Drying Up

What to do about droughts in the People's Republic of China

With a case study from Guiyang Municipality, Guizhou Province

By Qingfeng Zhang, Yoshiaki Kobayashi, Melissa Howell Alipalo, Yong Zheng

Asian Development Bank

ADB

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ISBN 978-92-9092-447-0 (Print), 978-92-9092-448-7 (PDF)
Publication Stock No. RPT113883

Cataloging-in-Publication Data

Zhang, Q., Y. Kobayashi, M. Howell Alipalo, and Y. Zheng.
Drying up: What to do about droughts in the People's Republic of China, with a case study from Guiyang Municipality, Guizhou Province.
Mandaluyong City, Philippines: Asian Development Bank, 2012.

1. Drought. 2. Disaster risk management. 3. People's Republic of China. I. Asian Development Bank.

Note: In this publication, "$" refers to US dollars.

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Contents

Foreword

Rare and severe droughts gripped the Southwest region of the People's Republic of China (PRC) in 2010 and its Yangtze River Basin in 2011, proving that even one of the largest basins in the world, and one known for its high rainfall, is not immune from the effects of climate change and unsustainable water consumption rates. Guizhou, the poorest province in the Southwest region of the PRC, was affected most severely—entire seasons of crops were lost, and more than 1 million people affected, including 725,000 people without drinking water and 170,000 needing grain rations to survive.

In response to the record-breaking water-related natural disasters including droughts that occurred in 2010, the PRC government issued its 2011 No. 1 Central Document, which explicitly targeted water conservation and watershed management for the first time in the 62-year history of modern PRC. The document estimated a planned spending of CNY4 trillion ($608 billion) through 2020, and called for comprehensive flood protection and drought management plans to be in place by 2020.

This publication addresses the issue of droughts and water management in the PRC for environmentally sustainable development. It consolidates the highlights from several recent ADB strategic studies that relate to improving disaster risk management and water resources management in the PRC, and represents current policy direction in the Ministry of Water Resources, with whom ADB worked closely in developing this knowledge product. One interesting finding from these studies is that drought management in the PRC follows the reactive mode of its flood management system, which limits official uses of disaster relief funds until after an emergency is declared.

These studies concluded that greater risk assessment, monitoring, and an early warning system would greatly improve response times and mitigate costs incurred from unnecessary losses, damages, and rebuilding. Through a case study of Guiyang—the economic, cultural, and industrial center of Guizhou Province—this report proposes demand management as a pathway toward increased resilience to droughts and ecological conservation, and examines three tracks to getting on that pathway: risk management, optimal infrastructure, and ecosystem-based management.

The Guiyang example stipulates that demand management measures such as water-saving fixtures in apartments, 30% greater industrial water efficiency, and leakage reduction could have provided Guiyang municipality with 20% more water during the 2010 Southwest drought. Investment costs of such a proposed efficiency program for Guiyang would only amount to CNY137 million ($21.5 million), representing a fraction of the industrial losses of CNY732 million ($115 million) incurred during the Southwest drought.

Moreover, in the PRC, where climate change is resulting in more unpredictable weather patterns, including more droughts and floods, the regulating services provided by ecosystems are critical for climate change adaptation and disaster risk reduction. This publication highlights that an integrated approach is essential to creating reserves and enabling ecosystem services to function in drought situations and in the long term. Only an integrated water resources management approach will reduce risks and impacts of natural hazards, and will ultimately help reduce economic losses.

Moving forward, the policy options available to the PRC on water resources management are laid out in this publication to contribute to the PRC's environmental goals under its 12th Five-Year Plan and the forthcoming ADB–PRC country partnership strategy.

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Acknowledgments

ADB staff members Qingfeng Zhang (task manager) and Yoshiaki Kobayashi, consultant Melissa Howell Alipalo, and Executive Director of Guiyang Water Resources Bureau Yong Zheng developed this publication through conceptualization, fieldwork, additional consultant inputs, drafting, peer review, and stakeholder feedback.

This publication features various findings and recommendations from three recent People's Republic of China (PRC)–related ADB technical assistance (TA) projects: (i) Strengthening Water Resources Management in Guiyang (TA 4912-PRC), (ii) Strategy for Drought Management (TA 7261-PRC), and (iii) the Country Environmental Analysis (2011–2015) (TA 7484-PRC). The ADB team appreciates the quality inputs of the consultants that conducted the TA studies and served as a solid knowledge base for this publication. The ADB team specifically thanks the additional technical guidance provided by the consultants Daniel Gunaratnam, Robert Crooks, Wayne Hancock, Jin Leshan, and Jerri Romm, all of whom worked on the original TA projects upon which this publication is based.

The ADB team also appreciates the partner organizations and authors who gave permission to reprint their important research. We acknowledge their contribution to the understanding of the challenges, opportunities, and successes of working in the water sector in the PRC. Specifically, we would like to acknowledge the work of the 2030 Water Resources Group and its *Charting Our Water Future* report (2009), and the World Bank for its *Addressing [the People's Republic of] China's Water Scarcity* report (2009). Both of these works contributed greater depth to the analysis.

Several reviewers in ADB offered valuable comments at different stages during the preparation of the publication. Roland C. Steiner, Tien Shao, and Lijin Zhong of the World Resources Institute provided insightful comments and valuable recommendations.

This publication has benefited from the support of the Ministry of Water Resources, the Ministry of Environmental Protection, the Guiyang Water Resources Bureau, and the Guiyang Municipality. The ADB team is especially grateful to Yuanyuan Li, Jianqiang Li, Aihua Li, Xin Wang, Wen Shuai, and Qiangzhong Kong for their attentive work, close coordination, and support.

Joy Quitazol-Gonzalez, Andrew Perrin, Priscila P. Del Rosario, Rodel S. Bautista, Anthony H. Victoria, and Kae Sugawara provided editorial and design services to produce and disseminate this publication.

