded to have an operating water level of 44.5m, storage capacity of 3.04 Bcm, of which the old lake comprises 880 Mcm and the new lake comprises 2.16 Bcm. Downstream of the Dongping detention area, levees in the delta area, and levees that protect the left bank of the lower Qin River and the adjoining irrigated plains would need to be raised and strengthened.
			Extension work to assist small communities in implementing and maintaining sound soil and water conservation measures, improved monitoring of conditions and of water and sediment yield, expansion of project areas by 12,000 km^2 a year, ongoing efforts in existing management areas, construction of 5,000 gully dams (by year 2010), research, development and training.
	Low flood modeling capacity	Development of a hydrodynamic flood model	There is a need to develop a hydrodynamic flood model for the major rivers that would provide information to determine which rivers should be upgraded and which reservoirs should be built.

Basin	Problem/Issue	Proposed Action	Description/Action
Huai	Flood losses are most severe in Anhui and Jiangsu Provinces where annual damage and deaths from flooding are very high. The flood-prone area for the Huai Basin includes the main branch of the Huai River.	Construction of dams and reservoirs.	Construction of a dam on Kanjing River, a tributary of the Sha-Ying River for flood detention. This would reduce the frequency of flooding of the Nehewa detention area which is used on average every two years. Construction of Bailianya Reservoir to reduce flooding downstream in the Pi River which only has a capacity of 7 year ARI. It would also reduce flooding in the main branch of the Huai River. There are two major dams (greater than 1 Bcm) which have low ARIs, below 10,000 years). These are Meishan and Suyahu Dams and should have risk analysis carried out to determine if they should be upgraded. Construction of an improved main floodway directly to the sea to reduce flooding and the duration of flooding in the flood areas of the Anhui and Jiangsu Projects. A major project to be undertaken is the Linhuaigang project. This involves construction of a large, gated regulator on the Huai River upstream of the Ying confluence, and levee embankments surrounding a large depression area adjoining the Huai River. It would enable onstream regulated flood storage to be used to better control flood discharges from the upper Huai and Hong-Ru into the middle river reach from Zhengyangguan to Hongze Lake. Raising of the Huaibei levee, or north bank levee of the Huai River from Zhengyangguan to Hongze Lake—this is a very strategic levee protecting a densely populated area of 12,000 km², including over 8,000 km² of intensively cultivated land, and more renovation and raising is required to achieve satisfactory standards throughout
	A high degree of operational management and intervention is necessary during large floods to divert floodwaters into detention areas for temporary storage and to distribute flood flows in original river channels and new river diversions through operation of regulators.	Develop flood forecasting capability	Very good forecasting accuracy was achieved in the 1991 flood, which greatly aided management of the situation. Flood forecasting therefore assumes great importance in flood management of the Huai River system. Upgrading to the latest technology and maximizing flood warning time is very important, and has been identified as an obiective in long-range planning to year 2010
	Lack of a hydrodynamic flood model.	Development of a hydrodynamic flood model	There is a need to develop a hydrodynamic flood model for the major rivers that would provide information to determine which rivers should be upgraded and which reservoirs should be built

D. SUMMARY OF ACTION PLAN FOR AGRICULTURE

Problem/Issue	Proposed Action	Action Plan and Current Government Program Addressing Problems	Description/Action	Areas of Focus for Action Plan	Proposed Financial Commitment to 2020 (10^8 Yuan)		
					SOCAD	Water Saving	LIS
Water supply to agriculture would not increase and so water-saving measures would be the major way to address water shortages to agriculture	Physical Improvements	LIS, Water Saving and SOCAD	Canal lining/control structures, low pressure pipes for small distributions systems, facilities for groundwater recharge and conjunctive use of surface and groundwater; drainage system and reuse of return flows, improved surface irrigation systems on-farm sprinkler system, micro irrigation systems	Water saving: Hai: South Hai Tuhaimajia Huai: Wangjiabu to Bengbu Shandong Peninsula Lower Yishusi Yellow: Longmeng to Sanmenxia Lanzhou to Hekouzhen	 196 60 116 50 98 57	 44 28 32 28 39 21	 55 78 80 44 103 158 128
	Agronomic measures	SOCAD	Precision land leveling, cropping pattern, plastic film mulch, stubble mulching, input substitution	Water saving: Hai: South Hai Tuhaimajia Huai: Wangjiabu to Bengbu Shandong Peninsula Lower Yishusi Yellow: Longmeng to Sanmenxia Lanzhou to Hekouzhen	 196 60 116 50 98 57		
	Irrigation management measures	Institutional	Irrigation and drainage system management improvement: water measurement, volumetric water price; institutional development; On-farm irrigation management improvement, soil moisture control, management of irrigation schedule	No specific area targeted but applied throughout North China.			
Previous central planning policy for water allocation and water management local initiative and irrigation by-pass prevent "ownership" of management policies. In addition, current financial arrangements prevent appropriate levels of operation and management causing infrastructure to become inefficient.	Institutional management reform	Institutional	Investigating at local level best mix of irrigation network management or transfer including contracts, lease, WUA, auction, joint stockholders, WSCs and SIDDs.	No specific area targeted but applied throughout North China.			
Current prices of water to irrigation do not allow cost of supply recovery, proper maintenance of system and promote wasteful consumption	Water demand management	Pricing reform	Increase prices to irrigators, separate resources charges from other administration changes to ensure direct link to reflect degree of scarcity of water at the 3-H basin level.	No specific area targeted but applied throughout North China.			

