



REVIVING LAKES AND WETLANDS IN THE PEOPLE'S REPUBLIC OF CHINA, VOLUME 2

LESSONS LEARNED ON INTEGRATED
WATER POLLUTION CONTROL FROM
CHAO LAKE BASIN

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Foreword

The severely polluted state of many freshwater lakes is one of the greatest challenges facing water management in the People's Republic of China (PRC). Since the mid-1990s, the government has made substantial efforts to address this problem, with an emphasis on the "Three Lakes" (Chao, Dianchi, and Tai). However, this was mostly without success, due largely to the failure to create an effective, cross-jurisdictional management system to address major externalities associated with aquatic ecosystem rehabilitation.

In 2007, the Asian Development Bank (ADB) began to look closely at the issues of lake rehabilitation with the rapid appraisal of various ADB-assisted rehabilitation projects in the Sanjiang Plain Wetlands in Heilongjiang Province, Baiyangdian Lake in Hebei Province, West Lake in Zhejiang Province, and Tai Lake in Jiangsu and Zhejiang provinces. The study was published as *Reviving Lakes and Wetlands: Lessons Learned from the People's Republic of China*. Each case has a unique combination of factors, but the analysis highlights four key common elements for success: strong and consistent political leadership, integrated planning and analysis, effective management structures, and financial engineering to address externalities.

Our most recent lessons to add to the growing knowledge on lake and wetland rehabilitation in the PRC come from Chao Lake, the country's fifth largest freshwater lake. It has one of the most serious eutrophication problems in the PRC despite efforts by the government since as far back as the 1990s. Most recently, during the summer of 2010, an outbreak of green algae threatened the drinking water supply of the 300,000 residents of eastern Chaohu City. It is estimated that agricultural nonpoint pollution sources make up about 68% of the total discharged phosphorus and about 74% of the total nitrogen within the lake, far exceeding the quantity from industrial and municipal point sources.

The government has taken unprecedented steps to create a basic framework to achieve its long-term objective of improving water quality in Chao Lake and protecting and maintaining all of its economic, ecological, and aesthetic values. The key steps were (i) the development of a coherent and comprehensive master plan, (ii) the creation of an administrative structure that places most of the upper catchment within the jurisdiction of a single administrative body (Hefei City), and (iii) the creation of the Chao Lake Management Authority (CLMA) as the institution with prime authority and responsibility for managing the lake.

The in-depth analysis of the history of the lake's pollution and rehabilitation efforts, which is only summarized in this publication, helped in the design of one of ADB's largest investments in the environment sector, the Anhui Chao Lake Environmental

Rehabilitation Project. ADB approved a loan of \$250 million in November 2012 to support the implementation of the Chao Lake Master Plan. The project is also testing an eco-compensation program and a water emissions trading system aimed at controlling the ubiquitous sources of rural water pollution.

This publication examines how the current situation in the Chao Lake Basin compares with international thinking on the conditions necessary for sustainable management of lake basins. The analysis highlights that the creation of the CLMA and the formulation of the master plan do not mean the problem has been solved, only that the basic and essential framework for solving the problem has been created. Many obstacles and challenges still remain in achieving the government's ultimate objectives. Four of the most important are (i) further capacity building and development of the CLMA, (ii) stronger empirical analysis of agricultural nonpoint emission factors for planning purposes, (iii) the application of economic incentives to change farmer behavior, and (iv) the updating of the master plan on at least a biannual basis to ensure that it remains relevant.

It is my sincere hope that this publication will contribute to a better understanding of the processes behind aquatic ecosystem deterioration and the enabling conditions for successful restoration. It will be gratifying if those concerned with reviving aquatic ecosystem in the PRC and other countries find our experience and findings useful in pursuing their own efforts.



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Acknowledgments

This knowledge product highlights the extensive reforms that the Anhui Provincial Government has undertaken to rehabilitate Chao Lake, the fifth largest freshwater lake in the People's Republic of China (PRC). Much of the information provided in this publication is based on staff consultant reports supported by the Asian Development Bank (ADB) and used as inputs for designing the Anhui Chao Lake Environmental Rehabilitation Project, a \$250 million loan approved by the ADB Board of Directors in November 2012.

Qingfeng Zhang, Director of the Environment, Natural Resources, and Agriculture Division, East Asia Department, concurrently Chair, Water Sector Group, ADB provided overall guidance for producing this knowledge product. ADB consultant Robert Cooks prepared the initial draft, which details the history of pollution in Chao Lake and reports the various reforms that Chao Lake has undertaken, while consultant Melissa Howell Alipalo helped collect the international case studies and consolidate various relevant reports and information. Consultant Chazhong Ge updated the information, reviewed the draft, and provided insightful comments. Joy Quitazol-Gonzalez helped edit, design, and publish this publication.

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Executive Summary

Since the mid-1990s, the water quality of Chao Lake in Anhui Province in the floodplain of the Yangtze River has been steadily deteriorating. In 1996, the central government identified Chao Lake as one of the top three priority lakes in the country for environmental rehabilitation. It is among the five largest freshwater lakes in the country. The Government of the People's Republic of China (PRC) and the Asian Development Bank (ADB) have provided large amounts of resources to control municipal and industrial pollution in the lake catchment. These investments have improved water quality, but they have not addressed all dimensions of the problem with the lake's persistently poor water quality.

This case study on Chao Lake contributes to ADB's body of knowledge on the success factors for reviving lakes and wetlands in the PRC. Expensive water cleanup programs across the PRC are not leading to substantial improvements in overall water quality. Rapid, unrestrained economic growth has led to dramatic ecological changes. Based on comparative case study work, ADB has identified four success factors to rehabilitating lakes and wetlands in the PRC: strong and consistent political leadership, integrated planning and analysis, effective management structures, and effective financial management.

Rising to the growing challenge of improving Chao Lake's water quality, the Anhui Provincial Government (APG) has initiated the most progressive reforms in lake management in the PRC. Reform, especially through integrated water resources management, is a long-term process and one the APG has only just begun. Although the APG has adopted many success factors from national experiences, it has not yet implemented them comprehensively. The ADB-supported Anhui Chao Lake Environmental Rehabilitation Project, which was approved in 2012, supports the strengthening of the Chao Lake Master Plan and the Chao Lake Management Authority (CLMA) by introducing even more integrated approaches, continuing strides made in municipal wastewater treatment, and making new investments in nonpoint source (NPS) pollution control. The project will include a \$3 million pilot to test various technologies, financing, and institutional innovations.

A. National Trends and Challenges in Lake Water Pollution Control and Protection

Despite the impressive progress in controlling industrial and municipal water pollution since 2000—mainly chemical oxygen demand (COD)—the overall water quality of freshwater lakes has not improved significantly and remains generally very poor.

According to 2012 data from the Ministry of Environmental Protection (MEP), 61.3% of the PRC's 62 key lakes are classified as classes I–III, 27.4% are classes IV–V, and 11.3% are Class V+ (worse than Class V). Class V quality water is suitable only for irrigation and landscaping and Class V+ is unsuitable for any use.

The main reasons why it is so difficult to reverse the trends in lake water quality in the PRC and elsewhere are that lakes are relatively closed natural systems, making them especially sensitive, and rural NPS pollution is particularly intractable. Rural nonpoint pollution comes from diffuse surface runoff from farmers' fields and discharges from livestock and aquaculture production enterprises, which, unlike point source emissions, are very difficult to control.

Rural NPS pollution accounts for 67% of total phosphorus (TP) emissions, 55% of total nitrogen (TN) emissions, and 44% of total organic emissions (in the form as COD). The biggest single source of nitrogen pollution in the PRC is diffuse runoff of fertilizer from agricultural land—either as nutrients dissolved in runoff water or as nutrients adsorbed onto soil particles carried into rivers, streams, and lakes due to soil erosion. This is also an important source of phosphorus pollution, accounting for 38% of phosphorus discharges from all nonpoint sources and 26% of phosphorus discharges from all sources. Controlling the problem of nutrient runoff will require changes in the way farmers use fertilizers—a matter largely outside the control of MEP. During 1984–2012, annual fertilizer use in the country rose by 3,625%, from 1.6 million tons (of pure nutrient) to 58 million tons. According to the China Agricultural Production Means Circulation Association, the PRC has become the largest producer and consumer of fertilizer in the world, annually producing about one-third of the world fertilizer and consuming about 35%. National average fertilizer consumption for the period 2010–2012 is reported at 647.6 kilograms per hectare of arable land, which is much higher than the world average consumption of 141.3 kilograms per hectare of arable land.

Animal waste from intensive livestock production is another major source of excessive nutrient emissions. As part of the notable change in the structure of the rural economy in the last 4 decades, livestock production has doubled its contribution to the gross value of agricultural output, from 14% in 1970 to 38% in 2010. The growth in output value has been accompanied by phenomenal increases in livestock numbers. During 1978–2010, cattle numbers increased by 2,000%; sheep and goats by 1,158%; pigs by 449%; and poultry by 945%. Due to the shortage of land in the PRC, much of the production of meat and dairy products is carried out in intensive animal production enterprises, which represent concentrated points of animal waste production.

Such developments represent a significant change over the situation during the 1990s, when industrial and municipal point source emissions were the major sources of pollution. After years of deep investments in expanding industrial and domestic wastewater treatment, NPS emissions (mainly from rural areas and organic discharges from animal husbandry) have now moved to the forefront of water pollution challenges in the PRC.

Further improvements in ambient water quality will require a broader water pollution control effort that maintains the momentum that has already been achieved in industrial and municipal point sources, while at the same time increasing regulatory and development controls on rural NPS, particularly intensive animal husbandry.

B. Chao Lake: A Promising Case Study

Much like what the national situation calls for, the APG is embarking on a strategy that aims to continue its progress in reducing industrial pollution while concentrating on expanding domestic and/or municipal wastewater treatment and tackling the most challenging pollution source of all—agricultural NPS pollution.

Chao Lake is by its nature and by engineering standards unusually sensitive to the accumulation of pollution. It has a naturally high surface-to-volume ratio and high incidence of soils with elevated phosphorus levels, and flood control works have reduced back flushing from the Yangtze River by as much as 90%. Together, these conditions predispose the lake to pollutant accumulation, in general, and phosphorus accumulation, in particular. As a result, Chao Lake's main pollution problem is eutrophication (nutrient enrichment), most frequently due to elevated levels of phosphorus. This leads to the development of seasonal algal blooms (mostly from April to November), depletion of dissolved oxygen, depletion of fish stocks, generation of odors, and loss of aesthetic quality.

In 2013, overall water quality was classified as Class IV (suitable for industrial water supply and recreation involving no direct contact). The east of the lake was still Class IV, but the water quality of the western half of the lake had declined from Class IV to Class V (suitable for agricultural and landscaping use only). The deterioration in water quality is caused by the total annual quantity of pollutants discharged into the lake significantly exceeding its assimilative capacity. In 2006, the Anhui Environmental Protection Department estimated that total discharges exceeded the assimilative capacity of the lake by 305% for COD; 1,730% for TN; and 606% for TP.

Although industrial and domestic wastewater flows are following national trends and coming under control as a result of regulation and investment, they remain the major source of phosphorus nutrients in the western half of the lake. A combination of fewer inefficient enterprises and stricter, more effective implementation of industrial wastewater standards has significantly reduced industrial water pollution, even as the gross value of industrial output has continued to increase rapidly.

The three activities believed to be the main contributors to rural NPS pollution in the up-slucce catchment area are (i) emissions of liquid wastes from livestock production enterprises; (ii) runoff from cultivated agricultural land, which contains fertilizer and pesticide residues; and (iii) discharges of untreated rural household wastewater.

As a result of worsening conditions in the lake, Hefei City has already relocated its water supply upstream of the lake. Chao Lake's frequent unsightliness as a result of the algal blooms in the western part of the lake adversely affects tourism and complicates the government's ambitions of turning the city into an urban showplace and knowledge-based economy.

C. New Strategies for Cleaning Up Chao Lake

Better informed of the pollution situation in Chao Lake, the APG began to set a course in 2008 for reforming how the lake could be better managed. The government recognized the need for a single authoritative body to govern all matters of lake management and a long-term road map to follow as it navigates the various financial, technical, and political steps needed for restoring the lake.

The APG has (i) developed a coherent and comprehensive master plan, (ii) created an administrative structure that places most of the upper catchment within the jurisdiction of a single administrative body (Hefei City), and (iii) created the CLMA as the institution with prime responsibility for managing the lake.

These three major reforms, in addition to the leadership required to make them happen, reflect the four success factors identified by ADB for lake rehabilitation in the PRC.

Success Factor 1: Strong and consistent political leadership

At the subnational level, no provincial government in the PRC has taken the drastic steps the APG has taken to restore the quality of its major water resource. These steps are what make Chao Lake such a promising case study. The APG has taken on political challenges to draw new administrative boundaries that would better serve the interests of protecting and managing the lake. It surpassed current planning modes when it drafted a long-term master plan for renewing the Chao Lake Basin. A new comprehensive authority made up of consolidated bureaus and agencies will manage the master plan.

Success Factor 2: Integrated analysis and planning

The Anhui Development and Reform Commission has prepared a master plan for reducing water pollution. The plan not only covers conventional environmental engineering strategies but also seeks to influence regional development strategies, industrial restructuring, urban development planning, integration of urban and rural areas, and other macro-level planning activities.

Success Factor 3: Effective management structure

After the master plan was developed, the APG took two significant steps to strengthen institutional arrangements for managing the lake environment. First, it consolidated subprovincial government boundaries within the lake catchment to concentrate management authority for the entire surface area of the lake, all of the lake foreshore, and a substantial portion of the up-sluice catchment area within a single local government authority—Hefei City. Second, during the administrative consolidation, the APG created a provincial-level agency, the CLMA, to unify management of all general affairs relating to Chao Lake. The CLMA functions at the deputy departmental level, although it is physically located within Hefei City. Its major functions are planning, water quality and quantity management, water conservancy, land use, fisheries, navigation, and tourism.

Success Factor 4: Effective financial engineering

In the past, the APG focused on revenue generation to the detriment of environmental sustainability, but this is changing with the new reform agenda. The APG formulated the Anhui Chao Lake Environmental Rehabilitation Project, and proposed ADB financing in three phases. Phase one, \$250 million (the ADB loan approved in 2012), will focus on the rehabilitation of upstream river courses, interception of wastewater, and piloting of nonpoint source pollution control; phase two, \$300 million, will address nonpoint source pollution; and phase three, \$250 million, will restore the important in-lake wetlands.

D. International Experiences

ADB's analysis of success factors in the PRC and the significant scope of the APG's initial reforms have been backed up by an international study of 28 lakes across the world. The study, financed by the Global Environmental Facility, identified several measures that would lead to effective lake basin management and which are either already in place or are in progress for Chao Lake. The study found that none of the 28 case studies had a single institution with authority over all aspects of lake basin management. In the case of Chao Lake, the CLMA is authorized with this comprehensive role, indicating that this step may be progressive in an international context, although challenges remain.

To further examine lessons in lake basin management, this knowledge product examines four case studies from Australia, Japan, Wales (United Kingdom), and the United States. Each of these case studies shares some common traits with the Chao Lake situation and demonstrates approaches that the APG could consider for strengthening its own management approach and practice. These brief international case studies highlight lessons that are still being learned in countries that are more developed than the PRC, yet have experienced similar problems to those identified in the Chao Lake Basin and elsewhere across the country. Issues in common with Chao Lake include (i) unsustainable water extraction and wastewater discharges in Lake Biwa in Japan before legal frameworks were strengthened to control industrial pollution; and (ii) the evolution of a management institution, as demonstrated by Australia's Murray–Darling Basin Authority and its principle of localism. The United States is still in the early stages of implementing and evaluating the effects and impacts of its progress with total maximum daily load and the National Pollutant Discharge Elimination System as the primary means for maintaining water quality standards. Wales have widened the scope of integrated water resources management to include special planning on how they can reinforce positive environmental outcomes.

E. Recommendations for Strengthening Chao Lake Strategy

The integrated water resources management is a long-term process that Anhui Province has only begun with Chao Lake. The Chao Lake Master Plan and the setup of the CLMA are examples to learn from, rather than blueprints for other governments to follow, as both need considerable strengthening. The master plan has gaps in the areas that most need to be addressed, reflecting a need for technical support. The CLMA, although established, must still consolidate its authority over the lake's management. The ADB-assisted Anhui

Chao Lake Environmental Rehabilitation Project is supporting the strengthening of both the master plan and the CLMA. Several recommendations for Anhui Province, however, are instructive for other efforts to consolidate water management functions. Some of the key recommendations are as follows.

1. Strengthening the Master Plan

The Chao Lake Master Plan is weak, particularly in areas where many water rehabilitation strategies across the country are lacking. The plan includes measures to reduce point source emissions, but programs for controlling NPS pollution are less well defined, even though this is precisely where quantitative, scientific targets and dedicated resources should be prioritized.

At the policy level, the APG should develop a research program to guide policy and a legal framework for environmental protection and utilization, land use management, and NPS pollution control. The consolidation of farms and communities should be considered to scale up successful pilots.

At the implementation level, the APG will have to turn to innovations and pilot testing of ideas, and collaborate more with the Ministry of Agriculture. The APG should explore and experiment with economic instruments, such as nutrient trading and incentive payments to farmers who adopt alternative technologies. Solutions are needed for the management of household waste in rural areas. Currently, the problem is not given any attention in the master plan.

Through the Anhui Chao Lake Environmental Rehabilitation Project, ADB is piloting the control of agricultural NPS pollution in livestock enterprises, including the development and trial of an eco-compensation mechanism to provide market-based incentives for farmers and rural residents.

2. Strengthening the Chao Lake Management Authority

While the creation of the CLMA is a step in the right direction for the long-term sustainability of Chao Lake, it needs considerable strengthening. The CLMA is still in its early stages and is struggling to establish its authority and distinguish responsibilities between itself and related provincial departments and Hefei City bureaus. To address issues of authority and delegation of responsibilities, the CLMA would benefit from a provincial-level commission, chaired by the vice-governor and composed of top officials from provincial departments and mayors from the catchment.

ADB and the UNESCO-IHE Institute for Water Education have been providing technical assistance to the CLMA to help address its capacity deficiencies. With the ADB-supported Anhui Chao Lake Environmental Rehabilitation Project now under implementation, the CLMA will benefit from a strategic institutional and capacity development program. The program provides staff training through domestic and international education, advanced equipment and technology, and a series of studies on (i) special land use management

in the Chao Lake catchment based on water quality functional zoning, (ii) early-warning systems for the algal blooms, and (iii) mechanisms to apply and promote achievements from demonstration projects to control NPS pollution.

F. Policy Directions from the Chao Lake Experience

Ecological and environmental degradation is likely to continue to be a key issue in the 13th Five-Year Plan (2016–2020). The scope of pollution (air, water, and soil), the complex structure of diverse sources of pollution (industrial, domestic, and agricultural), and the long-term impact of pollution require stronger policy imperatives, transformational financing at the local levels, and a more decisive, corrective role to be played by economic policy and the market. The 13th Five-Year Plan should address the following four key policy areas that could significantly affect water quality issues.

1. Water Pollution Prevention and Control

A key area for water pollution control for the 13th Five-Year Plan should be NPS pollution. The 12th Five-Year Plan remains focused on reducing industrial and domestic pollution. This is still needed, yet NPS pollution control receives only modest initiatives and ambitious targets, many of which are noncompulsory. NPS pollution prevention and control require legal foundations, scientifically based and compulsory targets, resources for monitoring, and financial instruments that use market-based incentives and rewards to promote voluntary compliance among farmers and partnerships between public and private enterprises.

To bring NPS pollution control into better focus and support the long-term success of NPS targets, the 13th Five-Year Plan for Environmental Protection should support the financing, operation, and maintenance of rural environmental infrastructure. Without regulation of rural NPS (such as rural domestic waste) and in the absence of substantial outside investments, local governments, farmers, and communities have no incentive or the appropriate financing to invest in scaled wastewater technology. Both individual farms and residential clusters need investments. To make these investments cost effective and financially viable, farm and community consolidation may be necessary.

NPS pollution of water resources can be mitigated through large-scale programs and targets that promote the use of organic fertilizer. More efficient irrigation and the installation of biogas digesters and biomass processing systems of various scales, which produce high-quality organic fertilizers, are two strategies to reduce chemical fertilizer use.

2. Legal and Institutional Reforms to Clarify Responsibility and Trigger Cooperation

The integrated water resources management is as much about managing what happens on land as is about managing what happens with the water. Subnational and local governments should align their economic and land use planning and zoning with their environment plans

to make balanced, sustainable growth possible. This requires high-level, integrated planning and coordination to manage reviews of sector plans and policies to ensure harmony between economic and environmental goals and policies.