Currency Equivalents

(as of 15 March 2012)

Currency Unit	–	yuan (CNY)
CNY1.00	=	$0.16
$1.00	=	CNY6.33

Weights and Measures

bcm	–	billion cubic meter
ha	–	hectare
km	–	kilometer
km^2	–	square kilometer
lpd	–	liters per person per day
m	–	meter
m^3	–	cubic meter
mcm	–	million cubic meter
mm	–	millimeter
1 mu	–	0.067 ha

Abbreviations

ADB	–	Asian Development Bank
GDP	–	gross domestic product
EWR	–	ecological water rights
IRBM	–	integrated river basin management
IWRM	–	integrated water resources management
PRC	–	People's Republic of China
US	–	United States

Executive Summary

This publication consolidates the highlights from several recent ADB technical assistance studies that relate to improving disaster risk management and water resources management in the People's Republic of China (PRC). The studies provided good references for examining how the PRC could holistically and simultaneously address its issues of water scarcity—especially drought, environmental degradation, fragmented and uncoordinated management, and climate-related disasters.

This publication also represents current thinking in the Ministry of Water Resources, with whom ADB worked closely on developing this knowledge product. It reflects the ministry's own sense of what the country's biggest challenges are and where the country is situated along the road to developing efficient institutions, lost and damaged resources, and responsible water usage. With a high level of government awareness, desire, and urgency to build resilience to droughts and consume resources at a more sustainable rate, the question becomes *how* to achieve this at the *municipal* level.

The PRC has a long history of supply-side management. With the natural imbalance between prime agricultural soil in the North and overly abundant water resources in the South, the PRC has depended for more than a millennium on its expert technocrats,

AFP China Xtra

The lowest water level on the banks of the Yangtze River, the PRC's longest and most economically important river, in Wuhan on 25 May 2011, where the water level was 40% lower than average levels of the past 50 years.

On the surface, the Nanming River provides a beautiful urban landscape, but its water quality drops dramatically as it winds through downtown Guiyang because of limited wastewater treatment and environmental enforcement. This affects the net water availability, which poses an especially high risk during drought.

engineering prowess, and abundance of labor. It has always been a "hydraulic civilization."[1] Now, the PRC must apply its engineering and technical strengths to saving water. Managing consumption not only requires technical solutions but also strong institutions and planning.

This publication is organized into five chapters. Each chapter begins by summarizing the magnitude of the challenges nationally and the general trend in thinking and results emanating from the central level. The second half of every chapter illustrates these realities in a specific place—Guiyang Municipality in Guizhou Province in the Southwest. The discussion on Guiyang begins with a detailed description of the place, which seems to be at a crucial moment in its development—between facing great risk and great potential.

Drought and Shortage—A New Normal or a Wake-Up Call? The first chapter introduces the scale of the challenges facing the PRC's general economic and social development because of constant water shortages in many places, the reoccurring menace of droughts, and a widening gap between what nature and engineering can supply versus what users from all sectors require. We propose demand management as a pathway to increased resilience to droughts and ecological conservation. We examine three tracks to getting on that pathway: risk management, optimal infrastructure, and ecosystem-based management.

[1] S. Solomon. 2010. *Water*. New York: HarperCollins.

Track 1: Risk Management. While the country has a finely tuned and sometimes stunningly agile disaster response system, a corresponding system of risk reduction and management does not exist. In effect, the country does not prepare for droughts; it only reacts to them. Infrastructure development may be alleviating some of the symptoms of water shortages, but it is not alleviating the fundamental determinants of shortages or addressing the risks associated with such severe impacts from droughts. The PRC is caught in a reactive mode to droughts and needs to focus policy and resources earlier in the disaster cycle. The country's focus on disaster emergency response should be expanded to *risk* management. Local governments need to understand their "weak spots"—the factors making them particularly vulnerable to droughts—and how to improve their chances by addressing the risk factors.

Our case study of Guiyang demonstrates the approach taken throughout the country, which tends to view infrastructure as a "root" cause of water shortages and vulnerability to drought. As a result, government has relied too heavily on engineering solutions. Guiyang's investments in infrastructure may be undermined by even stronger human and ecological factors at work. Guiyang could and should manage demand through any aggressive water-saving measures or tariff increases. Had it been managing demand among urban residents and industry, and preventing leaks in its piped networks, Guiyang could have had 20% more water during the Southwest drought and avoided much of the unnecessary losses and damages.

Track 2: Optimal Infrastructure. The PRC's rapid economic rise and social development have also led to rapid increases in demand for agricultural, industrial, and household water use, often leaving the environment without the minimal water amounts that ecosystems need to thrive and offer their value to economic production. The rise in water consumption has led to water shortages in many parts of the PRC, both from surface and groundwater, particularly in the North. Between 2001 and 2006, more than 400 cities experienced perennial water shortage, of which 11 cities had severe water shortages. This chapter looks at (i) raw water availability, (ii) extraction rates, (iii) demand (by sector: agriculture, industry, and urban/domestic), (iv) supply–demand balances, (v) water quality, (vi) responses to the supply–demand gap, and (vii) opportunities for saving more water through structural measures of demand management.

The Guiyang case study illuminates this track with encouraging findings from a cost–benefit analysis of structural demand-management options that would bridge a significant gap already opening between supply and demand. In all cases—for urban domestic users, industry, and in repairing system leaks—the economic benefits of water savings were far greater than the cost to achieve those savings. These benefits would be evident in increased supply for dry times, in avoided fixed and reoccurring costs of source development and water treatment, and in improved environmental flows.

Track 3: Ecosystem-Based Management. During the recent debate in the PRC regarding what actions need to be taken to reduce the risks of floods and droughts, it is becoming clear that a much more comprehensive approach needs to be taken to the whole question of water systems management in the PRC. This more integrated approach would treat water systems as complete ecosystems, taking into account all factors affecting the physical, chemical, and biological characteristics of both the water

A Chinese farmer holds dried vegetable seedlings in his drought-stricken fields in Zouping, in eastern PRC's Shandong Province, in January 2011.

system and its catchment with the aim to create a long-term and sustainable balance between the maintenance of a stable and intact ecosystem and meeting human welfare needs. The PRC has recognized the need to improve the comprehensive management of water resources, applying approaches consistent with integrated water resources management (IWRM) methodologies, and to shift the emphasis more toward managing demand, including the use of economic mechanisms. Achieving this, however, involves a reform process that is firmly established and well on its way to correcting the past, addressing the present, and preparing for the future.