E. SUMMARY OF ACTION PLAN FOR NONSTRUCTURAL POLLUTION CONTROL

Type of regulation	Component	Issue/Problem	Proposed Action Plan	Who is responsible for action
Command and control instruments	Pollutants discharge limits, based on allowable pollutants concentrations;	Discharge limits are expressed in terms of concentration and the fines (or environmental levies) are calculated only based on the worst pollutant, in addition, the levy is too low and applied too infrequently and selectively to be real deterrent; The standards applied for water quality are generally not affordable for China, being replications of Western standards and very few water bodies meet their currently designated beneficial uses.	Concentration-based standards must be replaced by mass-based standards expressed in terms of pollutant mass (for example COD-kg) per unit of output, such as kg. of product; Review environmental standards by (a) establishing current water quality situation in water body of concern; (b) evaluating sources of pollution loading; (c) evaluate effectiveness of government's regulatory system to control these sources; (d) collate and evaluate current IC standards for comparison only (e) compile experiences in other DCs to review standards, for example Thailand, and (f) use (a) to (e) to set tentative standards that match the reality of China's development situation. Review effluent standards by (a) determining treatment level (TL) for specific industrial waste to achieve significant reduction in pollution at relatively low cost (TL/1) using appropriate technology; (b) examine downstream environmental situation to assess essential beneficial water uses (BWUs) existing or projected. Irrigation/water supply for urban consumption/hydropower recharge/boating; (c) compare (a) and (b) to determine the particular additional removals which must be achieved to protect BWUs (TL/1+2) for each pertinent pollution parameter; (d) compare effluent values for pertinent pollution parameters for TL/1 and TL/1=2 with any existing established national or regional effluent standards and with standards published by ICs and by international assistance agencies; (v) based on (a), (b), (c) and (d), set appropriate TL which is not less than TL/1 and which exceeds TL/1 only to extent needed for essential environmental protection	
	Monitoring of water quality and effluents by EPBs	Monitoring of water quality is undertaken by both SEPA and MWR and there is little coordination between the two bodies.	Monitoring program needs to be revised to contain (a) minimum database needed to relate cause and effect, for example reflect improvement in pollution control measures; (b) combine MWR and SEPA monitoring program; (c) link monitored parameters to objectives such as public health, regulatory or descriptive "State of the environment" data. The latter is current design of monitoring system; (d) design monitoring program to allow tracking of mass load including behind gates, prior major confluence; (e) parameters to include toxic pollutants known to be generated by industries or mining upstream; (f) include river/lake sediment sampling on annual basis to determine toxic accumulation bound in sediments (legacy pollution); (vii) allow upgrade of laboratory analytical techniques for analysis of samples. This requires abolishing the current analysis standards which "lock" monitoring agency into outdated techniques Translate the latest version of "Standards Methods for Analysis of Water and Wastewater"; (g) increase EPB input into design of monitoring network to promote more decentralized design; (h) retrain EPBs' staff to focus on environmental outcomes rather than enterprise-specific pollution loads.	
	Mass-based controls on total provincial discharges, with pilot application to municipalities	Mass-based control has been applied in some circumstances/areas but not everywhere and this possibly confuse regulators and polluters because other areas have kept the concentration based control	Proceed to apply mass based regulatory system as quickly as possible with due attention to increased ambient monitoring data requirements and modeling. Apply mass-based system to pollution hot spots first but follow through without delay to all other areas to avoid dual regulatory system for prolonged periods which increases the difficulty of enforcement for the regulator and can promote confusion for the regulated.	