3. Market Failures in Resource Management

Water quality trading programs should allow, where feasible, trading between point and nonpoint pollution sources. In the current absence of regulation for nonpoint sources, this type of mixed trading leverages point source regulatory requirements to generate reductions from unregulated nonpoint pollution sources. The private sector and the markets should play a central role in these systems. However, an overly large public sector presence as buyer of environmental services risks crowding out the private sector.

4. Public Participation and Information Dissemination

The Government of the PRC has expressed commitment to improve information dissemination and public participation in environmental management. These goals require specific support to make them effective. To promote genuine public participation and information disclosure, the 13th Five-Year Plan should consider programs and targets that aim to

- (i) improve environmental monitoring systems (as well as pilot participatory monitoring methods);
- (ii) designate and build capacity of public information units in local government agencies, such as a management authority, water resources bureau, or environmental protection bureau;
- (iii) mainstream participation, awareness initiatives, and information disclosure through existing agricultural extension services;
- (iv) use eco-compensation arrangements and revenues to support information management systems, information disclosure, and environmental awareness initiatives; and
- (v) capitalize on the behavioral change opportunities inherent in financial incentive systems, such as conversion to organic inputs, and green technologies and methodologies.

Abbreviations

ADB	Asian Development Bank
APG	Anhui Provincial Government
bcm	billion cubic meter
CLMA	Chao Lake Management Authority
COD	chemical oxygen demand
GDP	gross domestic product
IWRM	integrated water resources management
mcm	million cubic meter
MEP	Ministry of Environmental Protection
MDBA	Murray–Darling Basin Authority
MOA	Ministry of Agriculture
NPDES	National Pollutant Discharge Elimination System
NPS	nonpoint source pollution
PRC	People’s Republic of China
QSAR	quantitative structure–activity relationship (model)
RBMP	river basin management plan
TMDL	total maximum daily load
TN	total nitrogen
TP	total phosphorus
WFD	Water Framework Directive
WWTP	wastewater treatment plant

I. Introduction

In 2007, Hefei City in Anhui Province became the latest city in the People’s Republic of China (PRC) to abandon its long-time source of drinking water and move upstream for a cleaner water source. The decision was significant because the city was abandoning one of the PRC’s largest freshwater lakes and one of the central government’s highest priority lakes for environmental improvement—Chao Lake.

The Chao Lake Basin is located near the center of Anhui Province, in the floodplain of the Yangtze River. Known as the “home of fish and rice,” it is a major producer of rice, oilseeds, cotton, vegetables, poultry, and aquatic products. More than 34 mineral deposits have been found in the catchment,¹ including vast amounts of magnetite, pyrite, alunite, limestone, and gypsum. The lake region is a national scenic area, encompassing more than 130 natural and cultural sites.

Since the mid-1990s, the water quality of Chao Lake has steadily deteriorated. In 1996, the central government identified Chao Lake as one of the top three lakes in the country programmed for rehabilitation.² The Government of the PRC, supported by the Asian Development Bank (ADB), has invested heavily in controlling municipal and industrial water pollution in the lake catchment. These investments have reduced industrial and municipal water pollution to a certain extent, but they have not addressed all dimensions of the water quality problem in the lake.

Expensive water rehabilitation programs across the PRC are not cleaning up lakes and wetlands as expected; and the rapid, unrestrained growth that has led to dramatic ecological changes is proving hard to reverse. What will make the difference—and change the course—for the PRC’s deteriorating lakes and wetlands?

This case study on Chao Lake contributes to knowledge that ADB has been accumulating on how to revive lakes and wetlands in the PRC. The first case study, in 2007–2008, compared the relative success of the West Lake rehabilitation project in Zhejiang Province with the inconsistent outcomes (at the time) of efforts to rehabilitate Tai Lake in Jiangsu and Zhejiang provinces, Baiyangdian Lake in Hebei Province, and the Sanjiang Plain Wetlands in Heilongjiang Province.

¹ A catchment is an area with several, often interconnected, water bodies (rivers, lakes, groundwater, and coastal waters).

² The other two priority lakes are Dianchi Lake in Yunnan Province and Tai Lake in Jiangsu and Zhejiang provinces.

The comparative study identified four essential success factors that were present in the West Lake case study:³

- (i) strong and consistent political leadership at high levels to help overcome coordination problems and mobilize resources,
- (ii) a plan that was comprehensive and integrated all elements of the problem rather than focusing on narrow sector issues,
- (iii) a management structure that had the authority and ability to coordinate the implementation of the plan, and
- (iv) financial engineering that ensured enough resources were available at the right time.

These four essential factors provide a context and framework for evaluating lake rehabilitation efforts in the PRC. Recent reforms to the management of Chao Lake and unprecedented levels of investment by both the PRC and ADB have necessitated close analysis of the problem and proposed solutions.

To save Chao Lake, national and provincial leaders have taken significant steps toward long-term and sustainable rehabilitation, beginning with administrative consolidation to bring the lake under singular management—one lake, one rule. They have redrawn administrative and geographic jurisdictions to support integrated management, but through one rule. The Anhui Provincial Government merged two city administrations, created a high-level lake management authority, extended planning beyond the customary 5-year cycle, and developed a 15-year master plan for reviving Chao Lake.

As a result of greater political support and investments, rural and agricultural water pollution emissions into Chao Lake have at last come into sharper focus. Rural pollution is typically underestimated and underfunded in countries, but in November 2012, the ADB Board of Directors approved its largest ever investment in the environment—a \$250 million loan to support the implementation of the Chao Lake Master Plan. The Anhui Chao Lake Environmental Rehabilitation Project is designed with a balanced, integrative approach to investing in industrial, domestic, and rural water pollution control. The balanced investment in all three pollution sources is also what makes the project so progressive. Funding for nonpoint source pollution control—which is difficult to control as it comes from diffuse sources—often lags investments in more easily controlled industrial and urban water pollution. However, the ADB-supported project is investing a total of \$194.53 million in nonpoint source pollution control stemming from agricultural and rural sources and \$166.98 million in increased municipal point source pollution control. The Government of the PRC has demonstrated unprecedented commitment to environmental cleanup and lake restoration by agreeing to borrow substantially for nonstructural measures, such as wetland construction and rural pollution control pilots, to address agricultural and rural pollution emissions.

³ Q. Zhang, Y. Kobayashi, T. Kadono, R. Crooks, and Z. Ma. 2008. *Reviving Lakes and Wetlands: Lessons Learned from the People's Republic of China*. Manila: ADB. These conclusions were similar to those of an earlier global study (International Lake Environment Committee Foundation. 2005. *Managing Lakes and their Basins for Sustainable Use: A Report for Lake Basin Managers and Stakeholders*. Kusatsu, Japan).

This report examines how and to what extent the Chao Lake reforms reflect these four success factors. It begins by setting the national context—trends in water quality of lakes around the country, the contribution of various sources of water pollution, and the policy responses. The national lake water scenario is similar to that of Chao Lake, where a decline in water resources has been precipitated and exacerbated by rapid industrialization, urbanization, and population growth. These pressures are examined in the Chao Lake context, and the changes they brought about in land use, agricultural practices, and ultimately water quality are discussed. Recent reforms aim to reverse history and reclaim Chao Lake as an economically and environmentally viable water resource. However, as ADB's analysis shows, they require more detailed planning and implementation to be successful. Other countries that have gone through similar stages of water resource decline, reforms, and rehabilitation have learned these lessons. The findings of four international case studies are summarized. They raise highly relevant questions for the Anhui Provincial Government, and are also potentially instructive for other planned or ongoing water cleanup efforts in the PRC. The final chapter offers recommendations for the 13th Five-Year Plan. Nonpoint source pollution control, complex though it is, must receive appropriate policy attention, investments, and incentives that will support new market players, innovative financing, and holistic approaches to lake rehabilitation and protection.

II. National Trends and Challenges in Lake Water Pollution Control and Protection

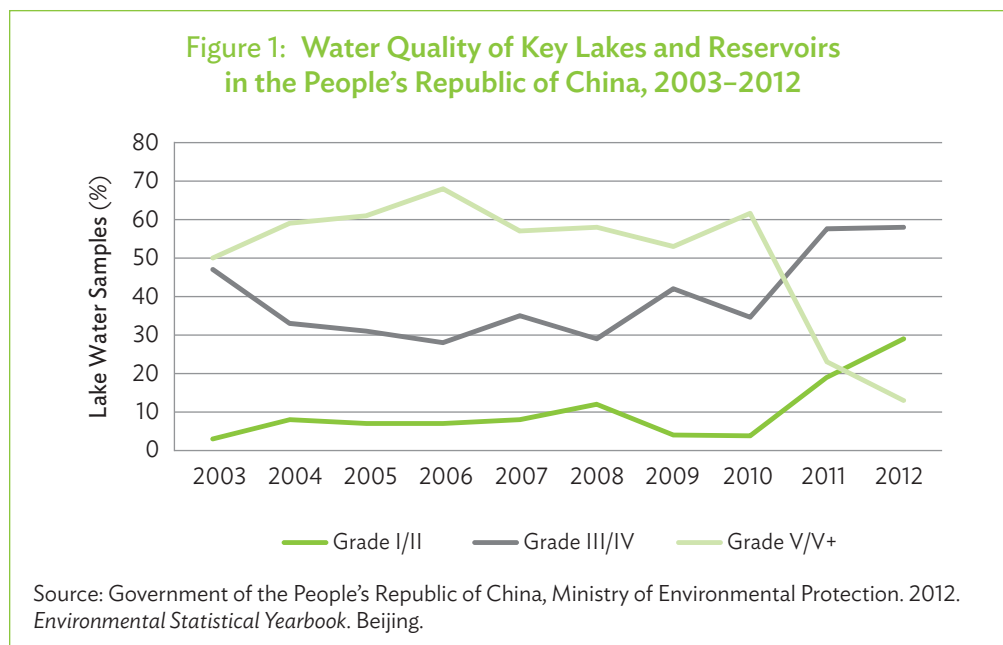
The PRC's impressive recent progress in controlling industrial and municipal sources of water pollution has been hailed internationally as a "wastewater management revolution." Since 2006, the volume and intensity of industrial wastewater discharges have dropped considerably and pollutant loads from this source now rank second to municipal (domestic) discharges. The volume of treated municipal wastewater has increased by 700% over the same period, and about 75% of all municipal wastewater discharges go through some level of treatment.

The general water quality of many of the larger water resources, especially freshwater lakes, has only nominally improved despite significantly expanded industrial and municipal wastewater treatment capacity and coverage. Throughout the 1990s and up to the end of the 10th Five-Year Plan period in 2005, the environmental quality of lakes throughout the PRC declined steadily. This trend continued into the 11th Five-Year Plan period, when more lakes were classified as having very poor water quality and the incidence of lakes with moderate water quality declined.

While recent progress to control industrial and municipal water pollution is unquestionably positive and necessary, the water quality of the PRC's bigger freshwater lakes remains very poor almost a decade into the wastewater management revolution. What might this environment movement be missing?

A. Water Quality of Lakes

According to 2012 data from the Ministry of Environmental Protection (MEP), 61.3% of the country's 62 key lakes are classified as I–III, 27.4% are Class IV and V, and 11.3% are Class V+. During 2003–2006, there was a steady deterioration of water quality in the monitored lakes, but 2010 appears to have been a turning point (Figure 1). During 2003–2006, the proportion of lake and reservoir water samples classified as V and V+ increased, the proportion in classes III and IV fell, and the proportion in classes I and II remained constant. Such deterioration mirrored the water quality conditions experienced throughout the 1990s. However, in 2010, the incidence of classes V and V+ declined while the proportion in classes I–IV increased. It should be noted that there was a significant increase in the incidence of classes III and IV samples, and the water quality of the bigger freshwater lakes is still classes V and V+. For example, in 2011, the water quality of Tai Lake was still Class V. No improvement was apparent compared with the previous year, and the main pollutants were chemical oxygen demand (COD) and total phosphorus (TP).



B. Sources of Water Pollution

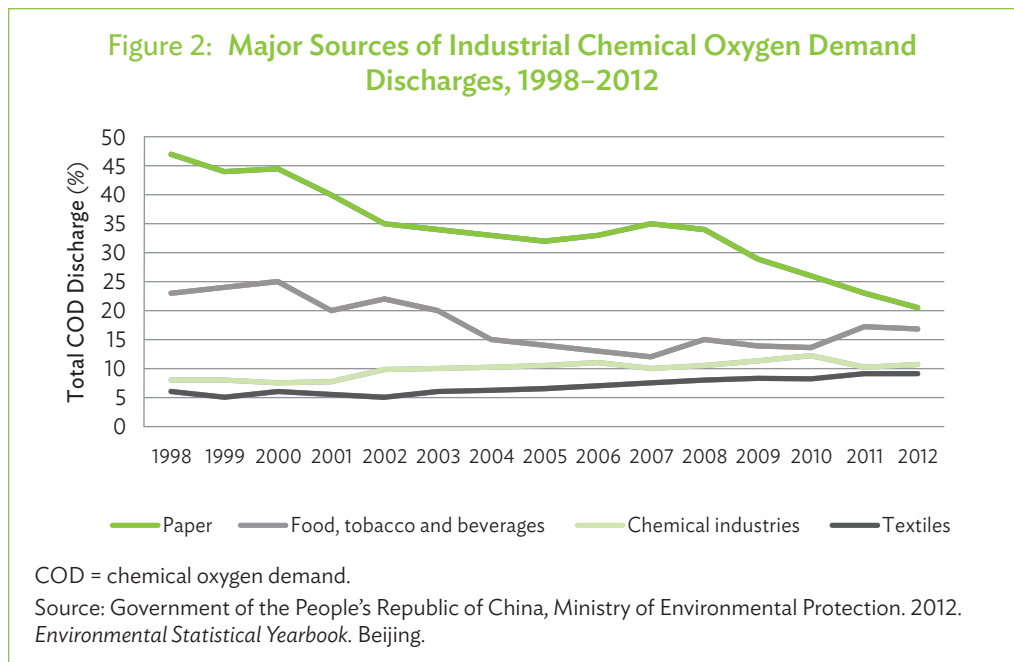
The main sources of water pollution are (i) point source discharges from industrial and commercial enterprises and from municipal domestic wastes; and (ii) nonpoint source (NPS) discharges of surface runoff, mainly from rural areas, due to soil erosion, agrochemical runoff (fertilizer, pesticide, and herbicide), and/or discharges from animal or aquatic production.

1. Point Source Discharges: Domestic and Industrial Wastewater

In 1999, domestic wastewater flow exceeded total industrial wastewater flow for the first time, and the gap has steadily increased ever since. Industrial wastewater flow started to flatten out in 2005, and then commenced a sustained downward trend until 2009. Since 2010, industrial wastewater flow has increased, but COD emissions have continued to decline.

The two major contributors to industrial COD loads since the late 1990s have been the pulp and paper industry and the food, tobacco, and beverages industries. In 2012, the pulp and paper industry accounted for nearly 21% of total industrial COD emissions, having declined from nearly 50% in 1998. The contribution of the food, tobacco, and beverage industries has declined from 1998, while those of the chemical industries and textiles have risen slightly (Figure 2).

The total industrial COD load has shown even more noticeable improvements throughout the period. These are remarkable achievements given that industrial growth and



development continued more or less unabated. The results attest to MEP's strenuous control efforts and massive investments in new wastewater treatment infrastructure, particularly during the 11th and 12th five-year planning periods.

In contrast, domestic wastewater flows increased almost every year throughout 2000–2010, with annual increases of 4%–10%. The domestic COD load, however, peaked in 2006 and then decreased each subsequent year by 0.9%–4.4%. This inverse trend shows the tangible benefits of the government's huge investments in new domestic wastewater treatment capacity. There was a 700% increase in municipal wastewater treatment capacity during the 11th and 12th five-year planning periods, and installed treatment capacity at the end of the 11th Five-Year Plan period (2010) was about 75% of estimated flows. By 2012, domestic wastewater flows had reached 462.7 million tons.

2. Nonpoint Sources: Rural and Agricultural Water Pollution

NPS water pollution includes fertilizer and pesticide runoff and discharges from intensive animal production enterprises (including aquaculture). They have become a major environmental issue in the PRC and are the major water pollution control challenge for the 13th Five-Year Plan. Results from MEP's first National General Survey of Pollution Sources between 2007 and 2010 generally confirm what many experts and analysts have been saying for many years—that NPS pollution is a major contributor to water pollution in the PRC and, in some respects, is the single greatest influence. The survey results are based on 2.9 million agricultural survey points, 1.6 million industrial survey points, and 1.4 million domestic survey points. The key findings from the survey are summarized in Table 1.

Table 1: Key Findings from National General Survey of Pollution Sources in the People's Republic of China, 2007–2010

Nutrient Pollution	Organic Pollution
<ul style="list-style-type: none"> • Agricultural NPS pollution is the source of 67% of all phosphorus pollution and 55% of all nitrogen pollution. • The biggest single source of nitrogen pollution is domestic wastewater (41% of TN discharged). • The biggest single source of phosphorus pollution is intensive animal husbandry enterprises (38% of TP discharged). • The biggest NPS of nitrogen pollution is diffuse runoff of fertilizer (59% of TN from nonpoint sources, and 32% of TN from all sources). • The biggest NPS of phosphorus pollution is intensive animal husbandry enterprises (56% of TP from nonpoint sources, and 38% of TP from all sources). 	<ul style="list-style-type: none"> • NPS accounts for 44% of all COD pollution. • COD from intensive animal husbandry enterprises is the single biggest source of organic pollution, accounting for 96% of nonpoint source COD and 42% of total COD from all sources. COD from intensive animal husbandry enterprises exceeds the total discharge from domestic sources (the second biggest source) by 14%.

COD = chemical oxygen demand, NPS = nonpoint source, TN = total nitrogen, TP = total phosphorus.

Source: Summary of the main results of the first National General Survey of Pollution Sources conducted by the Ministry of Environmental Protection of the People's Republic of China. Adapted from Q. Zhang, Y. Kobayashi, T. Kadono, R. Crooks, and Z. Ma. 2008. *Reviving Lakes and Wetlands: Lessons Learned from the People's Republic of China*. Manila: Asian Development Bank. pp. 47–48.

The findings on COD discharges are significant. While the government has been making substantial progress in controlling COD discharges from industries and cities, much less progress has been made in controlling organic discharges from animal husbandry enterprises. To improve ambient water quality, broader water pollution control is needed. This must maintain the momentum that has already been achieved in industrial and municipal point sources while increasing regulatory and development controls on rural nonpoint pollution sources, especially intensive animal husbandry.

Nutrient pollution. Diffuse runoff of fertilizer from agricultural land has been identified as the biggest single source of nitrogen pollution in the PRC and an important source of phosphorus pollution. Fertilizer runoff can be nutrients that are either dissolved in runoff or adsorbed onto soil particles and are carried into rivers, streams, and lakes through soil erosion. It accounts for 38% of phosphorus discharges from all nonpoint sources, and 26% of phosphorus discharges from all sources.

According to estimates from the Ministry of Agriculture (MOA), the relative ratios of fertilizers applied in the PRC are 1.0 nitrogen: 0.47 phosphorus: 0.10 potassium. If these ratios are applied to the PRC's average annual application of fertilizer of almost 15 million tons, and resultant figures are compared to MEP's estimates of total nitrogen (TN) and TP being discharged as nonpoint pollution, it can be calculated that 17% of TN and 2.4% of TP applied on the PRC's agricultural lands end up in rivers, streams, and lakes. These

amounts are daunting as they not only depict a critical pollution problem but also illustrate a substantial waste of financial resources.⁴

The problem with fertilizer runoff in the PRC comes from both sides of the market—suppliers and users. On one hand, because of significant overcapacity, dominant participation of small- and medium-sized producers,⁵ and the high level of competition in the country's fertilizer industry, prices are kept low and overapplication is rampant. Fertilizer subsidies aggravate the problem.⁶ On the other hand, most farmers choose cheap, low-quality, single-ingredient fertilizers, which they often overapply to compensate for their poor quality. Such practice increases fertilizer runoff. Compound fertilizers, which are more expensive but can help lessen the runoff problem, only accounted for 32.4% of all fertilizers consumed in 2010; but analysis of the markets shows that demand for domestic compound fertilizer has been increasing in 2013 as influenced by positive results from soil testing.⁷ However, the compound fertilizers used are likely to be the low-grade, general-purpose, premixed fertilizers instead of the specialized mixtures that are developed on the basis of soil testing or in-field fertilizer trials. Hence, compound fertilizers are not being used as effectively as they should be.