Conclusion. Given the national challenges, which were illustrated at the local level through a case study of Guiyang, demand management is a technical and economically rational and reliable option for addressing constant water shortages and drought situations. The country's growing water deficit as a result of human demands has rendered the engineering, supply-side paradigm as increasingly inadequate. IWRM and a balance between supply and demand are necessary. Local governments, as demonstrated in the efforts of the Guiyang Municipality case study, must be deliberate in their reforms and balance their water ledgers. Studies are validating conservation as a viable investment and technically reliable option for closing the supply–demand gap and "de-stressing" the water resources upon which ecosystems, economies, and people have always and will always depend.

Drought and Shortage—A New Normal or a Wake-Up Call?

Experiencing consecutive years of severe droughts, constant water shortages, and a yawning gap between what nature and engineering can supply and what the private and public sectors demand, the central government is investing $608 billion into the water sector over the next 10 years and hoping the private sector will reciprocate. The government could get better mileage if it steered investments toward risk management, optimal infrastructure, and ecosystem-based management. These are three tracks to help relieve cities and ecosystems of water stress while building resilience and ecological health.

In March 2009, in the southwest provinces of the People's Republic of China (PRC), the typical wet season grew unseasonably dry. It was the onset of what would become an unusual and severe drought—one that would spread across a region equivalent to the size of Western Europe and send 20 million people looking and waiting for drinking water as streams, springs, and wells went dry in their rural and mountain communities. Again in 2011, in another usually lush swath of the country, the central and eastern regions saw the Yangtze River Basin parched by drought. At the height of the Yangtze drought, 3.5 million people had minimal drinking water. After 6 months of drought, the rains came—in deadly torrents that caused widespread flooding. The consecutive disasters of drought and flood reaffirmed climate change as a reality to which the country's consumption rates and management practices must adapt, or face even worse impacts from future disasters.

Drought is a natural occurrence in many places of the PRC—a force of nature that needs to be accepted and reckoned with by better systems of risk management and water resources management. Managing demand—reducing consumption and using water more efficiently—is a central element of both systems. The droughts in the Yangtze Basin and the Southwest, however, had been highly unusual. Precipitation dropped 90% during the Southwest drought and the summer growing season was 1.5 degrees Celsius hotter than normal. The drought began to lift by April 2010, exactly a year after it started. By then, however, it had covered areas in Yunnan, Guizhou, and Guanxi provinces and spread into parts of Sichuan Province and Chongqing Municipality. Sixty million people felt the effects of the drought, and 6.5 million hectares (ha) of agricultural land was compromised.[1]

More droughts like these are happening more frequently in the country and lasting longer. Climate change scenarios for the PRC show an increased likelihood of more severe storms and droughts. One of the most striking features of climate change is the impact it has on the monsoon system, bringing new precipitation

[1] ADB. 2010. *Strategy for Drought Management in the People's Republic of China*. Consultant's report. Manila (TA 7261-PRC).

patterns to the country. Severe precipitation in the southern region has brought flooding, while changing rainfall patterns have brought more droughts in the northern part of the country. The higher temperatures resulting from climate change will reduce runoff into lakes, reservoirs, rivers, and groundwater. Under heat stress, more water than normal will be needed for agriculture, cities, industries, and generating electricity. Yet the ability of the state to meet water demand in "normal" years is already strained, let alone in dry or drought-stricken times.

Without any comprehensive early warning system or mitigation strategies to protect people and economies, droughts have become a costly natural hazard. Between 2004 and 2007, droughts cost the PRC an annual average of $8 billion in direct economic losses. The economic impacts are only beginning to be assessed for the most recent droughts in 2010–2011, as the early rice planting season is likely to have been affected. Before the Yangtze drought, the country's worst drought in recent history occurred in 2000 in the northern plains and cost CNY47 billion ($7.4 billion) in direct economic losses. The Southwest drought cost CNY1.4 billion ($0.2 billion)[2] in direct economic losses. The costs of relief efforts are less well known, but they included hardship allowances, relief money donated by Chinese citizens, and costs to stabilize food production and prices.

The nature of droughts no longer disproportionately affects the countryside, which relies on the rains for their agricultural economy. The general growing scarcity of water has instigated competition for supplies, and in the absence of integrated management and decision making over rational allocations during normal times and acute shortages, the impacts have spread to the cities. Cities in the PRC are now growing more vulnerable to the effects of droughts because of the mismatched distribution of water resources in the South and large cities in the North, and high consumption rates in general. For example, the northern provinces, which are already suffering from natural and man-made recurrent water shortages, have experienced successive years of drought and mostly in cities. Between 2001 and 2006, more than 400 cities experienced perennial water shortages, of which 11 cities had severe shortages.[3]

When the effects of pollution are factored in, only about 30% of the country's total renewable water resources are usable.

The Supply–Demand Gap

Undermining the country's resilience to droughts is a general growing scarcity of water. The amount of available (usable) water in the PRC is far less than its total renewable water resources, a result not only of the natural characteristics of the country's diverse landscape and micro-climates but also of the fragmented and uncoordinated management of its economic development and natural resources. When the effects of pollution are factored in, only about 30% of the country's total renewable water resources are usable.[4] Of that, 20% is consumed annually, which, in isolation, does not suggest an unsustainable or critical situation. The crisis is at a basin level, where there is considerable variation and there are cases of consumption exceeding usable supply, leading to groundwater extraction.

Although groundwater consumption only provides about 18% of the water consumed on a national basis (equivalent to 108 billion cubic meters [bcm] per annum, which is nearly twice the level in the 1970s), 76% of this consumption

[2] Ibid.
[3] Ibid.
[4] J. Xie. 2009. *Addressing [the People's Republic of] China's Water Scarcity: Recommendations for Selected Water Resource Management Issues*. Washington, DC: World Bank.

is confined to areas north of the Yangtze River, where surface water resources are fully or almost fully utilized. According to the China Institute for Geo-Environment Monitoring (CIGEM), groundwater resources are overexploited in Beijing, Hebei, and Tianjin. Groundwater consumption in Henan, Shandong, and Shanghai is 80%–100% of recharge.[5] The Ministry of Water Resources says that under the 12th Five-Year Plan (2011–2015), total groundwater extraction will be strictly controlled, especially in the water shortage basins such as the Hai and Liao basins.[6] Deep aquifer exploitation will also be banned.