Type of regulation	Component	Issue/Problem	Proposed Action Plan	Who is responsible for action
	Environmental impact assessments (EIAs)	EIAs are carried out by SEPA-appointed institutes but it is the EPBs that generally lack the skills and staff to fulfill their role in this important process.	The EIA process is focused on industrial pollution, leaving many other sources (such as TVEs and small livestock operations) with little planning. The first part of the action plan addressing rural point sources should categorize TVEs on the basis of pollution control costs, to show clearly which TVEs would likely not be able to afford to furnish the needed environmental protection, even with due attention to use of cleaner protection technologies by means of a registration system. Second is a review of water quality standards and strengthening of monitoring and enforcement procedures appropriate for the rural sector. This in fact forms part of the second element of the general water pollution control action plan. Thirdly, is the preparation of a manual of guidelines on planning, design, operation and monitoring of production TVEs appropriate for developing countries. This would require the adaptation of similar manuals produced for industrialized countries or other developing countries including attention to technical design criteria, costs for installation and for O&M, financing and cost recovery, and for environmental monitoring, for each and every type of TVE to be considered, for a range of production sizes covering smaller family to medium-scale operations, including production technologies, using appropriate environmental standards.	
	Mandatory EPB certification before new production lines operate, affirming that agreed pollution controls are installed and functioning (three synchronization program (*santongshi*)	There is adequate legislation to control pollution sources however where performance suffers, it reflects local choice or interpretation of the law rather than legal tools; The production licensing or three synchronous program which focuses on pollution prevention has had limited impact due to selective application at the local level.	The action plan calls for strengthening the permit allocation process by EPBs with improved transparency. Proceed to apply a mass-based regulatory system as quickly as possible with due attention to increased ambient monitoring data requirements and modeling. Apply mass-based system to pollution hot sports first but follow through without undue delay to all other areas to avoid dual regulatory system for prolonged periods which increases the difficulty of enforcement for the regulator and can promote confusion for the regulated. The problem of the extent of devolution or decentralization of responsibilities goes beyond the water sector and is a complex issue that impacts of all aspects of Chinese society. It reflects the relationship between central and provincial government. Thus it is not appropriate or useful to suggest possible adjustments. In addition the legal system and its implication at the local level, the dependence of the court system on funding from provincial government are also issues that go beyond the water sector but that have great impact on resource management.	
	For existing factories out of compliance with discharge limits, a program of mandatory pollution controls/treatment within specified time or plant closing	The production licensing or "three synchronization" program which focuses on pollution prevention has had limited impact due to selective application at the local level as explained in part	The action plan calls for strengthening permit allocation process by EPBs with improved transparency. Proceed to apply mass-based regulatory system as quickly as possible with due attention to increased ambient monitoring data requirements and modeling. Apply mass-based system to pollution hot spots first but follow through without undue delay to all other areas to avoid dual regulatory system for prolonged periods which increases the difficulty of enforcement for the regulator and can promote confusion for the regulated. The problem of the extent of devolution or decentralization of responsibilities goes beyond the water sector and is a complex issue that impacts of all aspects of Chinese society. It reflects the relationship between central and provincial government. Thus it is not appropriate or useful to suggest possible adjustments. In addition the legal system and its implication at the local level, the dependence of the court system on funding from provincial government are also issues that go beyond the water sector but that have great impact on resource management.	
Economic incentives	Pollution levy fee	There is adequate legislation to control pollution sources; however where performance suffers, it reflects local choice or interpretation of the law rather than legal tools; Discharge limits are expressed in terms of concentration and the fines (or environmental levies) are calculated only based on the worst pollutant, in addition, the levy is too low and applied too infrequently and selectively to be real deterrent.	Review pollution levy system with the intention to increase by 5-10 percent annually, for example, in order to ensure behavioral changes by polluters. Levy system to be based on mass loads as discussed in part 1 above.	
	Noncompliance fines	There is adequate legislation to control pollution sources; however where performance suffers, it reflects local choice or interpretation of the law rather than legal tools;	As for Part 6.	