As a result, annual fertilizer use in the PRC has increased from 1.6 million tons (of pure nutrient) in 1984 to 58.0 million tons in 2012—an increase of 3,625%. According to the China Agricultural Production Means Circulation Association, the PRC has become the largest producer and consumer of fertilizer in the world, annually producing about one-third of the world fertilizer and consuming about 35%.⁸ National average fertilizer consumption for the period 2010–2012 is reported at 647.6 kilograms per hectare of arable land, which is much higher than the world average consumption of 141.3 kilograms per hectare of arable land.⁹

⁴ The total annual cost of procurement and application of fertilizer in the PRC is said to exceed CNY200 billion per annum, representing 25% of total agricultural input costs (M. Chen. 2006. Fertilizer Use in Chinese Agriculture. Paper for the Organisation for Economic Co-operation and Development Workshop on Environment, Resources, and Agricultural Policies in the PRC. Beijing. 19–21 June). It is thus calculated that a total of CNY23 billion is being wasted each year on nitrogen and phosphorus fertilizers that are added to farmers' fields but are washed off and thereby yield no benefit in terms of agricultural production. This wastage is equivalent to 11.5% of total expenditures on fertilizer procurement and nearly 3% of total agricultural input costs. Other estimates of losses are much higher (e.g., D. Norse and Z. Zhu. 2004. Policy Responses to Non-Point Pollution from China's Crop Production. Special Report by the Task Force on Non-Point Pollution from Crop Production of the China Council for International Cooperation on Environment and Development. Beijing).

⁵ The 20 largest fertilizer manufacturers in the PRC only account for about 50% of total production. The sector is considered to comprise around 200 "significant producers" (one of which is Sinofert, the world's largest fertilizer company), although this is a considerable improvement from 10 years ago when there were more than 1,000 significant producers. Consolidation is likely to continue in response to overcapacity and the resulting cost pressures on inefficient producers.

⁶ *China Economic Review*. 2010. Overgrown. 1 September. <http://www.chinaeconomicreview.com/node/25525>; D. Norse and Z. Zhu. 2004. Policy Responses to Non-Point Pollution from China's Crop Production. Special report by the Task Force on Non-Point Pollution from Crop Production of the China Council for International Cooperation on Environment and Development. Beijing.

⁷ Beijing Shennong Kexin Agribusiness Consulting. 2013. China Compound Fertilizer Industry Analysis and Forecast Report (2013–2014). <http://www.agrichn.com/upload/CaseData/bxite-SP2013111309270001.pdf>

⁸ *Xinhua News Agency*. 2006. China Becomes Main Producer and Consumer of Fertilizer. 25 October. <http://www.china.org.cn/english/BAT/185923.htm>

⁹ World Bank. 2015. *World Development Indicators*. Agricultural Inputs. <http://wdi.worldbank.org/table/3.2>

Controlling the problem of nutrient runoff will require changes in the way farmers use fertilizers. This is a matter largely outside the control of MEP and more under the control of MOA.

Emissions from intensive animal production. The structure of the PRC's rural economy has undergone remarkable changes since the 1970s. Livestock production has almost tripled its contribution to the gross value of agricultural output, from 14% in 1970 to 38% in 2010, leading to unparalleled increases in livestock numbers. Between 1978 and 2010, cattle numbers increased by 2,000%, sheep and goats by 1,158%, pigs by 449%, and poultry by 945%.

Meat and dairy production in the PRC is largely carried out in intensive enterprises because of the shortage of agricultural land, creating concentrated points of animal waste. The predominance of small- and medium-scale livestock producers has become one of the country's major environmental issues. They often operate with low levels of technology, nutrient efficiency, management expertise, and organization. Because of the extremely large number of small- and medium-scale producers, MEP tends to concentrate its regulatory control on the large-scale producers—although the Environmental Protection Law gives it the legal authority to control discharges from all intensive animal production units. MEP needs the involvement of MOA in educating and supporting cleaner operations among small- and medium-scale livestock producers.

Pesticides. Pesticides are not typically reported in water quality data because MEP does not routinely test for them. But the growth in pesticide production indicates it is probably another major NPS pollution as about 30% of the pesticides used in the PRC are highly toxic. The steep rise of total domestic pesticide production—from only about 1,000 tons in the early 1950s to 625,000 tons by end of 1999—made the PRC the second-largest producer and consumer of pesticides in the world. Since 2009, usage of pesticides is estimated to have reached about 1 million tons per annum, of which about 0.4 million tons was exported. This has made the PRC the world's largest producer, consumer, and exporter of pesticides.¹⁰

C. Approach to Water Pollution Control

The PRC's current approach to general water pollution control is industry-centric and dependent on coercive, command-and-control policies. Domestic and agricultural water pollution control is undertaken primarily as an extension of industrial pollution control policies, which are not well suited for dealing with rural and agricultural point and nonpoint pollution sources. The overall policy landscape for water pollution control in the PRC depends on command-and-control instruments, such as the Three Simultaneous Processes policy, which requires the design, construction, and operation of pollution control facilities simultaneously with the development of capital projects. Other command-and-control instruments include the application and enforcement of discharge standards, total pollutant discharge control, and the issuance of discharge permits. To implement standards and permits, the PRC relies on coercive policies, such as penalties for exceeding discharge

¹⁰ Shanxi Petroleum and Chemistry Industry Office. 2006. *Production Monthly News*. 7 July; Y. Yang. 2007. *Pesticides and Environmental Health Trends in China*. A China Environmental Health Project Factsheet. 28 February.

standards. While elements of this approach are necessary, the approach has severely limited the use of economic, participatory, incentive-based, and voluntary policies.

The government's flagship policy response to lake deterioration has been the Three Rivers and Three Lakes Program, which commenced at the beginning of the 9th Five-Year Plan but has not achieved its intended results. It focuses on three of the largest and most polluted lakes in the country—Chao Lake (Anhui Province), Dianchi Lake (Yunnan Province), and Tai Lake (Jiangsu and Zhejiang provinces). A review by ADB suggested that the investment programs have been too broad and the plans too static and not forward-looking enough, failing to include measures to contain or restrict economic and urban growth in the lake catchments.¹¹ Focusing instead on the effects of unrestrained socioeconomic and urban development trends on the water environment, the plans included substantial funds for NPS pollution control, but no measures to control the growth of livestock numbers during the planning periods. This undermined some of the success achieved from restricting in-lake aquaculture. The net effect of this oversight has been a significant increase in concentrations of TN and TP even as the plans were being implemented.

Measures to control nutrient-based water pollution were included in the 11th and 12th five-year plans to deal with the fertilizer management problem. The measures included (i) promoting soil testing and fertilizer formulation technologies; (ii) improving the quality of cultivable land through increased use of organic fertilizers, better soil quality monitoring programs, and the adoption of water-saving agricultural techniques; (iii) enhancing farmer education; (iv) encouraging the use of advanced production techniques within the fertilizer production industry; and (v) tightening up regulatory supervision.

In 2004, the government took steps to reduce the use of five high-toxicity pesticides that accounted for 25% of total pesticide application in the PRC—methamidophos, parathion, methyl parathion, monocrotophos, and dimecron. Their use was banned at the beginning of 2007. The 2006 Law on Agricultural Product Quality and Safety included a new limit for pesticide residue on food items in the PRC and a pesticide education system for farmers. These changes represent a major step forward in food safety as well as reduced runoff of these chemicals into water bodies. These advances need to be sustained into the next planning period, but further improvements in ambient water quality will require a broader water pollution control effort that (i) maintains the momentum that has already been achieved in industrial and municipal point sources while at the same time (ii) increasing regulatory and development controls on rural NPS, particularly in the intensive animal husbandry sector. Controlling rural NPS is only likely to happen if MOA is directly involved. MOA is a prominent stakeholder in improving the management and control of small- and medium-scale animal production and the use of fertilizers and pesticides. There is a natural overlap between the roles of MOA and MEP in addressing runoff and direct emissions from rural NPS, but this should be seen as an opportunity for greater reinforcement, cooperation, and integrated management.

¹¹ Q. Zhang, Y. Kobayashi, T. Kadono, R. Crooks, and Z. Ma. 2008. *Reviving Lakes and Wetlands: Lessons Learned from the People's Republic of China*. Manila: ADB.

III. Chao Lake: A Promising Case Study

The Anhui Provincial Government (APG) has embarked on a strategy to clean up Chao Lake that could be considered an early blueprint for lake rehabilitation in the country and internationally. The model is based on singular management of the lake and holistic pollution control. In general terms, the APG has consolidated jurisdictions and institutions to create a more sensible structure for managing the lake, and is continuing to invest in industrial and municipal pollution control while taking nationally unprecedented steps to tackle the most challenging pollution sources of all—agricultural and rural nonpoint source (NPS) pollution.

This case study presents the basic background on the Chao Lake watershed, the development trends that led to its decline, and the sources and characteristics of water pollution in the lake. It then examines the APG's recent reforms aimed at rehabilitating the lake through better lake management. The analysis concludes that APG is moving in the right direction with its reforms, but its ultimate success depends on the ability of its new institutions and management structure to mature and adapt to change—socioeconomic, political, and environmental. The recommendations offered at the end of the case study and in the chapters that follow contain lessons for national and international policy advisors and practitioners working in lake rehabilitation, NPS water pollution control, institutional strengthening, and integrated water resources management.

A. The Watershed

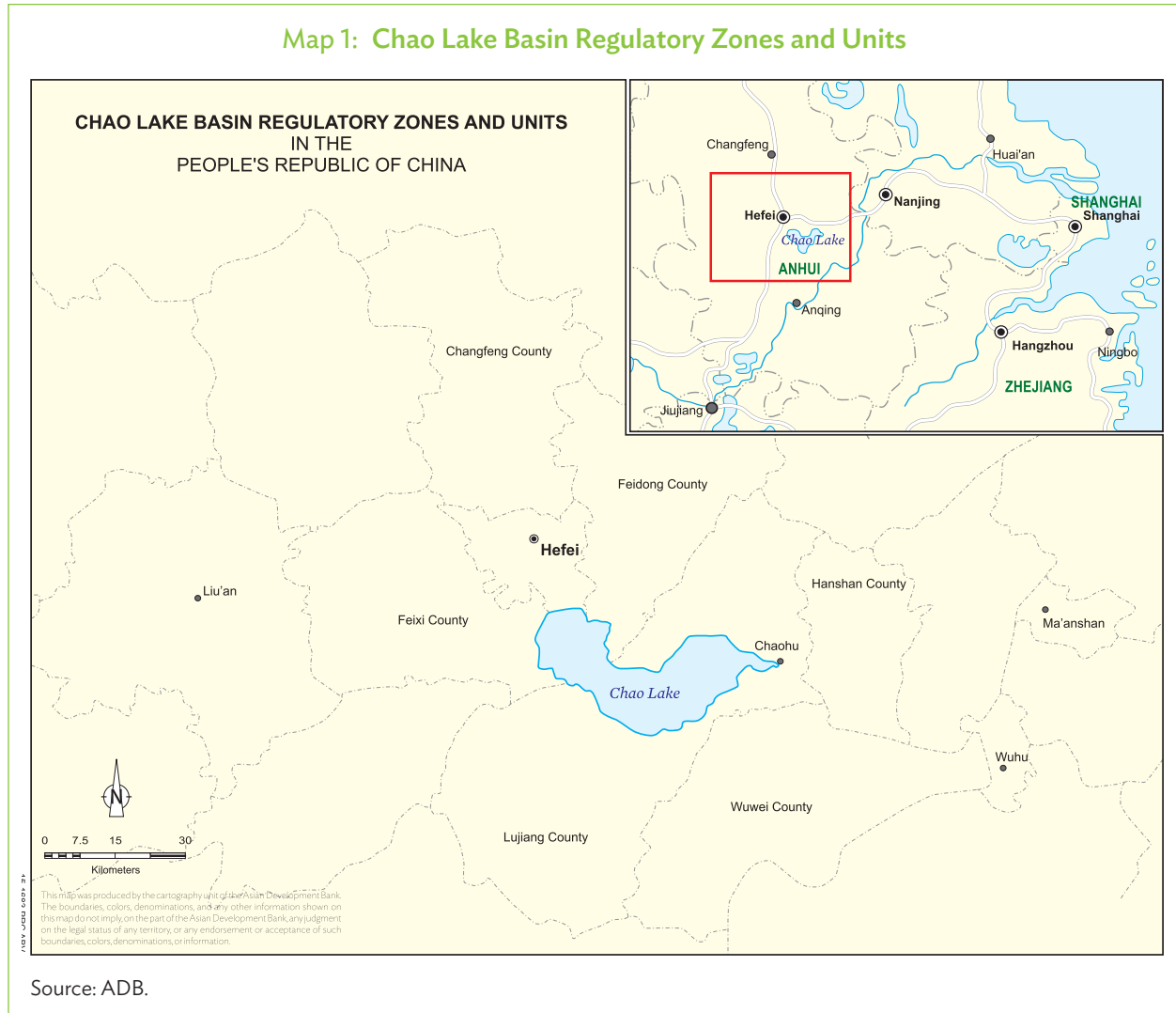
Chao Lake is located near the center of Anhui Province, in the floodplain of the Yangtze River. Its catchment occupies about 10% of the total area of the province and is important for industrial and agricultural water supply, water transport, tourism, and recreation in the province. The total area of the watershed is 13,130 square kilometers, with 33 tributaries belonging to 7 major river systems: the Baishishan, Hangbu-Fengle, Pai, Xifei-Dianbu, Yuxi, Zhao, and Zhegao.

The greater Chao Lake catchment area (upstream of the Yangtze River) covers Hefei City, Lu'an Prefecture, and Wuhu and Ma'anshan counties.¹² Hefei City and Lu'an Prefecture are located predominantly in the up-sluice (upper catchment) of the lake.¹³

¹² Most discharges from Ma'anshan and Wuhu counties do not flow directly into the lake. They are part of the Yuxi River catchment, which forms the greater Chao Lake catchment.

¹³ Chaohu Municipality no longer exists and has been dissolved into Hefei, Ma'anshan, and Wuhu municipalities. At the time of this analysis, local statistical data was still disaggregated, with Chaohu as a separate municipality.

Map 1: Chao Lake Basin Regulatory Zones and Units



The expanse of the lake and the numerous administrative boundaries within the watershed represent inherent difficulties in the standard top-down, sector structure of traditional water resources management. Institutional arrangements need to match the local context. For Chao Lake, this prompted the restructuring of municipal governments and boundaries in the basin, the consolidation of most of the watershed under the jurisdiction of a single local government authority, and the creation of a provincial-level agency to manage all aspects of the lake.

B. Socioeconomic Profile

A half-century of dynamic economic development in Anhui Province has had serious implications for Chao Lake and explains the poor environmental state of the lake. An increase in land reclamation in the Yangtze River Basin in the 1960s spurred a rapid decline in wetlands around the lake. At the same time, a variety of industries sprung up in the watershed. Currently, these include mechanical, electronic, chemical, metallurgy, textiles,



Chao Lake in early spring
(Anhui Chao Lake Environmental Rehabilitation Project Management Office)

food processing, and building materials industries. There is heavy stone-quarrying activity around the lake, especially in smaller quarries that have outdated technologies, causing soil erosion and risks of landslide. Since the late 1990s, the Chao Lake region has pursued even more aggressive urbanization and economic growth, which has increased pollutant emissions and caused serious deterioration of water quality. The pollution loads flowing into Chao Lake are indicative of the same macroeconomic pressures that ADB identified in its 2012 country environmental analysis: unrestrained economic growth, an industry-heavy economic structure, and rapid urbanization.¹⁴

Urbanization. The western and most polluted end of Chao Lake abuts Hefei City—the largest city in the basin and the location of almost all of the net increases in the urban population. In 2012, the total population of the catchment was 11 million, of which 70.5% were rural. During 2000–2012, the urban population of the basin grew by a substantial 46% (Figure 3).¹⁵

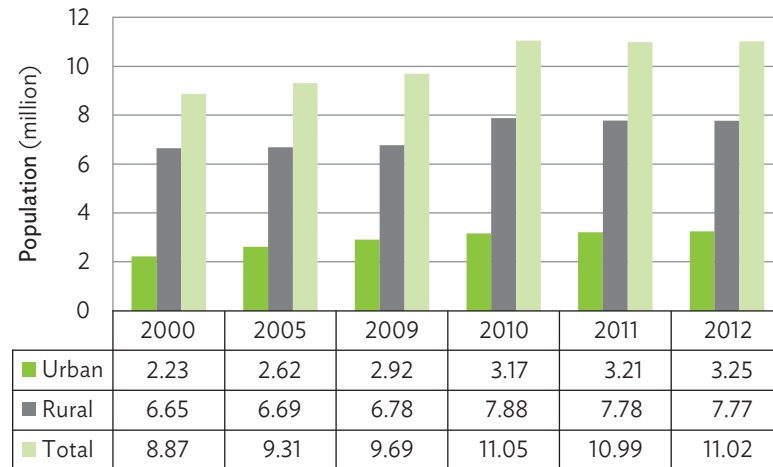
A study of satellite images suggest that during 1990–2013, urban land use around Hefei City increased by 785% and by 2,355% since 1979.¹⁶ Urban sprawl has consumed more than 100,000 hectares of farmland. The conversion of agricultural land is a major cause of increased production intensity on the remaining arable land, which, in turn, is related to

¹⁴ Q. Zhang and R. Crooks. 2012. *Toward an Environmentally Sustainable Future: Country Environmental Analysis of the People's Republic of China*. Manila: ADB.

¹⁵ This rate is higher than the provincial average of 43.7% but lower than the national average of about 50%. Total urban population for the catchment is 2.9 million.

¹⁶ C. Ji and D. Sun. Unpublished. *Non-Point Source Pollution in Chao Lake Basin, Anhui, PRC: A Preliminary Assessment*. Draft report prepared for ADB.

Figure 3: Growth of Total Catchment Population, 2000–2012



Source: People's Government of Anhui Province, Statistical Bureau. Various years. *Anhui Statistical Yearbook*. Beijing: China Statistics Press.



Hefei Binhuxin District with newly built residential quarters
(Anhui Chao Lake Environmental Rehabilitation Project Management Office)

increased NPS pollution. Urban population growth is likely to continue at high levels for the foreseeable future.

Spatial planning in the catchment envisages the continued development of Hefei City, four surrounding city clusters, and one new district, creating a combined population of 3.6 million by 2020. Much of the new development is planned for space between downtown Hefei City and the lakeshore, which would further jeopardize water quality.¹⁷ (See case study on Wales on page 39.)

¹⁷ The Planning Bureau of Hefei Municipality is expected to issue the Hefei Municipal Urban Spatial Development Strategy and the Plan for Ecological Protection and Restoration and Tourism Development in the Lake Region. Under this new plan, the development of new industrial parks within 10 kilometers of the lake will be prohibited.

Economic contribution. Chao Lake plays an important role in the provincial economy, providing potable water to some residential areas, water for industry and agriculture, water transport, and an amenity for tourism. In 2013, the Chao Lake catchment area contributed 19.8% of total provincial gross domestic product (GDP)—disproportionately higher than its share of area or population in the province, proving its economic significance. The economic contribution of agriculture is relatively small at only 16.9% of provincial GDP, but it produces important quantities of grain and meat.

The Chao Lake region is also a key relocation area for industries from the eastern parts of the country looking to transfer westward. The provincial government and the Ministry of Environmental Protection (MEP) have signed an agreement to control the adverse environmental effects of the industrial transfer program, but these developments still pose a significant challenge to water management. This challenge was specifically commented on in the 12th Five-Year Plan:

“The prevention and control of industrial pollution require not only more effective management of pollutant sources and environmental monitoring, but also more emphasis on utilization of favorable conditions of industrial transfer, intensification of cleaner production, development of [the] cyclic economy, strict [controls on] industrial access, optimization of industrial structure, etc., to relieve pressure on the water environment of the basin fundamentally.”

The provincial government is trying to reshape the industry-heavy growth strategy by shifting to hi-tech industries that produce less pollution per unit of output and a growing tertiary sector. For example, the vision of the strategic plan is for Hefei City to become a major national center for scientific research and education, innovation, and advanced manufacturing, as well as a national hub of integrated communications and a regional center of public services.

Even these broad economic shifts have implications on the lake water quality and should be examined for any environmental impacts that may occur, especially when physical plants—even ones from cleaner industries—are within what should be environmental buffer zones. For example, in 2012, the expansion of the Anhui Juchao Economic Development Zone, located 1 kilometer from Chao Lake harbor was approved.

C. Water Pollution Profile

Natural conditions and anthropogenic activity in the basin has made Chao Lake extremely sensitive to the accumulation of pollution, particularly phosphorus.

The lake has a high surface-to-volume ratio and high incidence of soils with elevated phosphorus levels. The ratio between the surface area of the catchment and the volume of the lake, at 4,888 square kilometers per cubic kilometer, is very high. One cubic meter of lake needs to accommodate the pollutants contained in runoff from about 5,300 square meters of catchment land (about half a hectare), which makes the lake naturally susceptible to pollution overloading. About 40% of soils tested from agricultural or arable land in the catchment exceeded phosphorus saturation levels by 25%, making them a natural source of phosphorus contamination.