Adding further stress to available water supplies is the uneven distribution of water resources. The South is home to 69% of available water supplies, while the North is home to 64% of arable land for agriculture as well as some of the country's largest cities. The per-capita water availability in both regions is dangerously low. At 1,100 cubic meters (m^3) per capita, the southern population is within a hairline of the international water scarcity threshold of 1,000 m^3 per capita, while the North is operating 50% below the line at only 424 m^3 per capita. PRC's per-capita water availability is among the lowest of any major country.[7] Rainfall distribution follows the same North–South divide, ranging from 320 millimeters (mm) per year in the northern river systems (i.e., north of the Yangtze River) to 1,128 mm per year in the southern river systems.

The PRC has demonstrated its capacity to reduce demand. Total water consumption between 2000 and 2008 increased by about 7%, yet gross domestic product (GDP) increased over the same period by about 300%, indicating significant improvements in the economic efficiency of water consumption (Figure 1).[8] Yet at current rates, these figures are projected to open a water supply–demand gap equivalent to 201 bcm by 2030.[9]

Minding the Gap

Citing the recent Southwest drought as a warning signal, the State Council threw what it hopes is a lifeline to the ailing water sector. In January 2011, in its No. 1 Central Document, an annual policy document which outlines the country's priority development issue, the central government committed to invest $608 billion over the next 10 years in water supply projects, water quality improvements, water and soil conservation, ecosystem rehabilitation, irrigation, and managing increasing demand. This new investment level amounts to an annual doubling of what was spent in 2010.

While the policy document does not explicitly identify drought risk prevention or relief as a key outcome of the investment plan, addressing the country's water scarcity issues could contribute to better drought management if water savings are properly managed. The policy document aims to maintain the national water consumption at levels not exceeding 670 bcm in 2020, although experts predict that the

5 An "overexploited" groundwater resource is one in which annual consumption is greater than or equal to the recharge rate, which means that the groundwater resource is being "mined." This is usually associated with a decline in the level of the water table. In near coastal areas, this may also be associated with pollution of the groundwater resource by salt water seeping into groundwater depression areas. Seawater intrusion due to the decline of groundwater levels is mainly being experienced at the present in Shandong and Hebei provinces. The cumulative seawater intrusion area in Shandong Province is estimated to exceed 3,000 km^2.

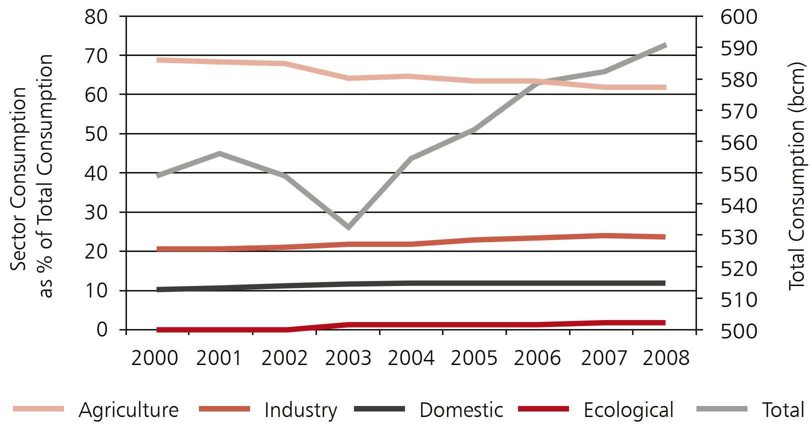
6 L. Chen. 2011. Enhance Water Security and Adapt to Global Climate Change. Speech at the High-Level Roundtable on Strategy of Extreme Climate Adaptation in the People's Republic of China. Beijing. 22 April.

7 See data from AQUASTAT, a global information system on water and agriculture developed by the Food and Agriculture Organization of the United Nations. Quoted in J. Xie. 2009. *Addressing [the People's Republic of] China's Water Scarcity: Recommendations for Selected Water Reource Management Issues*. Washington, DC: World Bank.

8 ADB. Forthcoming. *Toward an Environmentally Sustainable Future: Country Environmental Analysis of the People's Republic of China*. Manila.

9 2030 Water Resources Group. 2009. *Charting Our Water Future: Economic frameworks to inform decision-making*. Washington, DC. World Bank.

Figure 1 **Total and Sectoral Water Consumption in the PRC, 2000–2008**



bcm = billion cubic meter, PRC = People's Republic of China.
Source: National Bureau of Statistics.

PRC will exceed that amount by 2015.[10] The Minister of Water Resources says the country will accomplish this goal by following three red lines: less water exploitation, more efficient water use, and less water pollution. Instruments, such as water abstraction permits, water charges, and institutions that manage water at local levels, will also be strengthened.[11]

Despite the impressive investment levels, the question remains "Will it be enough?"

The answer depends on how much the investments focus on nontraditional measures and approaches. Traditional supply-side capture and storage solutions will still be required and could close the gap by as much as 35%.[12] But solutions must come from the other side as well. Demand must be scaled back, and technical and structural measures can provide the certainty that planners and engineers are looking for in solutions.

In determining the right mix of solutions, the PRC has to take into account some important facts of nature: uneven distribution of water resources, uneven rainfall patterns, and a natural proclivity to droughts—all in addition to climate change and a degraded environment. A critical aspect of addressing and preparing for water shortages and droughts is to introduce flexibility into the *source* of supply. This can be done in unnatural ways through diversions and other engineering measures, for which the PRC has the demonstrable ability, or it can be done naturally and in technically reliable ways, with which the PRC has far less experience, yet needs it.

The PRC has to take into account some important facts of nature: uneven distribution of water resources, uneven rainfall patterns, and a natural proclivity to droughts—all in addition to climate change and a degraded environment.

[10] Ibid.
[11] L. Chen. 2011. Enhance Water Security and Adapt to Global Climate Change. Speech at the High-Level Roundtable on Strategy of Extreme Climate Adaptation in the People's Republic of China. Beijing. 22 April.
[12] 2030 Water Resources Group. 2009. *Charting Our Water Future: Economic frameworks to inform decision-making*. Washington, DC: World Bank.