Type of regulation	Component	Issue/Problem	Proposed Action Plan	Who is responsible for action
	Environmental taxes on wastewater and sulfur discharges	There is adequate legislation to control pollution sources however where performance suffers, it reflects local choice or interpretation of the law rather than legal tools;	Proceed to apply mass-based regulatory system as quickly as possible with due attention to increased ambient monitoring data requirements and modeling. Apply mass-based system to pollution hot sports first but follow through without undue delay to all other areas to avoid dual regulatory system for prolonged periods which increases the difficulty of enforcement for the regulator and can promote confusion for the regulated. Permit issuance in a mass-based regulatory system needs to (a) consider the economic ramifications of limits to permit issues, (b) allow entrepreneurship and new entries into the market to develop while maintaining total maximum loads, (c) allow new technology which has cleaner production methods to replace old more polluting SOEs. Allocation of permits through auction offers efficiency gains but if there are restrictions on water intake such as in the 3-H basins, then there would be limits to discharge and these circumstances, nonmarket-based method of allocating allowances directly to existing polluters (or grandfathering) should be the preferred choice although this method is biased against new firms and slows the introduction of new technologies. China needs to be especially wary of this problematic aspect of permit allocation because the replacement of older highly polluting enterprises with newer, and larger enterprises with improved manufacturing processes is an important aspect of industrial policy and China's global competition. The action plan calls for training for EPBs and SEPA.	
Public management instrument	A managerial goal-responsibility system of environmental protection, fixing on individual leaders the responsibility for meeting overall environmental targets	The standards applied for water quality are generally not affordable for China, being replications of Western standards and very few water bodies meet their currently designated beneficial uses	As for part 1.	
Public disclosure instruments	Comprehensive evaluation system for city environmental quality, including citizen complaint bureaus; environmental awareness; cleanup campaign		Improve system by adopting modern information technology such as setting up a web page for citizen complaint bureaus.	

F. SUMMARY OF ACTION PLAN FOR STRUCTURAL POLLUTION CONTROL

Pollution source	Main problems in reducing pollution from the sources	Proposed Action	Investment for Proposed Action (1000 yuan)				
				Municipal Treatment	Sewerage	PPP	Pretreatment
Large industry (100 m^3/ day or more), State Owned Enterprises (SOE) or Non-SOEs	SOEs usually have older manufacturing process than non-SOEs and are more polluting and less efficient. Discharge to municipal treatment plants requires knowledge of wastewater characteristics and pretreatment which may not be feasible for some SOEs as noted above.	Industrial wastewater pretreatment and internal reuse of process water; pollution prevention programs including cleaner production; wastewater reclamation. artificial recharge or irrigation with wastewater or floodwater; municipal WWTP and combined industrial and municipal WWTP.	Luanhe & East Coast Hebei	652,616	652,616	2,701,427	523,908
			North Haihe	419,374	419,374	1,581,483	131,791
			South Haihe	2,975,303	2,975,303	10,131,814	1,626,489
			Tuhaimajia	1,087,852	1,087,852	4,102,167	956,003
			Hai Basin	5,135,145	5,135,145	18,516,889	3,238,191
			Upstream of Wangjiaba	172,020	172,020	682,662	120,646
			Wangjiaba to Bengbu	1,563,504	1,563,503	5,806,224	843,407
			Bengbu to Hongze lake	616,536	616,535	2,142,498	321,736
			Lower Huaihe, Hongze lake to Huang Sea	536,413	536,413	2,050,848	257,782
			Nansi Lake	1,287,125	1,287,125	4,744,245	734,259
			Lower Yishusi	756,581	756,580	2,630,257	417,418
			Shandong peninsula	474,390	474,390	1,878,261	141,069
			Huai Basin	5,406,567	5,406,567	19,934,993	2,836,318
Small industry (less than 100 m^3/day, township village enterprises)	These have also more primitive manufacturing processes that are much less efficient and more polluting than larger enterprises described above. Small industries are usually unable to cope with PPP and rudimentary end-of-pipe treatment. Marginal cost of pollution abatement is more expensive than for larger-scale non-SOE for example.	Rural Industry restructure with phasing out of many small rural TVEs in the next decades; registration system of TVEs and categorizing in order to assess their ability to afford pollution control; strengthening of monitoring and enforcement procedures appropriate for the rural sector; preparation of manual of guidelines on planning, design operation and monitoring of production TVEs appropriate for developing countries. This would require the adaptation of similar manuals produced for industrialized countries or other developing countries including attention to technical design criteria, costs for installation and for O&M, financing and cost recovery, and for environmental monitoring, for each and every type of TVE to be considered, for a range of production sizes covering smaller family to medium scale operations, including production technologies, using appropriate environmental standards		**Treatment**	**Sewerage**	**PPP**	
			Luanhe & East Coast Hebei	222,926	111,463	1,164,921	
			North Haihe	398,902	199,451	2,291,734	
			South Haihe	1,803,126	901,563	11,098,436	
			Tuhaimajia	224,916	112,458	1,102,865	
			Hai Basin	2,649,869	1,324,934	15,657,956	
			Upstream of Wangjiaba	204,735	102,367	1,383,919	
			Wangjiaba to Bengbu	1,144,630	572,315	9,602,330	
			Bengbu to Hongze lake	458,651	229,326	4,675,220	
			Lower Huaihe, Hongze lake to Huang Sea	318,719	159,360	3,311,456	
			Nansi Lake	348,576	174,288	3,709,807	
			Lower Yishusi	233,606	116,803	2,466,095	
			Shandong peninsula	204,501	102,250	1,626,448	
			Huai	2,913,418	1,456,709	26,775,275	