From an engineering standpoint, flood control works have reduced back flushing from the Yangtze River by as much as 90%. Before major engineering works, Chao Lake was a shallow lake, with high volumes of exchange with the Yangtze River. About 1.36 billion cubic meters (bcm) of Yangtze water used to flush back up into the lake each year, flooding lakeshore areas and helping to flush pollution out of the lake.

In 1962, the Chaohu sluice gate was constructed at the outlet of the lake; and in 1968, the Yuxi sluice gate was constructed to control floods on Yuxi River. After these control gates were built, Chao Lake became a half-closed water body and the volume of water exchange with Yangtze dropped by almost 90% to 0.17 bcm per year. Thus, the lake lost its natural throughput characteristics and its self-purifying capacity was greatly reduced.¹⁸ Operation of the control gates in spring to maximize the water level in the lake and increase the supply of water available for irrigation also has reduced the growth of emergent aquatic vegetation, which would otherwise have provided foreshore protection and helped absorb nutrients.¹⁹



Blue-green algae outbreak in Chao Lake during summer
(Anhui Chao Lake Environmental Rehabilitation Project Management Office)

¹⁸ The average annual runoff from the watershed into the lake before the 1962 construction of the sluice gate was approximately 30.3×10^8 cubic meters (or 1.36 bcm) and flow from the Yangtze into the lake was 13.6×10^9 cubic meters, a ratio of 1:0.45. The ratio dropped to 1:0.05 after the sluice gate was constructed.

¹⁹ In March 2012, a plan to divert water from the Yangtze River into Chao Lake was issued in order to increase the connectivity of the Yangtze to the lake, improve its self-purification ability, and provide water supply for industrial and landscaping needs. This CNY9 billion water diversion project would pump approximately 1 bcm of water a distance of 110 kilometers north from the Yangtze River's Congyang Gate to Chao Lake, and is the first section of a bigger 330-kilometer water diversion project between the Yangtze and Huai rivers in Anhui Province. This transfer of water is expected to restore the lake's natural connection to the Yangtze River, reducing the lake detention time from 12 years to 2 years and helping resolve water quality issues in the lake. The project will be implemented when the province secures the necessary funding.

From the 1980s, as the economy in surrounding areas started to develop, the lake water quality began to decline rapidly. Without the Yangtze River to help cleanse the lake, excessive pollution loads led to blue-green algae blooms in the western part of the lake, threatening surrounding agriculture and other activities that depend on the lake as a water supply.

1. Water Quality

In 2013, overall water quality was classified as Class IV, which is suitable for industries and recreation that involves no direct contact. There was slight change in the water quality compared to the previous year (Table 2).

The eastern side of the lake was still Class IV, but the water quality of the western part of the lake declined from Class IV to Class V (suitable only for agricultural and landscaping use). This represents an improvement over the situation in 2006, when overall lake quality was Class V+, but the situation remains serious (Table 3).

The main pollutants responsible for the poor water quality classifications are chemical oxygen demand (COD), which is a measure of organic pollution; total nitrogen (TN); and total phosphorus (TP), which is the major cause of Class V and V+ readings. Figures 4, 5, and 6 show the sources of each major pollutant. As can be seen from these figures, urban point source pollution is still a major contributor of COD and nitrogen, whereas rural nonpoint sources are almost solely responsible for the phosphorus levels in the lake. Also evident from these figures is the major progress the province has experienced in limiting industrial pollution, as this source is a minor contributor to all three pollution factors. At the western side of the lake, in the vicinity of Hefei City, the provincial capital, water quality is

Table 2: Chao Lake Water Quality Category and Nutritional Status, 2010–2013

Year	Category of Overall Water Quality	Nutritional Status
2010	Class IV	Light eutrophic
2011	Worse than Class V	Medium eutrophic
2012	Worse than Class V	Medium eutrophic
2013	Class IV	Light eutrophic

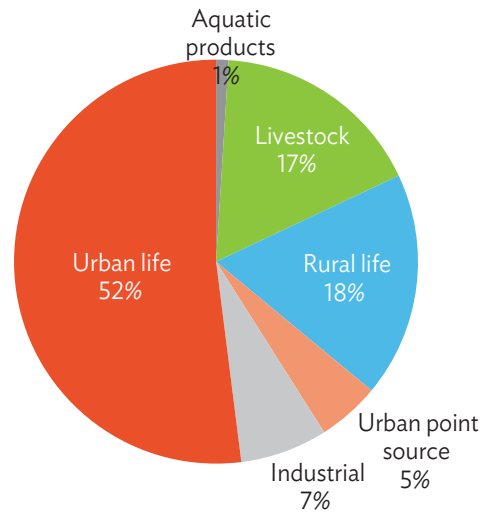
Source: Government of the People's Republic of China, National Bureau of Statistics, and Ministry of Environmental Protection. Various years. *China Statistical Yearbook on Environment*. Beijing: China Statistics Press; and Chao Lake Management Authority.

Table 3: Distribution of Chao Lake by Water Quality Class, 2013 (%)

Classes I–III	Classes IV–V	Class V+
63.1	5.3	31.6

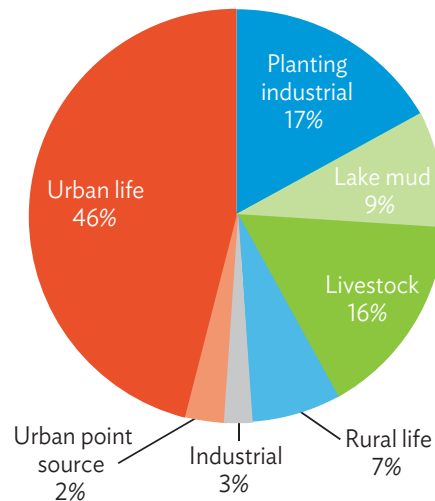
Source: People's Government of Anhui Province, Environmental Protection Department. 2013. *Anhui Environmental Bulletin*. Hefei.

Figure 4: Chemical Oxygen Demand by Source, 2011



Source: People's Government of Anhui Province, Environmental Protection Department. 2011. *Chao Lake Water Pollution Prevention Plan (2011–2015)*. Hefei.

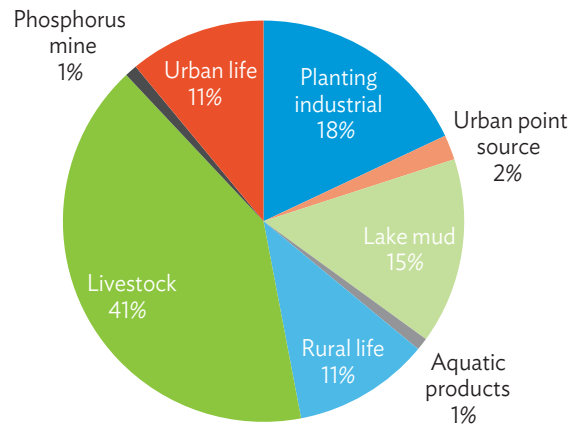
Figure 5: Total Nitrogen by Source, 2011



Note: Planting industrial refers to landscaping.

Source: People's Government of Anhui Province, Environmental Protection Department. 2011. *Chao Lake Water Pollution Prevention Plan (2011–2015)*. Hefei.

Figure 6: Total Phosphorus by Source, 2011



Note: Planting industrial refers to landscaping.

Source: People's Government of Anhui Province, Environmental Protection Department. 2011. *Chao Lake Water Pollution Prevention Plan (2011–2015)*. Hefei.

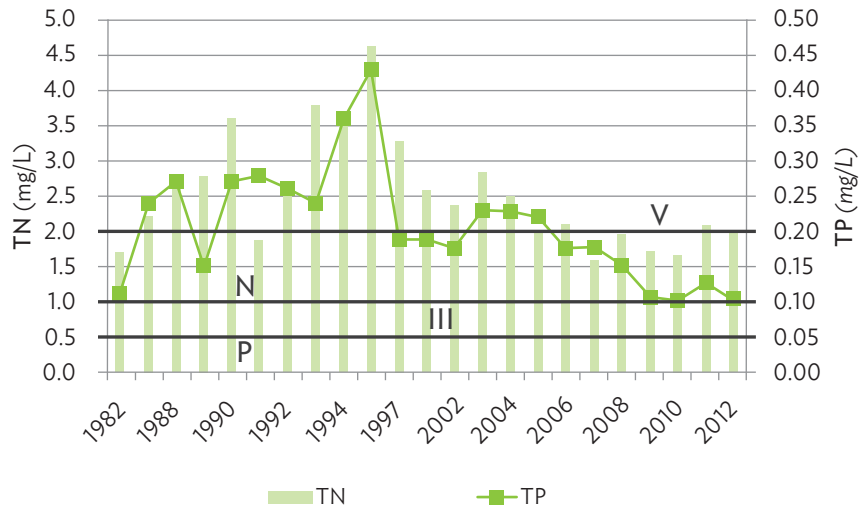
generally much worse than it is at the eastern end, near the outlet to the Yuxi River, which drains into the Yangtze River.

In 2006, the Anhui Environmental Protection Department estimated that total discharges of COD exceeded the assimilative capacity of the lake by 305%, TN by 1,730%, and TP by 606%.²⁰ Figure 7 shows that the concentration of TN and TP were rising from 1982 to 1995, peaked in 1995, and then declined to early 1980s levels by 2005. In 2010, 380 million tons of wastewater were discharged into Chao Lake, including 157,000 tons of total COD, 33,000 tons of TN, and 2,762 tons of TP.

The effects of recent reforms became evident in 2011. Total discharges of COD dropped to 84,000 tons, TN to 18,000 tons, and TP to 1,400 tons from their 2010 levels. Greater reductions are needed to meet the 2015 water quality objectives in the 12th Five-Year Plan. The total basin-wide industrial and household COD emissions should be controlled at 70,000 tons—a further reduction of 16% compared to 2011. Domestic and agricultural sources should reduce their TN discharges to 15,000 tons and TP to 1,015 tons. This would reduce TN emissions by 14% and TP by 18%. Other indicators should reach Class IV by 2015.

²⁰ People's Government of Anhui Province. 2008. Master Plan for the Integrated Water Environment Management in the Chao Lake Basin. Mimeo. p. 108. Assimilative capacity data from Table 4.1–5. These estimates need to be viewed cautiously due to the difficulties with estimating assimilative capacity and with quantifying some of the discharge volumes (particularly the nonpoint source discharges). Nevertheless, they are consistent with the observed water quality situation in general.

Figure 7: Changes in the Concentration of Total Nitrogen and Total Phosphorus in Chao Lake, 1982–2012



mg/l = milligram per liter, N = nitrogen, P = phosphorus, TN = total nitrogen, TP = total phosphorus.

Note: III and V refer to water classifications, with V being the most polluted.

Source: People's Government of Anhui Province, Environmental Protection Department. 2011. *Chao Lake Water Pollution Prevention Plan (2011–2015)*. Hefei.



Household wastewater discharge along the bank of Zhegao River, one of the rivers flowing into Chao Lake
(Anhui Chao Lake Environmental Rehabilitation Project Management Office)

2. Point Source Pollution

In 2010, a total of about 400 million cubic meters (mcm) of point source wastewater was discharged into Chao Lake, of which 300 mcm (75% of the total and equivalent to 17% of the volume of the lake) was discharged in the upper lake catchment area and flowed directly into the lake. About 86% of the total point source discharges were from municipal wastewater, with the remainder from industrial wastewater treatment plants (WWTPs).

Municipal wastewater emissions play a far more significant role in the overall water pollution situation than industrial emissions. According to 2010 estimates from the Anhui Environmental Protection Department, municipal wastewater accounted for 50% of total organic (COD) emissions in the catchment,²¹ 57% of TN, and 54% of TP.²² At the end of 2010, 20 municipal WWTPs were operating within the greater Chao Lake Basin, with a total treatment capacity of 1.17 mcm per day, and each county has at least one WWTP installed. The combined annual treatment capacity of the 20 WWTPs is about the same as the annual municipal wastewater flow. However, they are still insufficient because (i) the facilities are not evenly distributed to cover all wastewater sources, (ii) most of the WWTPs provide only basic biological treatment with only minimum nutrient removal, (iii) some areas lack an adequate wastewater collection network and the local WWTP cannot operate at full capacity, and (iv) many sewerage networks are combined stormwater and wastewater system, which can overload during storms. As a result, the system meets neither the existing needs nor the future challenges due to planned significant increases in urban populations, particularly in Hefei City.

Industrial wastewater emissions currently account for only 5%–8% of total loads, depending on pollutants. The picture of industrial wastewater treatment is more positive due to a combined approach of industrial restructuring, which shuts down small and/or highly polluting industrial enterprises; improved regulatory effectiveness; and prohibition of new, highly polluting enterprises. As a result, industrial wastewater emissions have progressively declined during 2000–2009 even as industrial GDP has continued to grow by 550%.

3. Nonpoint Source Pollution

With industrial and municipal point source emissions being slowly yet progressively brought under control, NPS pollutant emissions are emerging as the most significant and intractable water pollution problem facing the region.

The three primary nonpoint sources of pollution in the catchment are (i) direct discharges of untreated domestic wastewater from rural households, (ii) waste emissions from livestock production enterprises, and (iii) agricultural runoff, primarily fertilizer residues

²¹ Organic refers to the concentration of carbon-based compounds in wastewater, measured in terms of biochemical oxygen demand, COD, total organic carbon, or oil and grease.

²² These estimates relate to the total catchment. Figures for the upper catchment are not broken down but are probably of the same order.

from cultivated farmlands. In 2011, these primary nonpoint sources were the cause of 42% of organic (COD) inflows to the lake, 38% of TN, and 42% of TP.²³

In the upper catchment, household domestic wastes in rural areas have been identified as the biggest source of organic (COD) pollution and TP. Centralized collection and treatment facilities do not exist in rural areas, and public sanitation conditions are poor. As much as 62% of all rural household wastewater drains directly into ditches. Box 1 outlines a technology for dealing with waste in rural areas that deserves consideration.

Basinwide, agricultural intensification and rapid development of livestock production (particularly poultry farming) are the pollution flashpoint, and fertilizer application on farmlands is the biggest single nonpoint source of TN.²⁴ Other studies have identified emissions from livestock enterprises as the most significant source; but all are based on assumptions since there are very few reliable empirical data.

The secondary nonpoint sources of pollution, though less significant and generally intermittent, include (i) periodically resuspended sediments and stream or river bank erosion in lake tributaries, (ii) inflows of polluted groundwater, and (iii) releases of pollutants from lake sediments. There are areas around Chao Lake with naturally high phosphorus levels, and sediment from these areas increases the concentration of TP in the lake. Phosphorus is the key limiting factor of blue-green algae blooms in the lake.²⁵ Widespread blooms occurred in 2004, 2006, and 2007; but smaller blooms are an annual occurrence. The Anhui Environmental Protection Department estimates that bottom sediments contribute 4% of the total COD loading in the lake. In 2011, the lake sediment released 1,705.6 tons of TN and 220.4 tons of TP, which contributed 15% of TP and 9% of TN loading in the lake. The contribution of intermittent inflows of resuspended sediments in tributaries is yet to be determined.

Waste discharges from livestock production. The catchment's animal population is very highly concentrated in Feidong and Feixi counties within Hefei City, which account for 71% of all animal units in the up-slucice catchment of the lake. Thus, the greatest pollution loads attributable to animal production are (i) in the northwestern corner of the lake, which is also under the greatest pressure from industrial and municipal emissions from Hefei City; and (ii) in the corner of the lake that has the lowest assimilative capacity due to the poor circulation and shallowness of the lake there.

Figure 8 illustrates the trends in livestock numbers during 2001–2012. The population is expressed in animal units and indexed to the animal unit population in 2001. The rate of growth stabilized around 2005, and then the total equivalent population declined by about 4% due to a 13% reduction in the equivalent pig population, a 54% reduction in the equivalent sheep and goat population, and a 3% reduction in the equivalent poultry population.

²³ Estimates are from People's Government of Anhui Province, Environmental Protection Department. 2011. *Chao Lake Water Pollution Prevention Plan (2011–2015)*. Hefei. The estimates are assumptive and the results vary depending on the methods and assumptions used.

²⁴ L. Jin. Unpublished. *Agricultural Non-Point Source Pollution Control Policies for the Chao Lake Basin: A Review*. Draft report prepared for ADB. 53 pp.

²⁵ Algal blooms have adverse effects on freshwater systems used for recreation and drinking water supply due to their ability to produce cyano-toxins, which harm the liver and promote tumors.

Box 1: Small-Diameter Gravity Sewer Systems in Australia

The small-diameter gravity sewer (SDGS) system concept was developed during the 1960s in Australia, where much of the terrain is extremely flat and many rural towns and communities are small.

In an SDGS system, which is also referred to as a variable grade sewer system or Septic Tank Effluent Gravity (STEG) system, grease and solid materials in the wastewater are separated at each household connection in a small interceptor tank. The overflow from the tank, which is free of floatables and very low in suspended solids, flows (or is pumped, if necessary) into the sewer main via a small-diameter pipe—typically only 50 millimeters (mm) in diameter. Because settleable solids in the effluent are so low, the system requires lower hydraulic gradients and velocity to transport the wastewater through the lines than is necessary with conventional sewers. The size of the mains is calculated on the estimated peak hydraulic flow rates and the velocities required to transport the wastewater through the entire system but, typically, diameters range from 50 mm to 200 mm (the minimum diameter of a conventional sewer main is about 200 mm). The system requires no manhole access for cleanout, pumping requirements are lower, and the mains can be laid at shallower depths, all of which reduce installation costs.

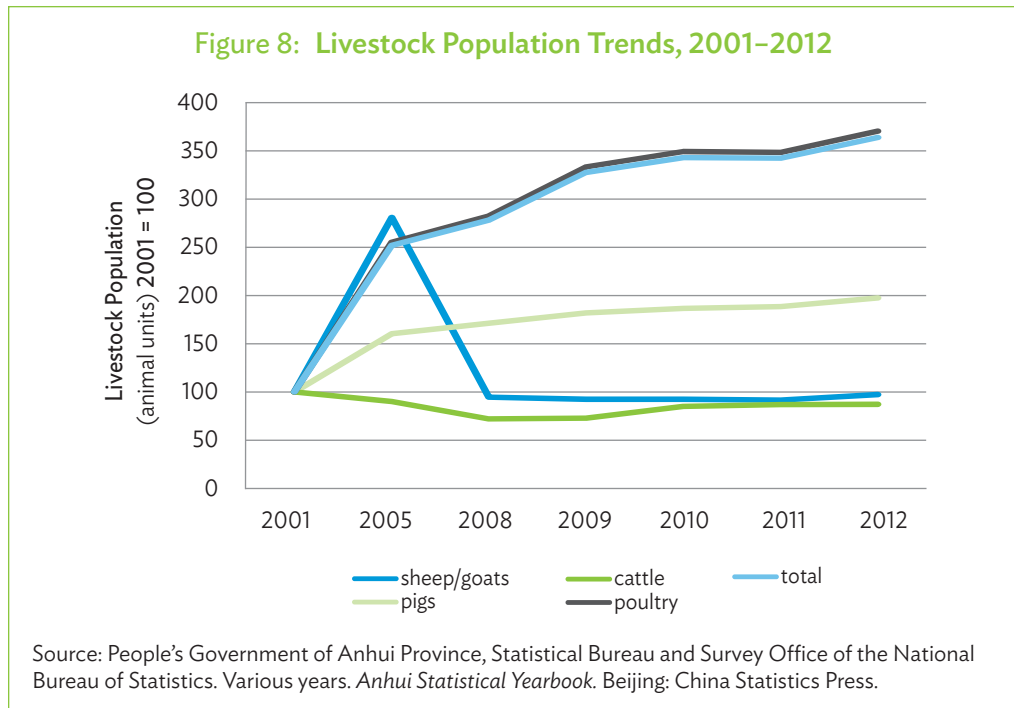
SDGS pipes are similar to pressure sewer lines and are made of polyvinyl chloride (PVC) or high-density polyethylene (HDPE) rather than concrete. The joints are solvent welded or rubber gasketed and, in combination with the lack of manholes, leakage tends to be very low.

SDGS lines are laid at a relatively constant, shallow depth, following the natural contour of the land. So in communities with hills, the wastewater will flow downhill in some areas and uphill in others (hence the term variable grade sewers). These up and down flow patterns are possible as long as the beginning of the SDGS system is higher overall than its final destination—the outlet to the local treatment facility which, ideally, should be located low enough to receive flows from most of the service connections by gravity.

Provided geographical conditions are right, the main attractions of SDGS systems are (i) lower excavation and installation costs due to the shallow depth of cover required, the use of PVC or HDPE pipes, and the less-rigorous vertical and horizontal alignment requirements; and (ii) reduced final wastewater treatment costs because solids and greases are separated and treated in the household septic tanks, screening and grit removal at the wastewater treatment plant is not required, and sludge disposal costs are virtually eliminated. These savings are offset by the need to provide a septic tank cleanout service; but, for most households, this would rarely be required more than once every 4 or 5 years.