Demand management, especially when driven by technical and structural measures, serves multiple functions and with a high degree of reliability. By increasing water supply through savings from various structural and nonstructural measures, demand management can create the opportunity for water reserves that reduce risks from drought impacts and help conserve ecosystem services, thereby building resilience to water shortages, droughts, and climate change.

International experiences show that demand management is the leading approach for addressing water shortages and building the resilience of water resources and communities to climate change.[13] In the United States (US), for example, an ongoing 10-year drought in the Southwest is forcing changes in the region's entire approach to water resources management and supply (Box 1). The physical, legal, political, and cultural dimensions of water management have to share the burden of the drought and cooperate on reforms.

New Normal?

The conundrum of climate change and droughts for governments is in the planning. The meteorological drought is difficult to plan for, yet its recent reoccurrence may be an indicator of a "new normal" that is marked by far less water availability for the foreseeable future. Lake Mead in the Southwest US, which is the country's largest shared reservoir, had a similar experience with the PRC's Yangtze River, where water levels reached 40% of their respective pre-drought levels.

PRC Prime Minister Wen Jiabao, while touring areas devastated by the Southwest drought, took a long and pragmatic view of the situation and called on local governments to prepare plans that would conserve water, control desertification, and restore the environment.

The Demand Management Pathway

This publication proposes demand management as a pathway to increased resilience to droughts and ecological conservation. We examine three tracks to getting on that pathway.

Track 1: Risk Management. This section looks at how natural conditions, environmental degradation, and climate change need to be addressed as they are substantial and growing risks to the country's ability to protect against and recover from droughts. Addressing these risks, however, is not part of the government's plan, which is currently limited to drought response, not risk management. The country also remains focused on infrastructure solutions, which may alleviate symptoms of drought without addressing the fundamental determinants of the recurrent issue of widespread water shortages.

Track 2: Optimal Infrastructure. Technical options exist for the supply and demand sides of the water sector, and both sides offer a reasonable level of certainty. The national government has signaled it will be cautious with new large-scale engineering works, such as reservoirs and diversions, and calls for reasonably sized new infrastructure coupled with water saving technologies and rehabilitation of existing systems. This section looks at the extent to which the country can rely on new water supply, and where demand-side structural options can make up the difference by improving the efficiency and productivity of bulk water consumers: agriculture, industry, and cities.

Track 3: Ecosystem-Based Management. This chapter examines the need to manage water consumption to preserve ecosystem services. Ecological conservation is a long-term benefit of demand management, so long as a portion

[13] Demand management programs in the United States, particularly by the Washington Suburban Sanitary Commission in Maryland, have also learned that a consequence of demand management is reduced revenues needed to support water supply agencies. A solution to the problem can be found in the development of a revenue-forecasting model, which would help determine the relationship between price and demand. Any proposed changes to water tariffs should be accompanied by an evaluation of the price elasticity of demand.

Box 1 **The Drying of the United States' West**

Standing on the Hoover Dam and looking upstream at Lake Mead, America's largest reservoir, the visitor notices a wide, white band ringing the cliffs. Nicknamed "the bathtub ring," this discoloration comes from minerals that were once deposited on the volcanic rock by the Colorado River and have become visible, as its level has dropped. It is one sign of a water crisis that threatens America's southwest. […]

The main reason why Lake Mead, currently only 40% full, has been getting emptier is a decade-long drought. Whether this is a cyclical and normal event, or an early sign of climate change, is unclear. […]

The other reason, says Douglas Kenney, the director of a water-policy program at the University of Colorado Law School, is the rapidly increasing demand for the river's water. The Colorado provides much or most of the water for many cities and farms in seven states—Colorado, Wyoming, Utah, New Mexico, Nevada, Arizona and California—before it peters out in the sands of Mexico.

[…] The metropolis closest to Lake Mead, Las Vegas, gets 90% of its water from this one source. […] Within a few years, though, it could leave Las Vegas' intakes completely dry.

The threat to Las Vegas is a good example of the four dimensions—physical, legal, political and cultural—of water in the West. For the physical, the standard response is to summon the engineers. Pat Mulroy, the boss of the Southern Nevada Water Authority, already has them digging a third intake […]. Given the weight of the water on top, this is fiendishly difficult and will not be ready until 2014. Ms. Mulroy also wants to pipe groundwater from the rural and wetter northern counties of Nevada to Las Vegas, but that has caused a vicious row.

Another response is to call in the lawyers. This was the preferred approach a century ago, in the era of the "water war." […] The problem is that the prevailing mother law took shape after two decades of record water flows, which became the basis for allocation. As a result, it apportions more water than there is in the river. For decades that did not matter, since there were so few people. Then the cattle, fruit and people using the river multiplied.

The law's seniority rules theoretically mean that, for example, the taps to Las Vegas would be shut completely before a single lettuce-grower in California's Imperial County lost a drop, which gives rise to the political dimension. These days, cooperation has supplemented, if not wholly replaced, the old rivalries among agricultural and urban users, and among the seven states. […]

The final dimension is the culture of the West. Does every middle-class house really need a lawn in a desert? Ms. Mulroy has already started paying Las Vegans to rip out their turf and opt for desert landscaping, which can be chic. Her own husband put up a fight but lost. So out went that lawn, too, just as the low-flow toilets and taps came in.

Source: *The Economist*. 2011. The Drying of the West. 27 January.
Note: This article was edited for brevity (as marked by "[…]") and clarity.

of water saved is retained in nature rather than reallocated for use by another sector. This chapter reviews how an integrated water resources management (IWRM) can strengthen water rights and allocation system and watershed protection. It also reviews the legal options that downstream users can employ to protect their upstream water sources through eco-compensation agreements. International experiences prove that demand management must be strategically designed and administered if it is to succeed in enhancing supplies for droughts and promote long-term ecological stability. A preliminary step is the right arrangement of institutions, roles, and responsibilities. This chapter examines how an IWRM may operate at a municipal level, why a single bureau is needed for municipal IWRM, and how it compares to current arrangements.