Pollution source	Main problems in reducing pollution from the sources	Proposed Action	Investment for Proposed Action (1000 yuan)				
Urban population	Pollution from urban population needs to be treated at WWTPs. Currently there is insufficient investment in infrastructure (collection interceptors and treatment-disposal) to treat loads from urban population. Reasons include institutional arrangements which (a) do not allow cost recovery and allow profit (although this is changing), (b) do not require provinces/cities to be responsible for the load they generate, (c) do not provide for of financing. In turn inadequate pricing of services restrains investment and causes excessive consumption of water, which generates large wastewater quantities.	Municipal WWTP; sewerage		**Treatment**	**Sewerage**		
			Luanhe & East Coast Hebei	1,825,211	1,825,211		
			North Haihe	7,011,252	7,011,252		
			South Haihe	13,243,576	13,243,576		
			Tuhaimajia	653,710	653,710		
			Hai Basin	22,733,749	22,733,749		
			Upstream of Wangjiaba	1,390,820	1,390,820		
			Wangjiaba to Bengbu	9,706,529	9,706,529		
			Bengbu to Hongze lake	2,291,173	2,291,173		
			Lower Huaihe, Hongze lake to Huang Sea	1,515,681	1,515,681		
			Nansi Lake	2,881,335	2,881,335		
			Lower Yishusi	1,861,277	1,861,277		
			Shandong peninsula	2,722,260	2,722,260		
			Huai Basin	22,369,074	22,369,074		
Rural population	Urban infrastructure in small towns in China is usually inadequate or even nonexistent with severe shortages of sustainable development infrastructure including sewage treatment systems. Much of excreta is washed away by rain and solid waste is usually dumped into natural channels.	Pit latrines, properly engineered for low-income urban community; reuse of wastewater		**Treatment**			
			Luanhe & East Coast Hebei	1,572,120			
			North Haihe	2,596,000			
			South Haihe	10,572,540			
			Tuhaimajia	2,402,620			
			Hai Basin	17,143,280			
			Upstream of Wangjiaba	2,426,380			
			Wangjiaba to Bengbu	10,228,240			
			Bengbu to Hongze lake	3,388,220			
			Lower Huaihe, Hongze lake to Huang Sea	2,942,500			
			Nansi Lake	4,702,500			
			Lower Yishusi	3,949,440			
			Shandong peninsula	4,336,200			
			Huai Basin	31,973,480			
Livestock	The projection for the livestock industry indicates continued rapid growth. At the moment, most livestock operations remain at the individual farmer level. The extent of pollution from these sources is not known but suspected to be serious because of limited reuse of waste. The trend is for amalgamation of these operations into larger ones whose propensity to pollute is greater and becomes point source. In 2020, model predictions are that some 85 percent of operations would have 10,000 or more animals. Pollution from these in terms of COD is already very significant (but not accounted for) but remains unchecked because of their "nonpoint source" status and because they fall under the jurisdiction of the Ministry of Agriculture.	Stabilization ponds, manual of guidelines for appropriate design and construction		**Treatment**	**Sewerage**		
			Luanhe & East Coast Hebei	357,342	178,671		
			North Haihe	625,476	312,738		
			South Haihe	1,589,788	794,894		
			Tuhaimajia	631,021	315,511		
			Hai Basin	3,203,627	1,601,814		
			Upstream of Wangjiaba	393,758	196,879		
			Wangjiaba to Bengbu	1,817,617	908,808		
			Bengbu to Hongze lake	587,984	293,992		
			Lower Huaihe, Hongze lake to Huang Sea	482,346	241,173		
			Nansi Lake	1,053,047	526,523		
			Lower Yishusi	632,998	316,499		
			Shandong peninsula	562,242	281,121		
			Huai Basin	5,529,990	2,764,995		