Sources: C. Falvey. 2001. Small-Diameter Gravity Sewers Can Mean Big Savings for Communities. *Small Flows Quarterly*, 1 (2). pp. 24–27; R. Otis. 1986. *Small-Diameter Gravity Sewers: An Alternative for Unsewered Communities*. Cincinnati: United States Environmental Protection Agency, Water Engineering Research Laboratory.

Runoff from cultivated lands. Runoff from cultivated lands accounts for 46% of TN emissions, but only 4% of TP emissions. Government statistics indicate that the overall fertilizer application rate within the greater Chao Lake Basin is about 8% higher than the national average and 6% higher than the Anhui provincial average. There are huge variations in estimated application rates within the catchment, however. The most notable



deviation from the catchment average is in Hefei City and its associated districts, where the fertilizer consumption rate is 200% higher than the basin average. Agricultural yields, on average, have not been increasing proportionally. Fertilizer use efficiency is only about 30%–40%, and the surplus is subject to loss through soil erosion in slope cultivation of rainfed crops and leaching and runoff in irrigated areas due to intensive applications of irrigation water.

The reason for the excessive rate of application in Hefei City is not known for certain, but two possible factors are as follows.

- (i) Farmers in the areas adjacent to the urban development zones, particularly in Hefei City, may be concentrating on the production of very high-value and perishable crops, such as vegetables, which are also often associated with excessive fertilizer application.²⁶
- (ii) Significant amounts of fertilizer may be applied to the extensive landscaped public areas in the new city development areas. These landscaped areas, however, would not appear in statistics on cultivated lands, but their fertilizer demand is likely to be included in the fertilizer consumption statistics, thereby raising the apparent application rate.²⁷

²⁶ Field surveys done in preparation for the assessment report by Ji and Sun (footnote 16) suggested that some local vegetable farmers are using as much as 900 kilograms of fertilizer per hectare.

²⁷ The statistical bureau calculates the application rate by dividing the statistic for the total quantity of fertilizer sold in the area by the total area of cultivated land.



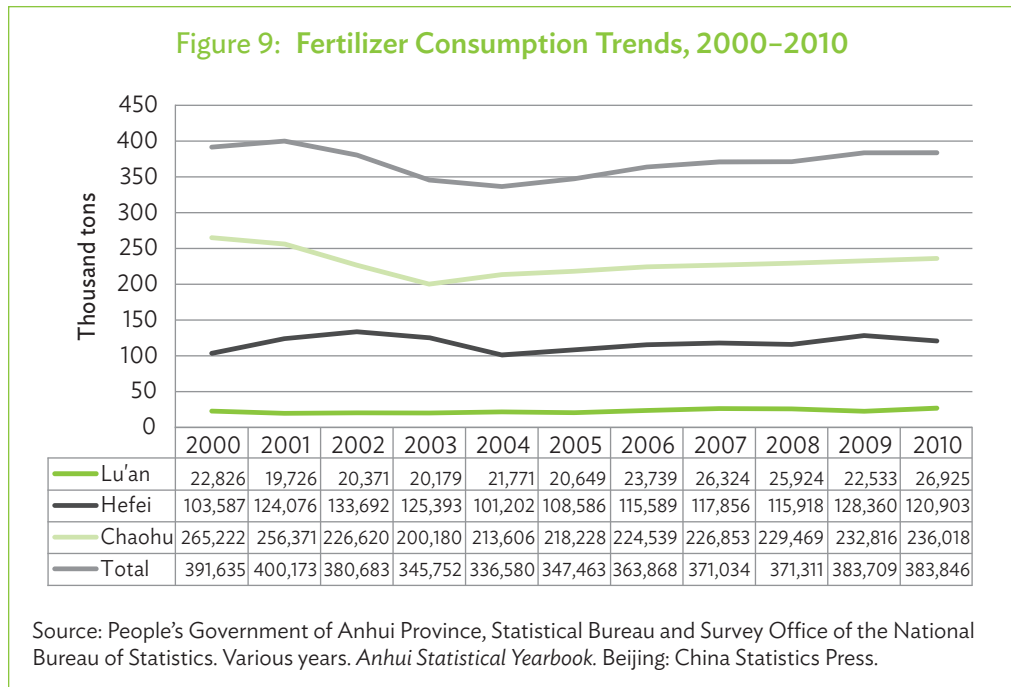
Farmer applying chemical fertilizer on his crops along the bank of Chao Lake
(Anhui Chao Lake Environmental Rehabilitation Project Management Office)

High application levels are also occurring in Feidong and Feixi counties, adjacent to Hefei City. Some of this may be due to extensive nursery plantations in these counties. For example, about 10,000 hectares of land in Feixi County is used for the production of landscaping plants (Footnote 16). The fertilizer application rates in nursery production are believed to be the second-highest after vegetable production. Other areas with high fertilizer use are Hanshan County (137% of the basin average) and He County (130% of the basin average), neither of which drains directly into the lake.

Aside from the intrabasin variations, the trends in overall fertilizer consumption within the up-sluice catchment during 2000–2010 were encouraging from an environmental viewpoint. As shown in Figure 9, fertilizer consumption in the up-sluice catchment was 2% less in 2010 than in 2000. Once again, however, there were significant variations at the municipal level, with consumption increasing in Hefei by 16.7% and in Lu'an by 1.7%, while consumption in the areas formerly known as Chaohu City decreased by 11%.

While there is a general need throughout the catchment to take steps to reduce the effects of high fertilizer use on water quality, there might be an opportunity to leverage benefits by concentrating on Hefei City. If the statistical data are correct, Hefei City is the biggest consumer in the up-sluice catchment (accounting for 60% of total consumption in 2009), and the only municipality where aggregate consumption increased during 2000–2009. Its application rates also appear to be significantly out of line with those elsewhere in the catchment.

The Anhui Department of Agriculture is well aware of the fertilizer runoff problem and has, thus, been educating farmers and testing soils to encourage greater use of compound



fertilizers and lower application rates. Farmers, however, tend to be very conservative and resist the messages from the Department of Agriculture on the adoption of new practices. Their reluctance to change is partly reinforced by the fact that they have supplementary sources of income from children who may have migrated to the city and have steady employment. These farmers may be referred to as cost minimizers rather than profit maximizers, and, hence, they are hesitant to adopt any practice that increases costs in terms of money and/or time regardless of how much more profit might accrue in the longer term.

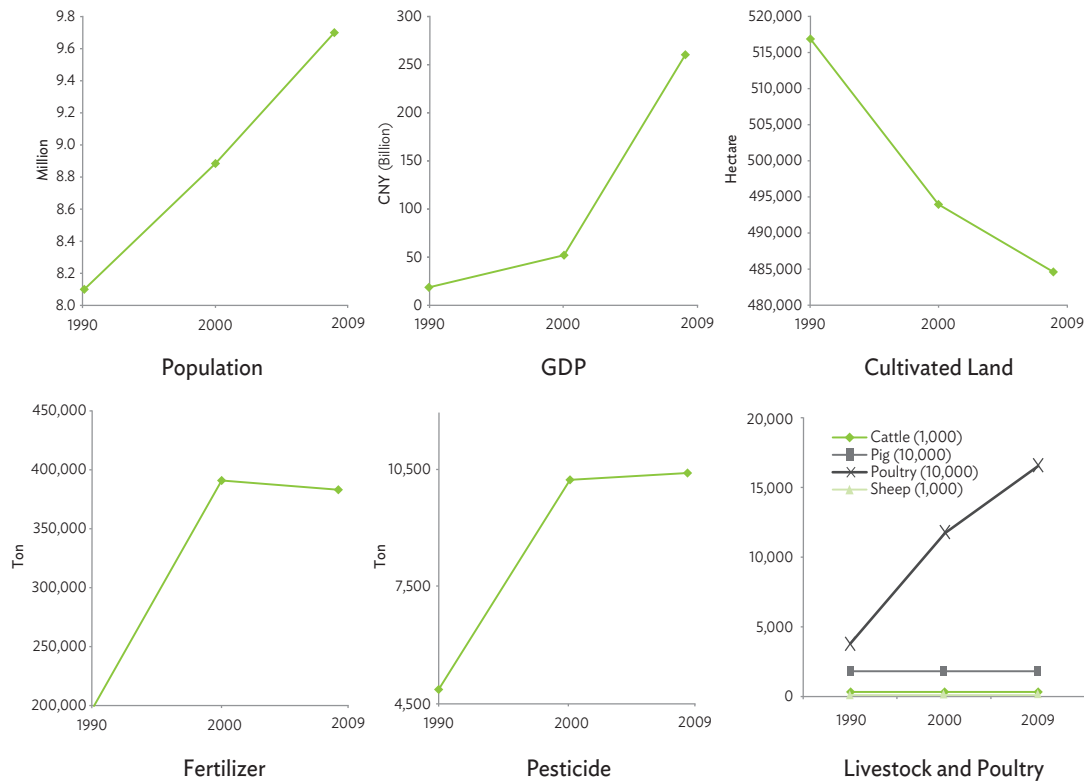
D. The Macro View: Bringing Factors Together

There is still much to be understood about the complex relationships between socioeconomic trends and the physical environment of lakes and wetlands.

Figure 10 illustrates some interesting correlations that have happened in the ecological environment of the Chao Lake Basin during 1990–2009. As population and GDP spiked, the availability of cultivated land declined sharply, an indication of land conversion that only naturally would be followed by the sharp increases in fertilizers and pesticides applications. The increase in livestock and poultry farming is also an indication of increased socioeconomic capacity of the population.

These socioeconomic changes and their impacts on land, agriculture, and consumption in the Chao Lake Basin reflect similar trends across central and eastern PRC. Steady population growth and urbanization have consumed precious farmland, which has

Figure 10: Basinwide Statistics that Correlate Socioeconomic Changes, Land Use Changes, and Agricultural Intensification, 1990–2009



GDP = gross domestic product.

Source: People's Government of Anhui Province, Statistical Bureau and Survey Office of the National Bureau of Statistics. Various years. *Anhui Statistical Yearbook*. Beijing: China Statistics Press.

put pressure on farmers to produce more from less land. Studies of other freshwater environments around the country have demonstrated that agricultural production is becoming increasingly detrimental to the aquatic environment. These trends require strong policy responses from government to manage the effects of these changes.

E. New Strategies for Cleaning Up Chao Lake

Better informed of the pollution situation in Chao Lake, the APG began to set a course in 2008 for reforming the management of Chao Lake. It recognized the need for a single authoritative body to govern all matters of lake management and a long-term road map to follow as it navigated the financial, technical, and political steps needed for restoring the lake.

The APG has taken three key steps. It has (i) developed a coherent and comprehensive master plan, (ii) created an administrative structure that places most of the upper catchment within the jurisdiction of a single administrative body (Hefei City), and (iii) established the Chao Lake Management Authority (CLMA) as the institution with prime responsibility for managing the lake.

This section examines these reforms according to the four success factors ADB identified in 2008 in the *Reviving Lakes and Wetlands* publication (footnote 11).

1. Strong and Consistent Political Leadership

Successful ecological rehabilitation projects take time and resources, but they also usually require coordination across sectors and jurisdictions. This is only possible if political leaders are engaged and can encourage—and, when necessary, require—cooperation. Leadership is particularly important for cooperation between sectors, and between different divisions of government, in establishing management structures and, if required, new laws and regulations. This process alone, especially during the early stages, can be cumbersome and time-consuming. Water conflicts must be resolved and ownership built for reforms.

The Government of the PRC demonstrated commitment to solving the pollution problem in Chao Lake by including it in the Three Rivers and Three Lakes rehabilitation program during the 9th Five-Year Plan and continuing to include it in the 10th and 11th five-year plans. Several billion yuan have been invested in Chao Lake's eutrophication control efforts. Although there is no compelling evidence to suggest there has been any significant improvement in the lake's water quality, the question is of technical capacity, not commitment. Improved information systems and data sharing would add considerable effectiveness to the government's commitment and investment levels.

At the subnational level, no provincial government in the PRC has taken steps as drastic as the APG has to restore the water quality of its major water resource. These steps are what make Chao Lake such a promising case. Leaders of the APG have taken on political challenges to draw new administrative boundaries that would better serve the interests of protecting and managing Chao Lake. The government also surpassed status quo planning modes when it drafted a long-term master plan for renewing the Chao Lake Basin. A new, comprehensive authority, made up of consolidated bureaus and agencies, will manage the master plan.

2. Integrated Analysis and Planning

The Anhui Development and Reform Commission has prepared a comprehensive master plan for reducing water pollution that not only covers conventional environmental engineering strategies, but seeks also to influence regional development strategies, industrial restructuring, urban development planning, integration of urban and rural areas, and other macro-level planning activities. In this sense, it differs significantly from most plans developed elsewhere in the PRC, and is the most comprehensive and ambitious environmental plan yet seen. What remains to be seen is whether the plans will attract financing and whether the newly established CLMA will be able to fully exercise its mandate.

The implementation period for the plan extends through to 2020. A total of 329 investment projects were identified—with an equivalent investment value of CNY46.1 billion (\$7.3 billion). Individual investment proposals to implement the plan would be selected for inclusion in the successive five-year plans.

Recognizing the natural and man-made sensitivities of the lake, the plan includes a schedule of progressively ambitious goals (Appendix 2). The ultimate objectives are to achieve complete coordination between economic and environmental goals, substantially improve water quality in the lake and surrounding rivers, and reestablish the lake's natural landscape and a good ecological environment. The master plan set time-based targets for 2010 (end of the 11th Five-Year Plan), 2012 (near term), and 2020 (long term).²⁸

3. Effective Management Structures

After the master plan was developed, and acting on instructions from the State Council, the APG took significant steps to strengthen institutional arrangements for managing the lake environment. The steps involved major administrative consolidations to create a “one-lake, one-rule” system.

Until 2012, Chao Lake was largely managed by two cities—Hefei City on the east half of the lake and Chaohu City on the west half, creating a “one-lake, two-rule” system. Chao Lake was not just divided between the two cities, but also between the Yangtze River Basin Management Commission (under the Ministry of Water Resources) and the East China Environmental Protection Supervisory Center (under MEP), as well as multiple agencies, including environmental protection, water resources, construction, agriculture, navigation, and tourism. Each of these authorities was also further divided into provincial, municipal, and county-level governments.

The APG consolidated government and redrew subprovincial boundaries within the catchment. Chaohu City was dissolved and absorbed by the surrounding areas, and Hefei City was given authority for the entire surface area of the lake, all of the lake foreshore, and a substantial proportion of the up-sluice catchment area. This was pragmatic given that the most polluted and sensitive area of the lake is nearest to Hefei City.

In August 2011, during the administrative consolidation, the State Council ordered the APG to create a provincial-level agency to unify management of all general affairs relating to Chao Lake. The new CLMA functions at the deputy departmental level, although it is physically located within Hefei City. Its oversight includes water quality and quantity issues, fisheries, navigation, and tourism.

While still at an early stage of institutional development, the creation of the CLMA is significant because (i) it may be the first lake or river management agency in the PRC with a sufficiently comprehensive management purview to be able to deal with all relevant aspects of the water cycle, and (ii) it may be the first institution in the PRC that is positioned at a

²⁸ The results of the 2010 interim targets are mixed. See Appendix 3. Most worrisome is that the quality of the major river Hangbu and the rivers flowing into the lake from the vicinity of Hefei City in the northwest is getting worse. Clearly, much more work will be required to turn the situation around, with particular emphasis on nonpoint source pollution.

sufficiently high level in the bureaucratic system to allow it to effectively coordinate and enforce water-related activities and regulations in the catchment.²⁹

The CLMA's main functional responsibilities cover planning, project implementation, and comprehensive management. Plans for environmental improvement, protection, and management of the lake come from the CLMA. The plans are likely to take a phased approach and cover comprehensive lake improvement and protection (flood control, water resource protection, water pollution control, ecological rehabilitation, and the development of shipping, fisheries, tourism, and coastline management).

At the project level, the CLMA is also responsible for developing construction plans related to environmental improvement and protection projects; coordinating implementation across departments, counties, and cities; and supervising construction.

The CLMA's day-to-day management of the lake includes managing river connection and lake control facilities (including the five control gates), and allocating resources for flood control, drought prevention, and pollutant discharge. It manages procedures for the supervision, law enforcement, and punishment of river, lake, and water affairs.

The CLMA is staffed by transferees from bureaus within the Hefei and former Chaohu city governments. At its creation, it had 70 (approved) staff positions in 10 divisions. Associated with the CLMA are 17 more affiliated institutes and organizations, with total staff of 480, divided into the following main units: planning and development, water conservancy, environment, transport, agriculture, forestry, fisheries, and tourism.

4. Effective Financial Engineering

While the APG once focused on revenue generation to the detriment of environmental sustainability, it is now trying to pursue a more balanced approach to development and securing innovatively packaged and financed projects to address its most difficult environmental challenges.

The APG has formulated the Anhui Chao Lake Environmental Rehabilitation Project, which represents a monumental opportunity to begin addressing NPS pollution control at the required scale. To be implemented in three phases, the first phase will cost \$432 million, with a \$250 million loan already secured from ADB. The second phase, estimated to cost \$300 million, will focus even more sharply on NPS pollution. The third phase, estimated at another \$250 million, would restore important in-lake wetlands.

The \$250 million ADB loan for the first phase is the largest loan to the environment sector that ADB has ever approved. Its design exhibits remarkable features. The project will continue necessary investments in municipal point source pollution control, but the APG accepts that wastewater treatment will not significantly improve the overall water quality of the lake. The lake is in a dismal state because of NPS pollution, and the APG has

²⁹ Many of the earlier-established river basin or lake authorities are only at the same administrative level as other sector agencies. One example is the Dianchi Lake Management Bureau, which was created at the same administrative level as the other line agencies and, as a result, has apparently not been very effective.

shown its willingness to address the issue by borrowing to finance needed nonstructural measures. The project includes investments in traditional environmental infrastructure, such as sewerage networks, WWTPs, and solid waste management; but also nonstructural innovations, such as pilots to test on-farm technologies, nutrient-trading eco-compensation schemes, more relevant and effective agricultural extension, and information management (Box 2). These areas are typically financed by grants and at smaller scales. The APG's willingness to borrow—and significantly—is a strong indication of Chao Lake's political, social, environmental, and economic value to the PRC.

Box 2: Pilot Project for Controlling Nonpoint Source Pollution in Chao Lake

As part of the Asian Development Bank (ADB)-supported Anhui Chao Lake Environmental Rehabilitation Project, a pilot project is being implemented to test, refine, and demonstrate technologies and institutional innovations for controlling nonpoint source (NPS) pollution. The pilot will be implemented on the southern side of Chao Lake, in three lakeside townships that have intensive agricultural farmlands and many medium- to large-sized animal farms. Their NPS pollution has direct and significant impacts on the water quality of Chao Lake.

Technologies to reduce animal, crop, and domestic pollution. The pilot will introduce 10 technologies for controlling NPS pollution from animal, crop, and rural domestic sources. Technologies include biogas systems, organic fertilizer, solid waste collection, and fermentation beds.

Eco-compensation. An eco-compensation mechanism will be designed to create incentives for shifting to organic fertilizer. The scheme will be developed through focus group discussions with farmers and service providers. The general scheme, which is based on a service provider (contracted through competitive bidding), will collect manure from animal farms, store the manure properly, and apply it on farmland per the farmer's request. The service provider may also procure commercial organic fertilizers, transport them, and apply them on the farmland as per the farmer's request. The eco-compensation fund will be used to subsidize the service providers and/or the farmers involved, and the optimal subsidy rate will be tested. To inform the design of a program, a survey will collect information on (i) farmers' practices, (ii) the impacts of various factors (e.g., farm scale, aging, and cropping system) on farmers' adoption of environmentally friendly agricultural practices, and the (iii) impacts of various policies (e.g., agricultural, environmental, urbanization, and land tenure policies) on farmers' adoption of environmentally friendly agricultural practices.

Improved extension services. Extension workers and farmers will be trained to identify environmentally friendly agricultural practices within the Chao Lake Basin and demonstrate their environmental benefits and implications for agricultural production. To ensure that organic farming is promoted beyond the project duration, this output will assess incentives for extension workers and develop an extension performance evaluation system. The effectiveness of the training program will be evaluated.

Management information system. A geographic information system for NPS pollution control in the Chao Lake Basin will be developed with information on land use and land-use change, animal farms, villages and their population, pollution outlets, monitoring points, water quality, NPS pollution control intervention location and its progress, etc.

Technical solutions and institutional innovations resulting from this demonstration component will constitute important options for replication and scaling up in the whole Chao Lake Basin in the next phase of the project.

Source: ADB. 2012. *Report and Recommendation of the President to the Board of Directors: Proposed Loan to the People's Republic of China for the Anhui Chao Lake Environmental Rehabilitation Project*. Manila.