Case in Point: Guiyang

We apply the discussion of the three tracks to the demand management pathway to Guiyang Municipality in the southwest province of Guizhou. In many ways, Guiyang is an ideal case study. It is embarking on a tricky, but navigable, road to reform.

Guiyang's recent history fits the popular modern narrative of Chinese cities: rapid growth at the expense of its water resource base. Despite a history of serious environmental degradation in the province, Guiyang, as a new city, can still correct its growth trajectory away from heavy industry and resource consumption toward an economy that is based more on the technology and service sectors. It is also an important city in the government's effort to develop the southwest and far-west regions. The National Development and Reform Commission and the Ministry of Environmental Protection (then State Environmental Protection Administration) selected Guiyang to model the circular economy growth policy supported by the central government in the 11th Five-Year Plan (2006–2010). A circular economy is structured to bring more balance between economic growth and environmental protection. Guiyang was chosen not only for its proactive development of a circular economy but also for its low GDP and heavy economic dependency on natural resources. Guiyang is also pursuing and marketing itself as an "ecological city," with the intent of bringing its hard-core mining and manufacturing up to environmental standards, restoring forests and desert landscapes, and improving water resources and infrastructure.

A Sense for Place

Better thought of as a region with an urban center, a suburban periphery, and agricultural and mountainous communities on the wide margins, Guiyang has become a major transportation crossroad and an industrial hub for Guizhou Province, as well as an ecotourism destination. Since 2003, its GDP has consistently grown at 11%, and peaked at 14.3% in 2010, compared to the national average of 8.7%. Half of Guiyang's growth is attributed to the services sector, which expanded at 14% in 2009. The local economy's primary contributor is the tourism sector, growing


Guiyang Municipality

Guiyang Municipality is embarking on a tricky, but navigable, road to reforming its water resources management.

With abundant natural resources, Guiyang markets itself as an ecological destination for domestic tourists. Serious water sustainability issues threaten the city's prosperity, which was especially evident during the Southwest drought in 2009–2010.

at 25% in 2009, and with income from tourism rising 57%.

The attraction of Guiyang is its cheap land, abundant natural resources, amicable climate, and unusual diversity. At an elevation of 1,100 meters, Guiyang has a coolness that is tempered by its subtropical latitude. The city is strewn with attractive bodies of water, protective mountains, and deep mineral caves and beds. Winding, tree-lined promenades usher the Nanming River through downtown Guiyang, and decorous bridges and island pagodas give the river a majestic status as it traverses through the city.

Guiyang's people also give the place an unusually rich cultural climate. More than 23 different minority groups reside in the area, the most populous of which are the Miaos followed by the Hans. Of Guiyang's 4 million residents, two-thirds live in the three urban districts, which are growing faster than the suburbs. By 2020, nearly 72% of the population is expected to reside in these urban areas, mainly because of the growing services industry.

There are numerous natural resources to protect and sustain in Guiyang. It has one of the three biggest phosphorous mines in the country, one-fifth of the country's bauxite, and 50 other kinds of mineral deposits being mined. It is situated in the world's largest deposit of karst, where the limestone and granite belt runs throughout the Southwest, making it an inherently beautiful but fragile ecosystem. This karst landscape, in fact, plays a defining role in Guiyang's precarious water situation—its towering, craggy, porous limestone formations allow rainfall to elude capture and storage.

Despite its growing prosperity, Guiyang consistently ranks at the bottom of economic polls of PRC's cities. In terms of market opportunities, Guiyang ranked 43 out of 44 cities in the country, largely because of its low per capita incomes.[14] The average daily wage of a rural resident in Guiyang is $0.74, and more than half a million residents live on less than $0.50 per day. In a 2010 ranking of PRC's provinces, Guizhou Province—of which Guiyang is the capital—ranked last with a per capita GDP of only $1,500 (after the exchange rate was adjusted for purchasing power parity).[15] Guiyang's per capita GDP in 2008 was twice that level at $3,035.

With scarce agricultural land and intense mountainous farming, up to 17% of Guiyang has experienced stone desertification and 32.5% of the land is being compromised by soil and water losses. Decades of mining and primary processing, without modern technologies and management practices in place, have caused landslides, erosion, and pollution.

Trouble with Water

One of the greatest threats to Guiyang's development is its water situation. Guiyang's mountain topography, wet climate, and forest coverage (about 33%) make it an ecotourism destination; but these characteristics also disguise the area's sensitivity to water. A popular assumption prevails in Guiyang that forest coverage guarantees rain and a reliable source of water. Guiyang does receive a relatively high amount of precipitation, averaging 1,096 mm annually. However, almost half of it evaporates because of the rocky terrain of Guiyang's karst landscape. Also, the amount of rainfall within a year varies widely. In a typical year, 85% of the annual rainfall comes within a 5-month period—May to September. Geographic distribution is yet another problem. Northern Guiyang receives only 60% of the amount of rain received in the South.

Having rain is not the same as having usable water. The general reliability of rainfall has given Guiyang a false sense of security and fueled a tendency to prefer large-scale infrastructure solutions that will increase the city's storage capacity without simultaneously improving the way water is managed, used, and conserved. Proving this to people in a way that changes policy and consumption habits, and inspires innovation, is difficult—unless, of course, there is a drought. Droughts can be terribly convincing, for a little while. And that is exactly what happened in March 2009 in Guiyang.

Not until months after the expected wet season failed to come did the central government

Guiyang Municipality

The towering, craggy, and porous, limestone formations of Guiyang's karst landscape allow rainfall to elude capture and storage.

Guiyang Municipality

Guiyang's mountain topography, wet climate, and forest coverage make it an ecotourism destination, but they also disguise the area's sensitivity to water.

[14] Economist Intelligence Unit. 2010. Access the People's Republic of China Guiyang. (Purchased online from https://www.eiu.com/public/)

[15] International Monetary Fund. 2010. *World Economic Outlook*. Washington, DC.