Pollution source	Main problems in reducing pollution from the sources	Proposed Action	Investment for Proposed Action (1000 yuan)
Nonpoint source	Return flows from irrigation and runoff from nonirrigation containing N, P and pesticides are difficult to address in most countries. Nonpoint sources are reported to contribute 25 percent of COD loads in the 3-H basins although at the same time irrigation is also suspected of being a COD "sink" capable of lowering the loads to rivers.		

G. SUMMARY OF ACTION PLAN FOR WASTEWATER REUSE

Problems/Issues	Proposed Action	Description
1. Water scarcity in the 3-H basins is so great that there is a need to put in place technology and institutional mechanisms to make appropriate use of wastewater	Wastewater quantities is the 3-H basins represent a significant resource which should be utilized in urban centers to alleviate shortages,.	Reuse of treated wastewater for agriculture may not represent new water source but would improve public health aspects of existing reuse schemes. Municipal reuse for landscape irrigation, parks, gardens, road median strips, wetlands ornamental lakes are recommended. Reuse wastewater can be to the river, back to industry, for groundwater recharge or irrigation.
2. Current treatment level of wastewater is too low to allow reuse schemes to operate. Informal reuse schemes already operate but the use of raw sewage for irrigation represents a threat to public health	Agricultural, municipal and industrial reuse have water quality requirements to be technically viable; appropriate treatment is needed to achieve this.	Treatment level for agriculture reuse can be primary while reuse for municipal context would need higher treatment because of community contacts. Industrial reuse is currently practiced internally and this practice should continue. Scarcity and not price is the main driving force for industry reuse schemes. Treatment can be at common industrial treatment plants, municipal treatment plants receiving industrial wastewater or in-plant treatment.
3. Institutional mechanisms needed for reuse schemes do not exist currently	Improve coordination of government departments at municipal level, provincial level and national level to provide workable reuse scheme. Develop industrial wastewater control program to ensure efficient operation of combined systems.	Level of institutional capacity/integrated currently does not permit operation of reuse schemes. Institutional development is needed to allow reuse schemes no operate efficiently. Government departments involved include MOC, MOF, SPD, MWR, MH, and Provincial Bureaus equivalents. Following are needed: (i) the development of database; (ii) preparation of local ordinance; (iii) establishment of limitations on industrial discharges to treatment systems and their enforcement; (iv) authority to enter and inspect industrial company to obtain samples of its wastewater discharges; (v) monitoring program; (vi) program to recover the cost of industrial waste treatment.
4. Price of water is too low to allow financial operation of wastewater treatment and reuse schemes.	Raise the price of water supplied to industry, domestic consumers and agriculture.	
5. Lack of infrastructure and finance prevents development of reuse schemes.	Construct needed infrastructure to allow operation of reuse schemes.	Collection/interceptors and WWTPs are needed in most cities in China. Investment needed to construct infrastructure is very large and action plan must span over many decades.
6. Wastewater reuse standards are derived from IC standards and are not developed for conditions and affordability in China. Current reuse schemes for agriculture operate without any treatment.	Review wastewater reuse standards to ensure these are affordable and can be met. Inability to meet ICs' wastewater standards should not preclude operation of reuse scheme.	Review of reuse standards can follow similar steps described in the water pollution section.