IV. International Experiences

ADB's analysis of success factors in the PRC and the significant scope of initial reforms of the Anhui Provincial Government (APG) have been further backed up by an international study of 28 lakes across the world.³⁰ The study, financed by the Global Environmental Facility, identified measures that would lead to effective lake basin management. As shown in Table 4, the factors identified in the study are either already in place for Chao Lake or at least some progress has been made toward putting them in place.

The study found that none of the 28 case studies had a single institution with authority over all aspects of lake basin management. The report suggested that due to the integrative nature of lake basin management, the best approach was to create a coordinating

Table 4: Status of International Key Indicators for Sustainable Lake Basin Management in the Chao Lake Basin

Success Factor	Status in Chao Lake
Adequate institutions for implementing change	Major step toward achieving this goal has been taken by the restructuring of local government within the up-sluice lake catchment and the creation of the Chao Lake Management Authority.
Efficient, effective, and equitable policies	The policy framework on point source pollution control is already in place. The policy framework for nonpoint source pollution control is less well developed.
Meaningful participation of all stakeholders involved	There has been considerable participation of government stakeholders, but more work needs to be done to improve participation by the private sector, local communities, and farmers.
Application of relevant technical measures to ameliorate specific problems	Relevant technical measures for point source pollution control and some aspects of nonpoint source control (e.g., sediment dredging) have been identified, but considerably more work needs to be done to pilot control strategies for nonpoint source pollution control.
Appropriate information about current and future environmental conditions	An environmental monitoring system is in place, but it needs to be significantly strengthened in terms of the density of sampling points, frequency of sampling, and range of parameters analyzed. Data from national and provincial or local monitoring points should be openly shared at regular intervals.

Source: International Lake Environment Committee Foundation. 2005. *Managing Lakes and their Basins for Sustainable Use: A Report for Lake Basin Managers and Stakeholders*. Kusatsu, Japan.

³⁰ International Lake Environment Committee Foundation. 2005. *Managing Lakes and their Basins for Sustainable Use: A Report for Lake Basin Managers and Stakeholders*. Kusatsu, Japan.

mechanism that brings together the relevant sectors and administrative units on issues related to lake management, although there would still be a need for a single lake basin management institution to implement and/or supervise measures. In the case of Chao Lake, the Chao Lake Management Authority (CLMA) is authorized with this comprehensive role, which was lacking in all the case studies, indicating that this step may be progressive on an international scale, although challenges remain.

To further explore lessons in lake basin management, this chapter examines four international case studies that relate to Chao Lake's history and indicate potential approaches that the APG could emulate. The case studies also highlight potential areas for policy development at the central planning level in the PRC.

A. Lake Biwa, Japan: Standard Bearer in Industrial Pollution Control

Chao Lake's history and current water quality challenges are reminiscent of what Shiga Prefecture began to experience decades ago with the deterioration of Lake Biwa, Japan's largest freshwater lake. Successful integrated basin management has saved the lake from eutrophication, although challenges remain with controlling agricultural water pollution.

Lake Biwa is located in the Yodo River Basin, in Shiga Prefecture. The lake is semitropical and consists of a small, shallow southern basin and a larger deep northern basin (Map 2). It is a critical water supply source for Shiga Prefecture and the cities of Kyoto and Osaka in the downstream sections of the Yodo River. It is also a highly valued fishery and tourist destination.

During the 1960s and 1970s, rapid socioeconomic growth in the region saw widespread urban and industrial expansion, deforestation of the watershed, and disturbance of littoral zones. The progressive need for further water resource development was met by infrastructure works, including the construction of a canal linking the lake to Kyoto City, a weir on the Seta River to control the outlet of the lake, and levees around the lake. The Seta River weir had the dual purpose of flood control and water supply control.

By 1969, the lake was experiencing red tides and severe eutrophication. The increased water extraction and wastewater discharge had put pressure on the available water supply and resulted in significant deterioration of water quality in the lake. Although the prefecture government introduced a new Eutrophication Control Ordinance in 1979, with stricter effluent standards, the lake had deteriorated further by the 1980s. Ultimately, Lake Biwa was suffering from conflicting government objectives over whether to manage the lake for flood control, conservation, or water resource development—all of which may be necessary but require integrated management.

Heading the restoration effort, the prefecture government demonstrated strong political commitment in the face of an active citizens' movement to clean up the lake. The prefecture government implemented legal and institutional reforms to improve the integrated management of the lake and its basin. A comprehensive and historical legal framework governs how the lake is managed. Legal reforms have influenced national laws,

Map 2: Lake Biwa and Yodo River Basin



such as the Eutrophication Control Ordinance, which set the first nitrogen and phosphorus standards for industrial effluent in the world, resulting in revision of the national Pollution Control Ordinance and the creation of the Special Law for Lake Water Quality Conservation. The prefecture government maintains the strictest industrial wastewater effluent standards in Japan. All municipal treatment plants are capable of removing nitrogen and phosphorus—two nutrients responsible for eutrophication. Yet, agricultural pollution still challenges the prefecture today.

The prefecture government has practiced adaptive management over the years, continuously evolving its administration system to respond to changing conditions. For example, since 1996, a prefecture-level Department of Lake Biwa and the Environment and nine key divisions were established to promote integrated watershed management. Despite continual institutional evolution, degrees of sectionalism among the ministries and divisions continue.

B. Murray–Darling Basin Authority, Australia: A National Authority Relies on Local Implementation

Australia's Murray–Darling Basin Authority (MDBA) spans four states, making it much larger than the CLMA, which is contained in a single PRC province—Anhui. Yet the MDBA's structure and approach to basin planning and implementation provide an interesting framework for the APG to evaluate its own master plan and, in particular, the highly engaged role local governments are expected to play.

As a national regulatory authority overseeing water resources in the Murray–Darling Basin, the MDBA is responsible for preparing a comprehensive but high-level basin plan that controls the actions of the state governments within the basin. Map 3 shows the states and the vast network of rivers comprising the catchments of the Darling, Murray, and Murrumbidgee rivers within the basin.

In the 1970s, the government recognized that the environmental health of the basin was deteriorating, mainly because of overallocation of water and salinization in the basin. In 1987, an integrated basin-wide management began with the establishment of the Murray–Darling Basin Commission, an interstate coordination group. The commission initiated a series of reforms to balance the needs of communities, industries, and the environment, such as caps on surface water use across the basin. In 2004, several initiatives focused on improving water efficiency, reforming the water entitlements system, and establishing a water market.

Despite these efforts, the basin was still under significant stress from the combined impacts of overallocation of water, severe drought, and climate change. The commission was also unable to deal with the conflicts between upstream and downstream states or address cross-border problems. So, in 2008, the MDBA replaced the commission as a single national body responsible for overseeing water resource planning in the Murray–Darling Basin. The MDBA is responsible for preparing a high-level but comprehensive basin-wide plan, which is a regulatory instrument under Commonwealth Law.

Map 3: Rivers within the Murray–Darling Basin



Source: ADB.

The plan has five key elements: (i) environmental water requirements, (ii) long-term average sustainable diversion limits, (iii) water trading rules, (iv) a water resources plan, and (v) a water quality and salinity management plan. The plan specifies the actions required of state governments. State water authorities are generally responsible for managing their state's water sources in a sustainable and integrated manner, and in ways that correspond to the catchment- and basin-scale plans. Many of the state water responsibilities are similar to those of the CLMA. They include preparing water-sharing plans; managing water allocations; undertaking monitoring and evaluation; coordinating licensing (including fees and charges); conducting modeling (to understand river and groundwater systems behavior, predict various scenarios, inform water-sharing plans, and audit compliance with current extraction limits); overseeing water quality management; supporting water efficiency projects; and providing technical assistance to local water utilities.

Localism is an important principle of the basin-wide plan. Key to the success of the plan and associated water reforms is local involvement. Mechanisms for sustainable water resource management at the local level include integrated water cycle management plans, drought management plans, regulation and pricing of water supply and sewerage services, water conservation plans, and water-sensitive urban design.

Governments partner with local and regional communities to involve them in the development and planning so they own decisions and the actions they will be implementing. This also is a strategy for accessing local knowledge to develop solutions to meet local needs.

The basin-wide plan is reviewed every 5–10 years and supported by a cycle of ongoing research, monitoring, and feedback to ensure the plan remains flexible and relevant to current water situations.

C. United States Environmental Protection Agency and the Maximum Daily Load System

An urgent need in the Chao Lake Basin is an intelligent dynamic system for monitoring and managing information on pollution sources and water quality. Industries and wastewater treatment plants in the basin are expected to meet the national integrated wastewater discharge standards. The revised draft of the Chao Lake Watershed Water Pollution Control Regulations also requires all counties and regions to meet total load limits, yet no standards have been established for allocating them.

In the United States, the nationally implemented total maximum daily load (TMDL) process and the National Pollutant Discharge Elimination System (NPDES) Program are the fundamental management mechanisms for maintaining water quality standards in water bodies.

The total maximum daily load process. The TMDL process involves the following four steps.

Step 1—Identification of impaired or threatened waters. States undertake water body survey or monitoring and assessments to investigate a number of physical, chemical, and biological factors that can be used to determine whether aquatic life protection is attainable for a given water body. Water bodies that meet the criteria for categorization as impaired or threatened are identified for the next step in the process.

Step 2—Priority ranking and targeting. Within 2 years of step 1 (identifying impaired or threatened waters), states prioritize their lists by considering the severity of pollution and the uses to be made of the water. Targeting high-priority water bodies for TMDL development involves an evaluation of their relative value and benefits within the state.

Step 3—Total maximum daily load development. The approach typically involves the following tasks:

- (i) Selection of pollutant(s) causing the impairment,
- (ii) Estimation of water body assimilative capacity,
- (iii) Estimation of the pollutant from all sources to the water body (existing and future),
- (iv) Predictive analysis of pollution in the water body and determination of total allowable pollution load, and
- (v) Allocation (with a margin of safety) of the allowable pollution among the different pollution sources in a manner that water quality standards are achieved.

For the development of TMDLs, design conditions need to be identified that represent critical conditions for the attainment of water quality standards. Simple analytical approaches are usually adequate for pollutant assessment and implementation planning.

For lake nutrient TMDLs, all sources contributing significantly to the overall loading need to be considered. This may include subwatershed loads, atmospheric deposition, internal recycling from lake sediments, and avian sources. For many lakes, a nutrient TMDL is more appropriately expressed as allowable annual, seasonal, or monthly loading because long-term average pollutant loadings are typically more critical to overall water quality. Hydraulic residence time is an important consideration in the assessment of TMDLs for lakes, as it can affect mixing, flushing, and pollutant processing. It may be appropriate to set more than one TMDL to address seasonal variability. In addition, most empirical lake models use annual loads rather than daily loads to estimate in-lake concentrations.

Step 4—Implementation of water quality-based control actions. Once a TMDL or phased TMDL is established for a water body and approved by the Environmental Protection Agency, control actions should be implemented to apply allowable load limits.

The National Pollutant Discharge Elimination System Program. The TMDL process links the water quality standards to the NPDES permits and other water quality control actions. Under the NPDES, all facilities that discharge pollutants from any point source into United States waters are required to obtain an NPDES permit. However, generally, agricultural discharges are considered to be nonpoint sources and exempt from NPDES regulation.

Status of implementing two programs in the United States. By 2009, more than 40,000 TMDLs had been completed across the United States. TMDLs developed for nonpoint sources far outnumber those completed for point sources, accounting for 51% compared to just 5% for point sources. The remaining 44% of TMDLs were a combination of point and nonpoint sources. This reflects the large number of listings of impaired waters caused primarily by nonpoint source pollution—a reality that is very close to the PRC and Chao Lake Basin situation. Pathogens were the most common cause of water body impairment, followed by mercury, other metals, and nutrients.

There have been limited efforts to assess the extent of implementation progress and related environmental improvements. Recovery of impaired waters often takes several years, and monitoring can be complex and costly; thus, many results may not have occurred yet, or have not yet been documented. Further, implementing a TMDL often involves numerous pollution control practices subsequent to completing the TMDL, and it can be difficult to pinpoint if the causes of success or failure are TMDL-related. A TMDL is a technical plan, one stage in a sequence by which other programs such as the NPDES implement that plan.

D. Wales, United Kingdom: Integration of River Basin Management and Spatial Planning

As the APG is learning with Chao Lake, development can adversely impact the water environment through physical modification of water bodies and increased pollutant generation. However, development can also provide a stimulus for investment in improving the water environment and urban regeneration. The integration of river basin management with planning policy is a crucial link to avoid inappropriate development in areas already under pressure (including floodplains) and development that adversely affects water quality. Yet linking the two can be a complicated coordination and political endeavor.

In Wales, the Environment Agency has overall responsibility for developing river basin management plans (RBMPs); yet, river basin planning involves integration across four different scales of planning, as well as numerous sectors:

- (i) **National.** National stakeholders provide input to policies and procedures.
- (ii) **River basin district.** This is the primary level of analysis and decision making. River basins are the most appropriate scale for strategic planning purposes. A river basin district (RBD) liaison panel is established with representatives from all tiers of government, planning authorities, business, industry, environmental organizations, navigational and fishing organizations, and water consumers, including water companies. This panel facilitates the stakeholder involvement that is an essential part of river basin planning.
- (iii) **Catchment.** The RBDs are subdivided into catchments for more detailed water planning purposes. In England and Wales, there are 100 catchments. Many of the problems facing water environments, such as water abstraction and flood risk management, are best understood and tackled at a catchment level.

- (iv) **Local.** Local authorities play a central role. They provide information on local issues and focus attention on where risks are greatest. They incorporate the RBMP objectives and plans into local land use and environmental planning. They also help deliver measures to achieve the environmental objectives of the RBMPs.

RBMPs are strategic plans that provide stakeholders within an RBD a clear picture of the future for the protection and sustainable use of the water environment in that district. They include objectives for each water body and a summary of the Programme of Measures necessary to reach those objectives. The programmes of measures are selected to deliver the environmental improvements required to meet the objectives for the water bodies in the RBD. They can include a range of regulatory, financial, or voluntary measures.

Links to spatial planning. The Planning and Compulsory Purchase Act, 2004 was introduced in the United Kingdom to ensure greater emphasis on sustainable development and community involvement in spatial planning. The act recognizes that spatial planning must correspond with the European Union's Water Framework Directive (WFD) in England and Wales. The new rigorous environmental objectives of the WFD entail placing potential constraints on development for water bodies to achieve "good status;" thus, water and spatial planners have a common interest in improving the water environment.³¹ This will require an integrated approach to tackling existing pressures and to mitigating any impacts of future development.

In locations where there is a risk of water bodies failing to achieve good status, spatial planning policy can contribute to or support the measures that will need to be implemented to achieve the WFD objectives by

- (i) incorporating sustainable water management in development plan policies;
- (ii) reflecting the overarching sustainable water management requirements in regional spatial strategies; and
- (iii) including appropriate planning conditions and planning obligations for new infill and redevelopments in planning permissions (e.g., requirements for the implementation of sustainable drainage systems).

Changes in land use and new developments can affect the ecological and chemical quality and physical characteristics of water bodies through disturbance and increased discharge of sewage effluent. They can also put additional pressure on water resources, threatening the achievement of the WFD objectives.

Local and regional planning authorities need to cooperate in the delivery of the WFD objectives in the following ways:

- (i) Regional spatial strategies should include strategic policies of the WFD, and ensure their objectives are integrated.

³¹ These rigorous WFD objectives include "protecting all high status waters, preventing further deterioration of all waters, and restoring degraded surface and ground waters to good status by 2015." (<http://www.epa.ie/water/watmg/wfd/#.VWPP-o0w-00>)

- (ii) Local and regional planning authorities should participate in the development of RBMPs to ensure that their understanding of the pressures of, and opportunities for, development are reflected in the analysis underpinning the RBMPs.
- (iii) Spatial plans should influence the RBMPs. Emerging development plans are an important source of information on future pressures (and opportunities) that can help the Environment Agency refine its understanding of the current status of water bodies, and how this might change if no action was taken. This should be reflected in the analysis underpinning the RBMPs.
- (iv) RBMPs should influence spatial plans. The river basin planning process produces the type of strategic regional policy information necessary to feed into the spatial planning processes.
- (v) Core policies in local development frameworks and plans need to identify the relevant WFD water management issues from RBMPs to ensure that they contribute to, rather than compromise, the achievement of WFD objectives.
- (vi) Plan policies should influence the design and location of new development to ensure it does not create adverse pressures on the water environment.
- (vii) Where RBMPs have a direct effect on the use and development of land, they will be material considerations in the preparation of statutory development plans for the areas they cover.
- (viii) Planning authorities will also need to consider WFD objectives at the detailed development control stage.

E. Conclusion

These brief international case studies highlight lessons that are still being learned in countries that are more developed than the PRC, yet have experienced similar problems to those being identified in the Chao Lake Basin and elsewhere across the country. Issues in common with Chao Lake include unsustainable water extraction and wastewater discharges in Lake Biwa, Japan, before legal frameworks were strengthened to control industrial pollution, and the evolution of management institutions, as demonstrated by the Murray–Darling Basin Authority and its principle of localism. The United States is still in the early stages of implementing and evaluating the effects and impacts of its process with TMDL and NPDES as the primary means for maintaining water quality standards. Wales have widened the scope of integrated water resources management to include spatial planning and reinforce positive environmental outcomes.

V. Observations and Recommendations for Strengthening Chao Lake Strategy

Integrated water resources management (IWRM) is a long-term process that Anhui Province has only begun with Chao Lake. It often takes governments years to build up knowledge, practice, and experience in adopting various approaches to find what works before their IWRM-based reforms start to yield results and provide reassurance that rehabilitation is truly under way. Institutional strengthening and improved workflow processes can take just as much time. Anhui Province is at the beginning of this lengthy process, and although the government has adopted the success factors from the few examples available on successful lake rehabilitation in the PRC, their implementation and the effects of having incorporated them have not yet reached an adequate level or scale.

A. Strengthening the Master Plan

In any master plan, strategies for both point and nonpoint source (NPS) emissions should be well defined. As expected for Chao Lake, the master plan's strategies for reducing point source emissions amplify past actions, such as expanding municipal wastewater treatment and collection capacity, strengthening industrial point source pollution control, and establishing industrial parks with centralized wastewater collection and treatment. The program for controlling NPS pollution is less well defined, yet this is precisely where quantitative, scientific targets and dedicated resources should be prioritized.

The NPS control program is a mixture of both substantive and aspirational components, with considerable gaps. Substantive components include proposals to provide domestic wastewater collection and treatment, manage solid waste, and establish geographic restrictions for livestock and production enterprises. The challenge is how to implement some of these proposals effectively when, for example, regulating livestock production enterprises has proved difficult. Aspirational components include proposals to promote customized compound fertilizers, integrated pest management, and ecological farms—all without quantitative targets. How will success be measured or attributed? Quantitative, time-bound targets and more specific direction are needed to implement these ideas, especially given that many have already been attempted without much success. For example, the Anhui Department of Agriculture offers soil testing and educates farmers about the economic benefits of compound fertilizers, but these efforts have been unsuccessful. With resources secured for financing the master plan, the Chao Lake Management Authority (CLMA) should collaborate with the Anhui Department of Agriculture on testing innovative approaches that could have substantial demonstration and replication value.

Recommendations for strengthening the Chao Lake Master Plan are as follows.

- (i) Use economic instruments (e.g., nutrient trading, incentive payments to adopt alternative technologies) to change farmers' practices and work with the Anhui Department of Agriculture to strengthen its extension services that relate to NPS pollution control.
- (ii) Test innovative solutions for managing household waste in rural areas where it is not feasible to install conventional centralized wastewater collection and treatment facilities. Currently, the problem is not given any attention in the master plan.
- (iii) Conduct pilot programs to test and adopt innovative ideas before they are implemented on a large scale. The master plan intends to significantly strengthen and expand the surface water quality monitoring system. This will be an essential activity. However, factors, such as the range of parameters monitored, the sampling frequency, and flow monitoring procedures, should be reviewed and, if necessary, revised to ensure that all relevant elements are accounted for and that the density of data collected (geographically and temporally) is adequate for management and research purposes.
- (iv) Promote farm consolidation to create greater economies of scale in farm production, and perhaps create a more progressive community of farmers interested in profit maximization and the adoption of improved and more efficient farm technologies. The master plan mentions the idea of supporting consolidation of rural residential patterns to encourage the development of medium-sized towns, which would be of the scale necessary for economic wastewater and solid waste collection services, but there is no mention of farm consolidation. This will not be an easy task, and is not a challenge that is unique to the Chao Lake Basin. There may be lessons from other parts of the PRC that are dealing with the same problem.