Guiyang does not, and never will have, enough water storage capacity to satisfy the demand of its growing population and economy.

declare a drought, which legally allowed local governments in affected areas to receive disaster response funds and various other kinds of relief—pumps, vehicles, fuel, drinking water, some small bores, and wells. By the time the funds and supplies started arriving, many people, mostly in the rural areas, were already suffering from the grave impacts of the drought. Almost 1.3 million people were affected, and 725,000 were without drinking water. The media portrayals of the suffering (and, in some cases, starving) rural poor motivated donations and volunteers from around the country.

The biggest economic loser from the drought in Guiyang was the industry sector, which absorbed 54% of the total economic cost of the drought; agriculture followed at 39%. If the drought had continued for a second year and the municipal reservoirs had not been replenished, the city would have been without water unless all industry was immobilized.

The drought lifted, but not Guiyang's vulnerability to it. Drought is not a new phenomenon in Guiyang. In fact, the city has seen dry times before—800,000 people were affected by a major water shortage in Guiyang in March 2007. It is vulnerable partly because of the very nature of the place: the dependency of Guiyang's water supply on the previous season's flow, the highly seasonal variability of rainfall, and its karst limestone landscape. Yet the bulk of the factors that make Guiyang vulnerable comes less from nature and more from Guiyang's use of nature.

Guiyang Municipality

During the Southwest drought in 2009–2010, almost 1.3 million people were affected in Guiyang, and 725,000 were without drinking water.

The Real Problem: Not Nature

In the midst of the Southwest drought, the Asian Development Bank (ADB) gave the Guiyang municipal government and its water resources bureau a draft report on the findings of a study it had commissioned on water use and management in Guiyang.[16] Although the report was certainly timely, given the ongoing drought, it focused on the bigger, more fundamental, systemic, and long-term problems the city has with its water supply.

The main message of the report is clear: Guiyang does not, and never will have, enough water storage capacity to satisfy the demand of its growing population and economy. It does not have the geographic disposition for capturing water or the space for sufficient man-made storage reservoirs. More water supply will have to come from less traditional sources, such as water savings, risk management, environmental conservation, and integrated management. Yet none of these measures are really achievable with the way water resources are currently managed in Guiyang.

According to the Guiyang Hydrology Bureau, an estimated total of 4.5 bcm of water flow through Guiyang in an average year, but only 33% of rainfall and runoff in Guiyang can be captured and stored or kept in river flows because of its mountain terrain, karst deposits, high evaporation from stone desertification, and rapid drainage out of Guiyang through underground channels. Consequently, only about 1.5 bcm of water is available for use in Guiyang, of which 75% (or 1.1 bcm) are consumed. Local surface and groundwater resources in Guiyang translate to an average of 1,300 m^3 per person per year, compared to the national annual average of 2,156 m^3 per person.[17] That is not, however, what users actually receive. Leakages and losses from urban water facilities and irrigation infrastructure have to be figured in along with extraction rates of non-connected users.

A water shortage can reasonably be expected in Guiyang. As stated in the ADB study, for every 1% growth in Guiyang's economy, there is a corresponding 0.33% increase in demand for water; with an average economic growth rate of 11%, the demand for water in Guiyang will grow at 3.7% annually.[18] By 2020, Guiyang will need about 1.7 bcm of water. If more cost-effective options are not pursued, this water shortage would require Guiyang to import 0.2 bcm of water from outside its jurisdiction or recycle its wastewater. Both are expensive, capital-intensive options in terms of their construction costs as well as the recurring energy costs involved in distant, inter-basin transfers and water treatment. Reservoir walls and storage lakes are especially difficult to build in Guiyang because of the local geology and topography.

In many cases, it is cheaper to control demand levels, save water, and rehabilitate ecosystems than continually build more supplies. There is much water-savings potential if existing urban and rural water systems are repaired for leaks, and if industry, which is the largest water user, be required to operate according to efficient water-conservation standards.

Minding the Gap

ADB is assisting Guiyang with a $150 million loan for the Guiyang Integrated Water Resources Management Project (Box 2). The project will finance part of Guiyang's water sector development plan through to 2020, and aims to promote greater community involvement in

16 ADB. 2010. *Strengthening of Water Resources Management in Guiyang (IWRM towards Demand Management)*. Consultant's report. Manila (TA 4912-PRC).

17 J. Xie. 2009. *Addressing [the People's Republic of] China's Water Scarcity: Recommendations for Selected Water Resouce Management Issue*. Washington, DC: World Bank.

18 This water consumption growth rate does not figure in any factor of demand management. Actual usage is likely to be less with demand management measures implemented.

water resources management. It represents the country's first large integrated water resources management project at the municipal level. To lay the groundwork for the project, ADB is providing technical assistance to develop the capacity and enhance the effectiveness of the numerous government agencies overseeing the water sector.

Guiyang's major problems—insufficient supply, high consumption, system losses, water pollution, and fragmented management—begin and end with a natural condition: a limited availability of water. To address this fundamental condition, Guiyang's reform agenda covers the three tracks of water resources management that were outlined earlier for building resilience through greater balance between water supply and demand.

We revisit Guiyang's case regularly throughout this publication in order to make the discussion more meaningful and real. The type of development trajectory that Guiyang has risen from has played out repeatedly across the country over the past 20 years. Many factors drive change and can threaten imbalances between the natural world and humankind: private investments, people's will, public policy, and natural disasters. At the same time, cities need to grow, industries need to thrive, and rural areas need to continue producing. Nature can only yield for so long before it either requires correction or imposes consequences to social and economic development and prosperity.

Box 2 ADB Supports Sweeping Changes in Water Management in Guiyang, People's Republic of China

The Asian Development Bank (ADB) is helping the People's Republic of China (PRC) enact wide-ranging, integrated measures in Guiyang, the capital of Guizhou Province, one of the poor provinces in the southwest region of the PRC, to tackle growing water shortages caused by rapid growth and urbanization.

To support that goal, the ADB Board of Directors approved in 2009 a $150 million loan for the Guiyang Integrated Water Resources Management (Sector) Project. The project will finance a portion of Guiyang Municipality's water sector development plan through to 2020, and represents the country's first large integrated water resources management (IWRM) project being considered for investment at the city and/or municipality level.