H. Summary of Action Plan for Groundwater

Issue/Problem	Proposed Action Plan
Groundwater management currently not focused on problem areas; Hydrologic basins not coincide with groundwater aquifers	Define Groundwater Management Units (GMU) 10 to 100 in the 3-H basins may be necessary. Characteristic of GMU include (i) large scale, (1:1500) (ii) defined aquifer system (several GMU can overly each other provided each has 1 discreet aquifer). Boundaries are chosen based on geographic/administrative criteria for example. GMU should include recharge area.
Unsustainable extraction exceeds sustainable yield of aquifer as evidenced by falling groundwater tables and decreased pressure levels	Define sustainable yield by adopting resource modeling such as Modflow. SY = Use of the resource in such a way that does not present future generations from haring similar level of access to the same resource
Licensing system is not resource related and therefore does not serve the intended purpose to regulate extraction to ensure sustainable use	Allocate licenses based on SY as defined above
Too many governments departments with similar or overlapping responsibilities	Licenses to be allocated by one department only. Different existing levels of government are appropriate MWR should have national level planning and coordination, river basin level allocation linked to provincial and lower level licensing of groundwater, GMU scale day-to-day management controlled at the provincial level. Independent review of GMU plans.
Water wells design and construction less than optimum leading to less efficient wells, possible contamination of groundwater	Set up system of licensing for drillers, require design to be approved by a qualified professional groundwater engineer
Information on groundwater resource, groundwater quality, well design parameters and subsurface geology is not readily available and not compiled on a data base, leading to the inability to manage groundwater based on objective resource management principles	Compile existing information on groundwater resource, groundwater quality, subsurface geology, well design parameters. Allow public access, develop database at national level. Maintenance of database at provincial level.
Groundwater pollution is widespread but not documented prevailing pollution prevention strategy to be implemented. Of particular concern are the toxic compounds that may be contaminating fresh groundwater supplies. Only extremely expensive remediation technology is capable of treating such kind of pollution and this is likely to be unaffordable.	For China, given the heavy reliance on groundwater for urban/irrigation water supply in normal years and as security in drought years, immediate action is required to develop a strategy to define the problem and start a program to present existing groundwater degradation from such pollution sources.
Shallow groundwater contamination forces users to shift to deeper aquifers, increasing reliance on less readily rechargeable and more expensive resource.	Broad scale planning/land use/sewerage planning, monitoring/ enforcement of industries. See pollution action plan.
Current groundwater prices are too low to reflect degree of scarcity or resources and promote increased efficiency of use fees charged to limited users.	Groundwater and management resource fees need to be applied to both urban and rural users and water supply companies. Identify true costs of poor management including subsidence, salinization, quality degradation etc. to promote development of groundwater management plans and identify costs associated with artificial recharge. These costs should be reflected in the water resource fee. Discontinue practice of subsidizing energy costs for pumping.
Communities are largely unaware of groundwater problem and consequences	Undertake immediate community awareness raising programs of serious groundwater issues including implication of "do-nothing" option.

I. Summary of Action Plan for Institutional Management

Issues/Problems	Description of Proposed Action
1. Water Resources Management in China	
1.1 Governance—provinces often have more influence on water resource management at operational level than the basin commissions or the Ministry of Water Resources. Provinces tend to act in a protectionist way with natural resources and prevent good basin management principles from governing water resources management. There is also overlapping jurisdiction between the ministries. Thus water resource management is confused, not cohesive and allocation are suboptimal.	Jurisdiction of provinces over water resources should be formally recognized subject to technical/economic oversight by river basin coordinating committees that would have basin-level interest in resource management. Interbasin allocations to provinces can be decided by commissions but how the water is used within each province should remain within the jurisdiction of the province. Floodplain management, pollution control and catchment management should also remain within the provinces jurisdiction.
1.2 River Basin agencies are currently effective only as agents of MWR. Their authority is limited or nonexistent over provinces and other ministries due to Chinese government structure.	Establish River Basin Councils (RBCNs) with power to undertake and require implementation of overall basin water utilization planning, industry water allocations, controlled by Board representing balance of central government and local government officials along with key civil societies, and reestablish River Basin Commissions (RBCMs), the working arms of RBCNs.
2. Allocation and Efficiency	
Increasing competition and conflict for water due to population growth and economic development including income rise, urbanization, industrialization, etc. Present system of water allocation would not cope with anticipated demand. Current supply levels have peaked and would probably decrease due to over extraction of groundwater. Water allocation is based on administrative system, problems include: Excessive withdrawals in the upper reaches; Disputes as to whether the allocation refers to consumptive use or gross withdrawals; Failure to clarify how shares are adjusted in response to available flows	Appropriate pricing of water and allocation based on market forces would ensure efficient allocation of water resources and would lead to higher growths. River Basin Coordinating Committees should be charged with (1) determining water resources allocations (surface and groundwater) for the various municipalities, provinces and autonomous regions; (2) development of broad policies and programs promoting sustainable water resources management, and particularly with respect to (a) flood control and drought relief: (b) groundwater management; (c) water resources protection and pollution control; and (d) promotion of increased water use (especially irrigation) efficiency through demand management mechanisms and community/farmer education; and (3) preparation and supervision of comprehensive basin development and operating plans which would provide the basis for guiding the development and management of major multipurpose projects, present structural and nonstructural floodplain management proposals, and outline mainstream water quality and environmental conditions etc. These plans would be essential to the preparation of provincial plans but would not dictate in any way in which the provinces should utilize their water allocations; (4) with regard to regulation, RBCMs could issue water use permits to major users above a certain water amount or licensing powers could remain wholly with the provincial regulatory agency or agencies, subject to approval by the RBCM for all permits that fall within the prescribed criteria.
3. Current groundwater management does not prevent unsustainable exploitation of the resources.	Key actions required as discussed in the groundwater action plan, include: groundwater management plans, licensing, database, interbasin groundwater issues, groundwater investigations, groundwater management area control
4. Demand Management	