Box 2, on page 31, summarizes how the ADB-financed project will address some of these issues through a pilot project to control NPS pollution. The pilot is limited to one county that contributes significantly to Chao Lake's water quality issues. Lessons from the pilot will need to be replicated throughout the basin in the subsequent implementation phases of the master plan.

B. Strengthening the Chao Lake Management Authority

The ability of the CLMA to bring sustainable environmental integrity to Chao Lake is jeopardized by (i) a general technical and administrative capacity to implement IWRM, (ii) insufficient authority, and (iii) unclear roles and responsibilities between itself and provincial-level departments and their city bureaus, which have either competing or conflicting roles. The efforts of the CLMA may also go unrealized because of fragmented environmental monitoring and law enforcement.

To address these key issues, ADB recommends the Anhui Provincial Government consider the following priority steps.

1. Legally establish the scope of the CLMA's authority and clarify responsibilities between basin management stakeholders.

The responsibilities delegated to the CLMA are not clearly differentiated from provincial line agencies and the counterpart bureaus in Hefei City. The Provincial National People's Congress should develop an institutional framework to clarify the functions and responsibilities of the CLMA in relation to other provincial line agencies and city government bureaus. A provincial-level leading group should be formed to support the CLMA by keeping it informed and providing it with guidance on macro-level policies, strategies, and planning. The leading group would also facilitate communication and coordination among the departments and bureaus within the institutional framework.

The responsibilities of some of the provincial bureaus should be delegated to the CLMA, thereby supporting the CLMA's legitimacy for regional coordination and management of the lake. For example, the provincial environmental protection bureau should entrust the CLMA to draft the Chao Lake environmental protection plan, while it holds the review and coordination for the plan. The provincial environmental protection bureau could also delegate water quality monitoring to the CLMA, particularly by delegating the management of a 1-kilometer buffer zone around the water area of Chao Lake.

Unless the authority of the CLMA is legitimized and its role clearly defined, there will be redundancies and conflicts in responsibilities that will cause inefficient management and decision making.

2. Establish a joint environmental monitoring and law enforcement division

Environmental monitoring and law enforcement are fragmented across many centers and divisions that cover water resources, transport, environmental protection, tourism management, agriculture, forestry, and fisheries. These responsibilities should be consolidated under the CLMA in a single joint monitoring and law enforcement center for the environment and water resources. This would conserve resources and promote more effective monitoring and enforcement. The joint monitoring and law enforcement center should be trained in, and provided resources for, uniform data collection and information management.

C. Research Data to Inform and Sustain Reforms

As is the case across the country, one of the greatest weaknesses facing the planning and management of Chao Lake is the speculative data and nonempirical measurements of NPS pollution in the Chao Lake area. The lack of compelling evidence that the several billion yuan invested in Chao Lake's eutrophication control has significantly improved the lake's

water quality raises serious questions about the effectiveness of the effort and strategies being pursued. Some argue that the design of projects and allocation of investments are largely random because decisions are based on insufficient information.³² Information and a system to manage it are urgently needed to underpin the decision-making processes to remediate NPS pollution. This will help ensure that resources are allocated where needed and projects are designed to target critical issues and areas.

A credible assessment of agricultural NPS pollution depends on the collection of accurate information. Statistical data on rural population size, livestock and poultry stocking density, and the use of chemical fertilizer and pesticide are all available from the statistical yearbooks published by the governments at various levels; but there are many problems with these data. The national and provincial statistical databases have a much broader purpose and are not well adapted to the particular problem of NPS analysis. Accurate and timely information about water quality levels, pollution loads, and their spatial and temporal dynamics is essential for decision making and formulating policies for mitigating and controlling pollution. A starting point for any analysis would be to verify statistical data through sample surveys and to use remote sensing to verify parameters, such as areas of cultivated land, areas of different crop types, fertilizer application rates, and livestock numbers.

The market is also filled with technologies that can support decision making with timely information and analysis on land and aquatic resources. For example, geographic information systems can pull disparate data from different administrative units, topographical data, and field observations to assist researchers, planners, project officers, and decision makers in resource management. Modeling of NPS pollution can generate spatially specific information on the sources and intensity of nutrient loadings, identify critical areas, and contribute to the design of best management practices within each subbasin or watershed. Expert systems can combine human knowledge with information from various sources through a reference engine to aid the decision-making process.

The CLMA should coordinate a research program to guide policy and legislation on environmental protection and utilization, land use management, and NPS source pollution control. Currently, the master plan does not include any substantive proposals for applied research to address the many knowledge gaps surrounding the NPS pollution control problem. Research on Chao Lake rehabilitation would benefit from collaboration with both the environmental protection and agriculture departments and a relevant university or research institute. An ecological research institute under the CLMA could (i) organize and conduct strategic research on comprehensive treatment of the Chao Lake Basin and advise on land use planning, along with a mid- to long-term development plan; (ii) provide technical support for establishing the CLMA's legal, regulatory, and planning roles; and (iii) conduct training of the CLMA staff.

³² F. Yin and Z. Zhang. 2003. Survey of Chaohu Lake Eutrophication Research. *Journal of Lake Science*. 15 (4). pp. 377-384. (in Chinese)

D. Capacity Development Under Way

To help the provincial government address these issues, ADB and the UNESCO-IHE Water Resources Institute have been working with the CLMA to improve its general technical and administrative performance, especially in preparation for the implementation of the ADB-supported Anhui Chao Lake Environmental Rehabilitation Project. Now under implementation, the project is the major support vehicle for the CLMA, benefiting from a strategic institutional and capacity development program. The program provides staff training through domestic and international education, advanced equipment and technology, and priority studies on (i) special land use management in the Chao Lake catchment based on water quality functional zoning, (ii) early-warning systems for the algal blooms, and (iii) mechanisms to apply and promote achievements from demonstration projects to control NPS pollution.

Under the project, an advisory commission will be established to provide information services to the CLMA. The body will be composed of acknowledged experts in economics, development, water resources management, and environmental protection from the province or other parts of the PRC. A research institute will also be set up to develop and strengthen the CLMA's own scientific and technological capacity for Chao Lake management. Although the CLMA could use an existing scientific and technological organization in the PRC to conduct studies, in the long run, it should have its own scientific capacity.

VI. Policy Directions from Chao Lake Experience

Ecological and environmental degradation is a key issue in the 13th Five-Year Plan (2016–2020). The scope of the country’s air, water, and soil pollution, the complex structure of diverse pollution sources (industrial, domestic, but particularly rural and agricultural), and their long-term impact require stronger policy imperatives, transformational financing at the local levels, and a more decisive, corrective response from economic policy and the market.

The Chao Lake case study and the international experiences provided in this knowledge product demonstrate the extent of changes that governments across the PRC will need to start adopting if they are serious about cleaning up the country’s water resources and embarking on environmentally sustainable growth, or “green development.” Provincial, municipal, and especially local governments need both the guidance and incentives of central-level policy and targets to raise the financing for rural environmental infrastructure and nonpoint source (NPS) pollution control—two critical areas for improving water quality in the country. As progressive as it has been, the Anhui Provincial Government is not exempt from this need for stronger policy directives in the 13th Five-Year Plan. It has only begun its journey down a long road of reform that, if implemented seriously and adjusted as needed, should lead to a recovery of the lake.

This concluding chapter offers a summary discussion of key policy areas and associated actions that are needed in the 13th Five-Year Plan to address water quality issues.

A. Pollution Prevention and Control

A key area for water pollution control in the next planning era is NPS pollution. The 12th Five-Year Plan (2011–2015) remains focused on reducing industrial and domestic pollution. While this is also still needed, NPS pollution control receives only modest initiatives and ambitious targets, many of which are noncompulsory. For example, the 12th Five-Year Plan calls for a 40% reduction in chemical oxygen demand (COD), which stems from rural livelihood and livestock management, but reductions in total phosphorus (TP) and total nitrogen (TN)—both of which are closely associated with COD—are not compulsory, so it is difficult to see how the COD target will be achieved. Centralized treatment of rural wastes is extremely difficult and costly because of the large number of dispersed settlements. Moreover, the number of enterprises to be regulated is sure to exceed the ability of environmental bureaus to supervise.

NPS pollution control requires legal foundations, scientifically based and compulsory targets, resources for monitoring, and financial instruments that use market-based incentives and rewards to promote voluntary compliance among farmers and partnerships between public, private, and individual enterprises. Much of this is beyond the reach of current regulation, monitoring systems, targeted investment programs, and new technology. Substantial programs are needed. The ongoing total emission control program set quantitative water quality targets to reduce COD and ammonia nitrogen on a 5-year basis, but TP and TN targets are not compulsory. On a more limited scale, the 12th Five-Year Plan's Water Pollution Control in Key River Basins Program has integrated TN and TP into the total emission control program. The experience with this program may provide the basis for later expansion beyond the key river basins.

B. Development of a Policy Framework for Nonpoint Source Pollution Control

To bring NPS pollution control into better focus and support the sustainable achievement of NPS targets, the development of a national policy framework for NPS pollution control should be considered in the 13th Five-Year Plan for Environmental Protection to better guide planning and financing. This framework should address the following priority concerns.

Support financing, operation, and maintenance of rural environmental infrastructure.

Water supply and wastewater infrastructure projects have largely bypassed rural counties, townships, and districts. Both individual farms and residential clusters need investments. Community wastewater treatment systems may be scaled to treat wastes coming from the small rural clusters of homes, while technologies, such as lagoon treatment systems, should be explored. Without regulation of rural NPS (such as rural domestic waste) and substantial outside investment, local governments, farmers, and communities lack the incentive and financing to invest in scaled wastewater technology (See Box 1, page 23, for an example of such a system).

Pilot and scale up technologies for clean agricultural production. NPS pollution of water resources can be mitigated through large-scale programs and targets to increase the use of organic fertilizer. More efficient irrigation and the installation of variously scaled biogas digesters and biomass processing systems that produce high-quality organic fertilizers are two strategies to reduce chemical fertilizer use. For example, farmers in the Chao Lake Basin typically use flood irrigation, which involves inundation of the entire cultivated land surface. More focused irrigation, through furrow or sprinkler systems, would use less water, create less runoff, and thus reduce the amount of fertilizer carried into the lake.

The conversion of biomass from crops and animal wastes into energy and organic fertilizer by-products is a practical, affordable, and culturally sensitive approach that manages the use of agrochemicals and the volume of agricultural and household wastes, while also improving public health and the environment.

ADB envisions supporting the installation of small-scale, household-level biogas digesters and the development of large-scale biogas digesters for medium- and large-scale livestock

enterprises, both of which continue to be government priorities. One of the main areas for development and innovation will be through environmentally sustainable management and disposal of digester sludge (which could be used as organic fertilizer), particularly from medium- and large-scale enterprises. There may also be opportunities to work with the Ministry of Agriculture (MOA) to promote environmentally sustainable practices among small- and medium-scale household livestock and poultry enterprises. Opportunities could include training and extension for the design and construction of environmentally sustainable animal housing units and farmers' education.

ADB could also support MOA's efforts to strengthen fertilizer management through activities such as (i) the promotion of soil testing and fertilizer formulation technologies, (ii) improved quality of cultivatable land, including promotion of the use of organic fertilizers, (iii) improved soil quality monitoring programs and the use of water-saving agricultural techniques, (iv) increased farmers' education, (v) adoption of advanced production techniques within the fertilizer production industry, and (vi) tightening of regulatory supervision. Environmental farm planning and rural environmental planning with respect to safe disposal of household wastes could also be piloted.

The way to support this agenda is by mainstreaming these strategies and technologies into rural development projects as opportunities arise.

C. Formulation of Legal and Institutional Reforms to Clarify Responsibility and Trigger Cooperation

Environmentally sustainable development challenges the traditional way institutions have worked, how policies have been formulated, and how resources have been governed. Integrated water resources management is as much about managing what happens on land as it is about managing what happens with the water resources. This brings new government stakeholders around the table. MOA should be encouraged as a key stakeholder in controlling rural water pollutants, along with the Ministry of Environmental Protection (MEP), with its critical roles in monitoring pollution sources and implementing innovative control measures. The roles and responsibilities of these agencies are bound to evolve as the focus sharpens on rural and agricultural sources of water pollution.

Greater integration of land and water resources management is a significant long-term activity. Subnational and local governments should align their economic and land use planning and/or zoning with environment plans to make balanced, sustainable growth possible. Sound economic and development policy considers the capacity of the environment and natural resources. This requires high-level, integrated planning and management to coordinate reviews of sector plans and policies to ensure harmony between both economic and environmental goals and policies. The Chao Lake Management Authority (CLMA) is an example of the kind of authority that—once established—can gradually assume a broad coordination role and strengthen the integrative planning process.

D. Addressing Market Failures in Resource Management

Market-based mechanisms, such as water pollutant trading, have been introduced in the 12th Five-Year Plan as a potentially innovative approach to help achieve pollutant reduction targets.³³ This new policy development recognizes one of the reasons for the uneven performance of national command-and-control lake rehabilitation programs—the overreliance on administrative approaches.

Water quality trading programs should allow, where feasible, trading between point and nonpoint sources. In the current absence of regulation of nonpoint sources, mixed trading would address point source regulatory requirements while generating reductions from unregulated nonpoint pollution sources. More than 70% of active water quality trading programs in the world allow trade between point and nonpoint sources. Box 3 summarizes lessons from the water emissions trading program in the PRC's Tai Lake.

The private sector and the markets should play a central role in these systems. The government, in particular, through the work of MEP and the National Development and Reform Commission, is advocating the application of eco-compensation principles to solve certain intractable natural resources conservation problems, such as catchment protection and the rehabilitation of degraded watersheds. However, an overly large public sector presence as buyer of environmental services risks crowding out the private sector.

E. Promotion of Public Participation and Information Dissemination

The Government of the PRC has expressed commitment to improved information dissemination and public participation in environmental management. These ambitions require support to make them effective. Several factors in the Chao Lake experience highlight the challenges to meaningful participation and effective information dissemination. For example, about 70% of the population in the Chao Lake watershed is considered rural, with limited education levels and environmental awareness. This is not conducive for environmental action, and there is no division in the CLMA in charge of environmental education either. Poor or incomplete data and data management systems are also likely to hamper the best intentions of disclosure.

To promote genuine public participation and information disclosure, the 13th Five-Year Plan should consider programs and targets that aim to

- (i) improve environmental monitoring systems (and pilot participatory monitoring methods);

³³ Government of the People's Republic of China, State Council. 2011. *National 12th Five-Year-Plan for Environmental Protection*. http://www.gov.cn/zwggk/2011-12/20/content_2024895.htm (in Chinese)

Box 3: Lessons in Market-based Trading System from Tai Lake Experience

Water quality trading was introduced in the Tai Lake Basin in 2008 with the aim of achieving water quality goals more efficiently. The Tai Lake program was the first effort of the People's Republic of China (PRC) to use market-based mechanisms at the river basin level. The following recommendations are some of the many important lessons to be drawn from the program.

Set a science-based loading capacity for water quality trading. Loading capacity is the maximum amount of pollutants a water body can receive without violating water quality standards. However, basin-wide water quality models that are commonly used in developed countries to quantify loading capacity have not been applied in the PRC due to inadequate data availability. Instead, arbitrary limits have been used (e.g., chemical oxygen demand should be reduced by a certain arbitrary amount). Without a science-based assessment of loading capacity, it is difficult to benchmark initial allocations and set realistic and effective reduction quotas for different pollution sources.

Build a standardized allocation framework for basin-wide trading. Differences in allocation principles among provinces undermine an effective pollutant trading scheme. Three principles— auction, purchase, and allocation free of charge (grandfather)—are commonly adopted in quota allocation. In the case of Tai Lake, the adoption of different allocation and trading principles in the participating provinces (Jiangsu and Zhejiang) has made cross-provincial trading difficult.

Develop a market-driven approach. In Tai Lake, trading has received strong government support, but the approach taken has been very similar to a command-and-control approach. More economic incentives should be created to allow market forces to function. Current trading demand from enterprises is weak—only 5% of 1,357 enterprises registered in the online transaction system have traded in the secondary market, which is far below the anticipated scale. Two key factors were identified:

- (i) The credit price is set by government but not by the market. This reduces the frequency of transactions as it underestimates the credit price and poses the risk of long-term policy uncertainty. Enterprises tend to retain discharge credits as an asset either in expectation of a future rise in their value due to stricter environmental policies, or to provide a reserve to cover potential future increases in production.
- (ii) Credit aggregators should be encouraged. Although the Tai Lake program has established an online exchange platform to enhance information transparency, the volume and duration of credit buyer and seller for a single transaction are rarely matched. International experience shows that credit aggregators will function as a bank to solve this double mismatch and to evaluate the risk more professionally.

Enhance monitoring capacity. The lack of real-time monitoring capacity complicates the task of verifying the pollutant load from enterprises. Apart from the key point sources that have installed online monitoring equipment, monitoring in most enterprises is irregular. Obtaining sufficient and accurate information on the discharge of pollutants is the prerequisite to verify and implement pollutant discharge trading. Drawbacks in monitoring capacity became a major barrier to an effective trading program.

Source: Asian Development Bank.

- (ii) designate and build the capacity of public information units in local government agencies, such as a management authority (similar to the CLMA), water resources bureau, and environmental protection bureau;
- (iii) mainstream participation, awareness initiatives, and information disclosure through existing agricultural extension services;
- (iv) use eco-compensation arrangements and revenues to support information management systems, information disclosure, and environmental awareness initiatives; and
- (v) capitalize on the behavioral change opportunities that are inherent in financial incentive systems, such as conversion to organic inputs, and green technologies and methodologies.

APPENDIX 1

Tributary Water Quality

The Hangbu and Nanfei rivers account for the largest catchment area and total runoff— about 68% of the up-sluice catchment area (excluding the area of the lake) and 66% of total inflow. The lake has eight principal tributaries (Table A1.1). Table A1.2 shows their contribution to the pollutant load as estimated by the Anhui Environmental Protection Department based on water quality monitoring data. Water quality in the Hangbu River, the lake’s largest tributary, which drains into the lake from the southwest, has been Class IV since 2007. Before that, it was Class III, so water quality conditions there have deteriorated. It contributes about 31% of chemical oxygen demand (COD), 17% of total phosphorus (TP), and 18% of total nitrogen (TN), all of which are disproportionately less than its contribution to average annual inflow (55% of the total).

Table A1.1: Principal Tributaries of Chao Lake and Contributions to Average Annual Inflows

River	Catchment Area (km ²)	Length (km)	Proportion of Total Catchment (%)	Average Annual Flow (bcm)	Proportion of Total Inflow (%)
Hangbu	4,246	263	46.3	1.92	55.1
Nanfei	1,464	70	16.0	0.38	10.9
Pai	585	60	6.3	0.17	5.0
Baishitian	577	34	6.3	0.33	9.4
Zhegao	518	35	5.6	0.15	4.3
Zhao	504	34	5.5	0.15	4.2
Shiwuli	111	27	1.2	0.03	0.9
Shuangqiao	27	4	0.3	0.01	0.2
Others (including lake surface)	1,143		12.5	0.35	10.0
Total	9,175	527	100.0	3.49	100.0

bcm = billion cubic meter, km = kilometer, km² = square kilometer.

Note: Percentages may not total 100% because of rounding.

Source: People’s Government of Anhui Province. 2008. Master Plan for the Integrated Water Environment Management in the Chao Lake Basin. Mimeo.

Table A1.2: Contributions of Major Tributaries to Chao Lake Pollution Load

River	Pollutant (%)		
	COD	TP	TN
Hangbu	31.4	17.1	18.2
Nanfei	21.3	24.9	8.9
Pai	14.6	23.7	40.9
Baishitian	10.8	2.7	4.1
Zhegao	8.4	3.0	2.6
Zhao	7.4	3.9	4.1
Shiwuli	4.5	24.6	19.7
Shuangqiao	1.7	0.9	1.5
Total	100.0	100.0	100.0

COD = chemical oxygen demand, TN = total nitrogen, TP = total phosphorus.

Note: Percentages may not total 100% because of rounding.

Source: People's Government of Anhui Province. 2008. Master Plan for the Integrated Water Environment Management in the Chao Lake Basin. Mimeo.

The Nanfei, Pai, and Shiwuli rivers are the three main rivers that drain the municipal area surrounding Hefei City. Because of Hefei City pollution, monitoring sections in all three of these rivers averaged Class V+ in 2010. They contribute about 40% of total COD, 73% of TP, and 70% of TN even though they account for only 17% of average annual inflow.

APPENDIX 2

Objectives, Goals, and Components of the Master Plan

This appendix provides more detailed information on the near- and longer-term targets of the Master Plan for the Integrated Water Environment Management in the Chao Lake Basin.¹

The objective targets for 2020 are:

- (i) Water quality in Chao Lake:
 - a. Permanganate index will reach Class III.²
 - b. Total phosphorus (TP) and total nitrogen (TN) will reach Class IV or better.
- (ii) Water quality in the surrounding rivers:
 - a. The Nanfei, Pai, Shiwuli, and Shuangqiao rivers will be kept at Class IV or better.
 - b. Other rivers will be kept at Class III or better.

These goals will be reached by achieving the following objectively defined controls on pollution sources and other controls.

- (i) **Emissions.** Chemical oxygen demand (COD) will be reduced to 89,700 tons (31% reduction over 2006 level); ammonia nitrogen (NH₃-N) to 6,400 tons (59% reduction); TP to 1,900 tons (64% reduction); and TN emissions to 16,800 tons (55% reduction). Point source emissions would be reduced to 66,200 tons of COD; 3,700 tons of NH₃-N; 600 tons of TP; and 6,000 tons of TN. Nonpoint source emissions would be reduced to 18,800 tons of COD; 1,300 tons of NH₃-N; 1,000 tons of TP; and 9,000 tons of TN.
- (ii) **Wastewater treatment ratios.** Centralized treatment ratio of urban wastewater will reach 90%, rural domestic wastewater 30%, and night soil and solid wastes 50%.
- (iii) **Agrochemical consumption.** Fertilizer and pesticide consumption will drop by 30% compared to 2006 levels, and 80% of animal manure will be reused.
- (iv) **Wetlands construction.** An estimated 30 square kilometers (km²) of wetlands along the lakeshore will be reconstructed or rehabilitated.

¹ People's Government of Anhui Province. 2008. Master Plan for the Integrated Water Environment Management in the Chao Lake Basin. Mimeo.

² Permanganate index, sometimes referred to as chemical oxygen consumption, measures the total quantity of moderately oxidizable organic material in a sample using potassium permanganate as the oxidizing agent. The more commonly used measure of organic pollution is COD, which is determined using potassium dichromate, a more powerful oxidizing agent that fully oxidizes both organic and inorganic sources of oxygen consumption.

- (v) **Hydrological controls.** Total river inflow to the lake will be maintained at about 1 billion cubic meters (bcm) per year.

The master plan has the following main components:

- (i) total pollutant quantity control;
- (ii) agricultural and industrial restructuring and improved spatial development in rural areas;
- (iii) pollution source control;
- (iv) ecological rehabilitation;
- (v) water transfer from the Yangtze River to increase lake flushing; and
- (vi) education, research, and institutional development.

Component 1: Total Quantity Control

Mathematical models were used to calculate the lake's assimilative capacity. The details of the models are not included in the master plan although the text mentions the use of a Vollenweider model and a quantitative structure–activity relationship (QSAR) model. The Vollenweider model makes use of very simple and (mostly) readily available data³ to predict phosphorus concentrations and thus the lake's trophic status—assuming that phosphorus is the limiting factor, which, in freshwater systems such as Chao Lake, it commonly is. QSAR models use measured relationships between various inputs (e.g., a total inflow of a pollutant such as COD) and response variables (e.g., the resulting concentration of COD in the lake) to construct regression equations that can be used to predict responses to input levels that have not been measured or experienced. The success of any QSAR model depends on the accuracy of the input data, which, for the Chao Lake situation, would have to be considered low given that such a large proportion of total inputs (i.e., the nonpoint source pollutant quantities, which account for well over half of estimated TN and TP loads) are based only on very speculative estimates rather than empirical data.

Nevertheless, the estimates are the best that are possible given the availability of data. Table A2 shows, for COD, TP, and TN, the estimated assimilative capacity, estimated permissible discharge,⁴ and loads estimated for 2006—the baseline for the plan. Regardless of the accuracy of the data and estimates, the results are generally consistent with current observations. Discharges of COD, TP, and TN significantly exceed both the estimated assimilative capacity and the less stringent estimated permissible discharge levels. These data are consistent with the fact that the lake is eutrophic in the summer time and has an average water quality of Class V or V+.

³ The inputs include hydraulic residence time (volume divided by inflow quantity), overflow rate (average depth divided by hydraulic residence time), and areal phosphorus load (quantity of inflowing phosphorus divided by lake area). In the Chao Lake context, the quantity of inflowing phosphorus is the most difficult variable to determine.

⁴ The master plan does not explain how the permissible discharge limits were calculated. The text states: “On basis of the water environmental capacity of Chao Lake and division of functional area of the water body, we reckon that the allowed quantity of pollutants discharged of COD, NH₃-N, TP, and TN in the integrated water environment management area is 89,700 tons, 6,400 tons, 1,900 tons, and 1,6800 tons, respectively.” It is possible that the “estimated permissible discharge” is an estimate of what might reasonably be aimed for, given that the estimated assimilative capacities are so low as to be unachievable in any practical sense.

Table A2: Estimated Assimilative Capacities of Chao Lake

Parameter	Pollutant (tons/year)		
	COD	TP	TN
Estimated assimilative capacity	37,175	310	6,196
Estimated permissible discharge	89,700	1,900	16,800
Estimated load in 2006	130,246	5,360	37,558
Ratio 2006: assimilative capacity (%)	350	1,730	606
Ratio 2006: permissible discharge (%)	145	282	224

COD = chemical oxygen demand, TN = total nitrogen, TP = total phosphorus.

Source: People's Government of Anhui Province. 2008. Master Plan for the Integrated Water Environment Management in the Chao Lake Basin. Mimeo.

The estimates of the actual quantities of pollutant reduction required also took account of assumptions regarding future economic and population growth and the associated growth in pollutant emissions. The required reductions were allocated to individual local government areas based on the pattern of existing emissions and the growth projections.

Component 2: Agricultural and Industrial Restructuring and Improved Spatial Planning

The master plan sets out a series of restructuring objectives but provides little indication of how they would be achieved.

In agriculture, some of the main reforms proposed are as follows:

- (i) **Crop production.** Efforts will be made to reduce the use of pesticides and fertilizers, and to increase the use of organic fertilizers and low toxicity, low persistence pesticides. Efforts will be made to increase the scale of farming operations. In certain (unspecified) key high priority protection zones around the lake, restrictions would be placed on the production of crops requiring high fertilizer applications, and the production of organically grown vegetables would be encouraged. An objective would be to establish a 100,000 *mu* pollution-free agricultural production base.⁵
- (ii) **Livestock and poultry production.** Attempts will be made to increase the scale of operations and gradually increase the levels of waste recycling. The distribution of poultry and livestock farms will be regulated and will be forbidden in certain (unspecified) areas. It was proposed that some existing operations would be closed down or relocated before the end of 2009.
- (iii) **Aquaculture.** Purse seine fishing and fish farming in Chao Lake will be prohibited by the end of 2014. Before then, some operations in the lake will be required

⁵ A *mu* is a Chinese unit of measurement (1 *mu* = 666.67 square meters).

to relocate out of certain (unspecified) restricted zones. Pond-based aquaculture with suitable environmental controls (properly circulated water and zero or very low levels of fertilization) will be encouraged as an alternative to in-lake aquaculture.

In industry, proposed reforms are as follows:

- (i) Encourage development of hi-tech industries that produce less pollution per unit of output. Industries to be encouraged in Hefei City include software development, electronics, biotechnology, automobiles, and home appliances. In Chaohu City, the emphasis will be on new materials, processing of agricultural products, pharmaceuticals, biomass energy, and electronic information.
- (ii) Efforts will be made to further develop the “circular economy” (i.e., to increase recycling and promote concepts such as zero waste production) and continue to control industrial pollution. Time limits will be set for the shutdown or relocation of certain types of industrial enterprises, and the designs of provincial and higher-level development zones will be upgraded to provide advanced centralized industrial wastewater treatment and promote the reuse of process water.

The following steps are proposed to speed up development of the tertiary sector:

- (i) Regional transport and logistics will be improved by establishing special zones in the three main cities to improve the handling of building materials, agricultural produce, and industrial goods.
- (ii) The tourism industry will be promoted.
- (iii) Efforts will be made to promote the development of the finance sector, particularly in Hefei City.

Spatial planning covers both rural and urban areas. In rural areas, the large number of small villages and towns around the lake make it very difficult to provide centralized wastewater collection and treatment. Efforts will be made to encourage rural consolidation by supporting the development of the larger towns, particularly those with populations greater than 30,000, with the aim of “providing moderate concentration, saving land, promoting production, and making life convenient” (footnote 1). Efforts will be made to control the population size of big cities and prevent urban expansion toward the lake.⁶

Component 3: Pollution Source Control

The strategy for pollution source control is a continuation of the work already being done on point sources, but with a strengthening of standards and a widening of the approach to provide better coverage of nonpoint source pollution control, improved water use efficiency, ship pollution control, and stronger water supply protection against extreme pollution events in the lake.

⁶ Around Hefei City, efforts in this regard may be too late as development of almost all of the area of land between the city center and Chao Lake is already well under way.

- **Point source control**

- (i) **Municipal liquid and solid wastes.** Treatment standards at municipal wastewater treatment plants (WWTPs) will be raised. New municipal WWTPs and recently completed WWTPs will be designed and/or upgraded to provide a Class 1A level of treatment (biological treatment plus nutrient removal).⁷ Greater efforts will be made to ensure that sewage collection systems and sludge treatment systems are upgraded and/or expanded to match WWTP capacity and ensure that installed treatment capacity is fully used, and that sludge can be disposed of in an environmentally acceptable manner.⁸ Efforts will be made to separate sewage and stormwater collection systems to reduce overloading sewerage systems. Leachate collection and treatment at sanitary landfills will be improved.

Quantitative objectives include: wastewater treatment ratio in all urban areas to reach 80% by 2012 and 90% by 2020; and solid waste collection rate in urban areas to reach 75% by 2012 and 100% by 2020.

- (ii) **Industrial pollution control.** Strengthen efforts to eliminate obsolete industrial processes in key industries such as paper making, brewing, dyeing and printing, leather processing, pharmaceuticals, mineral processing, and chemicals. Enterprises that cannot meet the required standards will be closed down or relocated. Industrial enterprises using obsolete industrial technology and causing serious pollution shall be shut down. New acceptance standards will be developed for large water-consuming industries, such as chemicals, brewing, dyeing and printing, and food processing, to take account of the situation in Chao Lake. All chemical factories in Hefei City will be moved to an industrial park which will have centralized wastewater collection and treatment and will apply strong environmental control measures.

Commencing in 2009, unlicensed industrial pollutant discharges will be prohibited. Enterprises that are unable to meet relevant discharge standards will be required to restrict production and come into compliance within a defined time limit. Failure to comply within the defined time limit may result in closure.⁹ Industrial enterprises that are able to meet pollution discharge standards will be encouraged to control pollution in a comprehensive way and promote clean production. Automatic, real-time discharge monitoring systems will be installed at certain key enterprises to permit real-time

⁷ Most existing WWTPs in the catchment were designed to the national Class 2 standard. Class 1A WWTPs are designed to produce COD concentrations 50% lower than Class 2 (50 milligrams per liter [mg/l] compared to 100 mg/l), NH₃-N concentrations about 80% lower than Class 2 (5 mg/l instead of 25 mg/l), and TP concentrations about 85% lower than Class 2 (0.5 mg/l instead of 3.0 mg/l). The sale and use of phosphorus-containing detergents have already been banned in the catchment.

⁸ Failure to expand sewage collection systems to match treatment capacity has been a widespread problem in the PRC, although, starting in the 11th Five-Year Plan, the government has strengthened measures to improve coordination. The measures seem to be having some effect since the utilization rate of installed WWTP capacity has gradually been rising nationwide.

⁹ None of these requirements are new. MEP included all of these measures in the national program for the 11th Five-Year Plan, but it has been very difficult to get some local governments to comply.

supervision. Centralized wastewater treatment facilities must be provided in industrial zones by 2012. The long-term objective is to treat 80% of industrial wastewater emissions to a tertiary level (i.e., including nutrient removal) by 2020.

- **Nonpoint source control**
 - (i) Increased use of customized compound fertilizers will be encouraged based on soil testing.
 - (ii) Integrated pest management, needs-based (rather than calendar-based) use of agrochemicals, and use of organic pest control or the use of nonpersistent agrochemicals will be promoted.
 - (iii) Treatment will be provided for domestic wastewater, and solid waste collection facilities will be set up in selected rural towns and villages.
 - (iv) Regulation of livestock and poultry production through zoning (i.e., identifying special production zones) will begin.
 - (v) Ecological farms and zones will be encouraged to promote waste recycling.

- **2012 objective targets**
 - (i) Soil testing will be done on 100% cultivated land.
 - (ii) 15% domestic sewage in the countryside will be treated.
 - (iii) 30% solid waste will be collected and disposed of.
 - (iv) 50% of animal manure will be recycled.
 - (v) All wastewater discharged from large livestock farms will meet specified standards.

- **2020 objective targets**
 - (i) 30% of rural domestic sewage will be treated.
 - (ii) 50% of solid waste will be collected.
 - (iii) Consumption of chemical fertilizer and pesticides will drop by 30%.
 - (iv) 80% of manure will be recycled.
 - (v) All wastewater discharged from large farms shall be up to standard.

- **Water use efficiency measures**
 - (i) Urban water supply distribution systems will be renovated to reduce leakage.
 - (ii) Regulations will require installation of water-saving facilities (e.g., low-flush toilets and water-saving showerheads) on new developments.
 - (iii) Irrigation efficiency will be improved through promotion of low-water-consumption crops, revision of irrigation quotas, promotion of water-saving irrigation technologies, and renovation of an existing artesian irrigation system.
 - (iv) A water-saving management system will be established to control the total amount of water used by industry. It will include a water use licensing system and preparation and evaluation of plans for water use and water saving. Pilot

water-saving projects will be supported to promote technological innovation in high-water-consumption industries, such as thermal power, iron and steel, textiles, and chemicals.

- **On the control of pollution from ships**
 - (i) Facilities for collecting and treating pollutants from ships will be improved.
 - (ii) Emergency response plans to deal with areas polluted by ships will be established.
 - (iii) Monitoring of special types of shipping (e.g., ships carrying dangerous articles, passenger ferries, and tourist vessels) will be strengthened.

- **Measures proposed to strengthen drinking water supply protection against extreme pollution events in the lake**
 - (i) An emergency back-up water supply system from the Zhao River will be established for use in emergencies.
 - (ii) A system will be established for removing large tracts of algae in the western part of the lake and near the water supply intake for Chaohu City. It is envisaged that collected algae would be used to make organic fertilizer. Research will also be done on the possibility of using it for energy production.

Component 4: Ecological Rehabilitation

The proposed measures are as follows:

- (i) Lake-bottom dredging, initiated under the 9th Five-Year Plan, will be continued. The total dredged area will be about 50 km² and the dredged quantity will be 18 million cubic meters.
- (ii) Engineered wetlands will be constructed by transforming low-lying land beside the lake and using dredged material to construct artificial wetlands by reclaiming foreshore areas. The total planned area is 30 km² with an average width of 50–200 meters.
- (iii) Sediments will be dredged and river bank protection work done on key tributaries of the lake (particularly the Fei, Pai, Shiwuli, and Shuangqiao rivers).¹⁰ Where possible, engineered wetlands will also be constructed, particularly where the rivers flow into the lake and reforestation works will be done along river courses to a distances of 3 kilometers from the river bank. The reforestation target is 300,000 mu (20,000 hectares). Particular efforts will be made to concentrate work in areas with hyper-phosphoric soils (mainly in Feidong County).
- (iv) Catchment-protection forests will be planted in the headwaters of the main rivers and in drinking water protection areas.

¹⁰ Some river sediments contain significant quantities of organic pollution and nutrients, which get resuspended during high flows and floods and are transported into the lake. River sediment dredging can be an effective control strategy provided that the dredged sediments are disposed of properly to prevent contaminants leaching back into the river or the lake.

Component 5: Possible Future Water Transfer

Recognizing that it may be impossible to reduce total emissions to an environmentally sustainable level, regardless of the stringency of controls applied, research is proposed to design and develop a project to transfer 1 bcm per year of water into Chao Lake from the Yangtze River.

Component 6: Research, Development, Demonstration, and Education

Given the large gaps in understanding of the dynamics of the lake's ecosystem and its interaction with pollutants, a wide range of research and development activities are proposed in addition to the establishment, in association with existing research institutes and universities, of some key laboratories for research and development of engineering technologies. One series of activities will focus on integrated environmental management of the lake, and a second series will focus on strategies and processes for controlling emissions at source, particularly in urban areas.

Monitoring. At the same time, the environmental monitoring system will be significantly upgraded by the addition of two city-level and seven county-level monitoring stations, and the establishment of six automatic monitoring stations on the major water courses and drinking water sources (the Fengle, Hangbu, Nanfei, Pai, and Shiwuli rivers and the Dongpu Reservoir). This will significantly strengthen capacity to monitor incoming pollutant loads and create the basis for the construction of a nonpoint source pollution management network and professional information platform to better manage nonpoint sources of pollution.

Enforcement. There are numerous opportunities to strengthen the enforcement of standards and controls. Beginning with people, personnel will be trained to better monitor and enforce standards. Emission standards will be aligned with the limited assimilative capacity of the lake. Oversight of industrial pollution, in particular, will be significantly strengthened. For example, industries will be required to pretreat to National Class 1 standard any liquid wastes before discharging to sewers. Heavily polluting industries will be prohibited from being established or, where they already exist, from being extended. And new industrial development will adhere to zero TN and TP emission standards.

APPENDIX 3

Results of 2010 Interim Targets

Progress made in achieving the interim objectives set out in the Master Plan for the Integrated Water Environment Management in the Chao Lake Basin is summarized in Table A3.¹

Table A3: Master Plan Objectives for 2010: Planned versus Actual

Item	2006 Actual ^a	2010 Plan ^b	2010 Actual ^c	Comment
Overall water quality indicators:				
COD in the Chao Lake	Class V+	Class III	Class V	
Shiwuli River	Class V+	Class V	Class V+	
Pai River	Class V+	Class V	Class V	
Nanfei River	Class V	Class V	Class V+	
Baishitian River	Class V	Class V	Class V	
Yuxi River	Class III	Class III	Class III	
Hangbu River	Class III	Class III	Class IV	
Fengle River	Class III	Class III	Class IV	
Zhao River	Class III	Class III	Class III	
Total emissions (tons):				
COD	125,113	120,700	176,000	+ 41% instead of -3%
NH ₃ -N	13,912	15,000	14,000	
TP	4,947	5,000	2,000	
TN	35,310	34,400	25,000	
Point source emissions (tons):				
COD	75,548	66,200	101,200	+34% instead of -12%
NH ₃ -N	9,268	9,100	12,278	+32% instead of -2%
TP	1,448	1,300	1,166	
TN	14,879	12,900	15,600	+4% instead of -13%

continued on next page

¹ The master plan set three targets: 2010 (end of 11th Five-Year Plan); 2012 (near term), and 2020 (long term). 2010 targets were set by the 2006–2010 pollution control plan for Chao Lake, which preceded the master plan, and were absorbed by the master plan. (People's Government of Anhui Province. 2008. Master Plan for the Integrated Water Environment Management in the Chao Lake Basin. Mimeo.)

Table A3 *continued*

Item	2006 Actual ^a	2010 Plan ^b	2010 Actual ^c	Comment
Nonpoint source emissions (tons):				
COD	52,565 ^d	49,900	74,800	+46% instead of -5%
NH ₃ -N	4,644	4,400	1,722	
TP	3,499	3,300	834	
TN	20,431	19,400	9,400	

COD = chemical oxygen demand, NH₃-N = ammonia nitrogen, TN = total nitrogen, TP = total phosphorus.

^a From Table 2.1-8 of the master plan. Figures do not include estimates of pollution from internal sources since targets do not mention any reductions in these levels, which cannot be directly controlled.

^b From Chapter 3.4 General Goal (p. 44) of the master plan.

^c From 12th Five-Year Plan p. 6.

^d Value in the master plan is 5,133, which was a misprint. The actual value from Table 2.1-8 is as shown.

Sources: People's Government of Anhui Province. 2008. Master Plan for the Integrated Water Environment Management in the Chao Lake Basin. Mimeo; Government of the People's Republic of China, State Council. 2011. *National 12th Five-Year-Plan for Environmental Protection*. http://www.gov.cn/zwggk/2011-12/20/content_2024895.htm (in Chinese)

Reviving Lakes and Wetlands in the People's Republic of China, Volume 2

Lessons Learned on Integrated Water Pollution Control from Chao Lake Basin

This publication continues the Asian Development Bank's analysis of lake and wetland rehabilitation in the People's Republic of China. It examines how the current situation in the Chao Lake Basin compares with international thinking on the conditions necessary for sustainable management of lake basins. The analysis highlights that the creation of the Chao Lake Management Authority (CLMA) and the formulation of the master plan do not mean the problem has been solved, only that the basic framework for solving the problem has been created. Building CLMA capacity, focusing more on managing agricultural pollution, introducing incentives to change farmer behavior, and updating the master plan to ensure its relevance are four key actions for the government to undertake in the coming years, if not decades.

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