Issues/Problems	Description of Proposed Action
Current resource charges are administrative and are levied to recover staff cost, permit administration costs, etc. Thus they have little impact as economic incentives to guide consumption. Irrigators are exempt from paying charge. Collection from small well operators is difficult. Level of resource charge is too low to have impact of water use. Pollution charges suffer from similar problems.	Resource charges can play an important role to balance allocation between upper and lower reaches of river basins and a better balance between surface and groundwater use. Resources charge should not be linked to administration but should be set as an economic incentive mechanism that incorporates opportunity costs into water charges. The charges should vary to reflect specific conditions of scarcity.
Urban water use per capita is higher than in most towns and cities of the world (600 lcd) despite freshwater resources levels approximately 5 percent that of the rest of the world (450 m^3/capita/year). Urban domestic and industrial users pay only a very small proportion of their income in water charges (0.3 + 0.2 percent respectively) willingness to pay could be 1 percent or more. Price bureaus give more emphasis on social issues and inflation rather than efficient service provision	Full cost recovery water prices in 3-H could be set at Y 2-2.5/m^3 excluding resource charge to account for opportunity costs. The recommendation for north China is that water prices should be raised, applied on a volumetric basis, prices should apply to all users with a simple uniform rate with a minimum number of categories of users. Where water is plentiful or income are high, a part fixed-part volumetric tariff may be appropriate. However, where water is scarce and incomes are low, as in the 3-H basins, uniform volume tariff rates are almost certainly the most sensible structure to adapt. Economic regulator needs to define service obligations and standards, determine and supervise water tariffs, approve investment plans, standardize accounting system, oversee financial planning and industry structure, enforce regulatory requirements, resolve disputes involving water entities. Regulator needs to be independent of external pressure and should build specialist knowledge base for effective industry control.
Irrigation water price currently charged is far below the theoretical equilibrium price. In addition agriculture would take up all water left after urban industrial and domestic needs are satisfied. Difficulties are measuring water consumption at farm level.	Higher prices would increase efficiency of water use by improving economic reforms per unit of irrigation water by promoting reductions in field applications, changes in cropping pattern, extensions of actual irrigated areas and/or farm restructuring. Higher water charges would help cover O&M costs and some capital costs and so help promote sustainable irrigation. Area-based or crop-based charges can be important mechanisms for cost recovery. Willingness to pay for irrigation water is between 50 and 100 Yuan/mu. Farmers would adjust water consumption to use water more efficiently.
5. Organizational Issues and Service Delivery	
Commercial water supply organizations are currently not widely in operation. China needs to investigate the best mix of service delivery entities to account for its own circumstances, bearing in mind the degree of local control, transparently resource management implications and optimization of economic benefit. Current problems with devolution/privatization of water supply entities include (a) failure to provide service entities with true autonomy, (b) failure to clarify ownership and risk; (c) failure to address service requirements in an integrated and balanced manner.	The action plan recommends that service delivery entities such as government departments, government publicly owned utilities; public/private partnerships; privately owned facilities; customer owned facilities be adapted throughout the 3-H basins and in China according to their suitability for local socioeconomic and hydrologic conditions.
6. Permit System at Municipal Level for municipalities with expansive impacted water.	Expand scope of permit system for wastewater use/reuse to cover all "water handlers" including all water supplies, water users for all sectors, wastewater management systems, reuse of treated wastewater.

IMAGING

Report No.: 22040 CHA

Type: SR