To improve urban water supply, reservoirs, dams, transmission pipelines, and a treatment plant will be built. In rural areas, over 40 small reservoirs will be established, dilapidated irrigation systems will be restored, and tree planting will be carried out on sloping land. At the farm level, over 100,000 small water storage tanks will be built to collect spring and rainwater.

To lay the groundwork for the project, ADB is providing technical assistance to boost the capacity and effectiveness of the many government agencies that oversee the water sector. It also aims to promote greater community involvement in water resources management.

An innovative feature of the project is the introduction of a payment for environmental services scheme, which will provide a financial incentive to reduce pollution and make environmental improvements in areas where water supply reservoir work is being undertaken.

Source: ADB. 2009. *Report and Recommendation of the President to the Board of Directors: Proposed Loan to the People's Republic of China for the Guiyang Integrated Water Resources Management (Sector) Project.* Manila.

Track 1: Drought Risk Management

A recent ADB study of drought management in the PRC concluded that while the country has a stunningly agile disaster response system, it does not have a corresponding system of risk reduction and management. The country does not prepare for droughts; it only reacts to them. While droughts cannot be predicted, they can be detected earlier and people can be warned. Programs for reducing water use in normal times can create reserves when drought conditions prevail. Governments do not have to be as surprised by and as unprepared for droughts as they often are in the PRC.

The PRC experienced two drastic dry spells in 2010–2011. The first extended dry period began in October 2010 in a key wheat-producing region in the Northeast. The second dry period began in early 2011 in the typically lush Yangtze River Basin. As of June 2011, the price tag on relief efforts for the Northeast drought surpassed $1 billion for wells, diesel, fertilizers, and pesticides. World grain markets were at a precarious stage, as two-thirds of the country's wheat crops were affected.

At the height of the Yangtze drought, 3.5 million people had limited drinking water and cargo shipping was suspended for 224 kilometers (km) in the middle and lower reaches of the river. Rains in June 2011 brought relief but also deadly landslides in parts of Guizhou and Hunan provinces. Torrential rain and flooding, following the acute drought, affected 13 of the country's 33 provinces, killed 98 people and destroyed 27,000 houses.

The country's recent, successive years of drought have occurred in various swaths of the North and are a growing problem for cities. Before the 2011 Yangtze drought, the most serious drought in the history of modern PRC occurred in 2000 in the North. It affected more than 26 million people in 620 cities and towns in 18 provinces and cost CNY47 billion ($7.4 billion) in direct economic losses. The 2009–2010 drought in the Southwest, which has seen a relapse in some places in 2011, exposed the volatile nature of the hazard—to occur where least experienced. By government estimates, the Southwest drought cost CNY1.4 billion ($0.2 billion) in direct economic losses.

The general water stress in the North and the increasing number of droughts has convinced many planners of the need for big infrastructure projects, such as the South–North Water Diversion Project. It is the country's most ambitious attempt to control nature, and the world's largest. Three man-made channels will divert 23 bcm of water from the Yangtze River in the South to the northern plains and its 440 million people. The project is also being built to replenish severely depleted groundwater tables, and will cost $62 billion (twice the cost of the Three Gorges Dam, which was affected by the Yangtze drought). Project construction will be accelerated during the 12th Five-Year Plan period (2011–2015).[19]

The growing impacts of droughts suggest that there may be a greater determinant of impacts than what the greatest of engineering responses can solve. Infrastructure development is a rather risky strategy as it does not address the fundamental human and ecological drivers that are making droughts more unbearable and costly.

Human and Ecological Drivers

Three factors relating to the ecosystems in the PRC assure the regular occurrence of droughts in the country and the chances that these droughts will last longer and prove harder to recover from in the future unless the country begins managing the risks in addition to disaster response.

First, drought is a normal, recurring feature of the climate in the PRC, and severe droughts with major social impacts have occurred regularly in history. Records show that, between 206 BC and 1949, the PRC experienced a total of 1,056 severe droughts, indicating at least one such drought every 2 years. Between 1950 and 2008, 18 extreme droughts hit the PRC.

Second, environmental degradation—especially wetland destruction and desertification—has impaired nature's capacity to respond to droughts as well as meet the growing demand for water from industry, agriculture, and cities. According to the first large-scale national lake and wetlands survey undertaken by the State Forestry Administration, over 1,000 natural lakes and wetlands have disappeared since 1949,

AFP Photo/Mark Ralston

This file photo dated 7 March 2007 shows a rubbish dump on the edge of Poyang Lake, which is PRC's largest freshwater lake and is connected to the Yangtze River in Jiangxi Province. At that time, Poyang Lake was nearing record lows as a result of drought, causing severe water shortages for industrial and residential users.

[19] L. Chen. 2011. Enhance Water Security and Adapt to Global Climate Change. Speech at the High-Level Roundtable on Strategy of Extreme Climate Adaptation in the People's Republic of China. Beijing. 22 April.

and a total of 1.3 million ha of lake area have been reclaimed for both agricultural and urban development. The growing risk of flooding in the central and lower Yangtze region is partly due to the reclamation of floodplains for agricultural purposes and the increased siltation from erosion in the watershed. The Ministry of Environmental Protection presented the scale of water quality in a 2008 water quality survey of 3,219 water "zones," which are supposed to be monitored and evaluated by the local governments for compliance to water standards. The survey found that only 43% of those zones had water quality consistent with their functional classification. For example, only 37% of surveyed zones classified for centralized drinking water actually maintained the appropriate levels of quality.

Third, climate change is aggravating the country's proclivity to droughts. Higher temperatures and heat stress lead people, land, and machinery to require more water, yet the runoff into storage and groundwater is decreasing. National and regional rainfall patterns have changed significantly over the past 20 years.[20] The most dramatic changes are in the northern river basins, where demand is high and water is scarce. Rainfall in the North has been 2%–10% less and runoff 10%–40% less because of changes in land use.[21] Global warming is likewise causing increased rainfall intensity and increased risk to floods. As a result of climate change, the country's water resources rank in the medium–high range of vulnerability to impacts.[22] The national climate change assessment concluded that global warming would increase the frequency of floods and droughts. Between 2004 and 2007, droughts cost the PRC an estimated annual cost of $8 billion in direct economic losses, threatening food security and rural social development.[23]

The incidence of certain types of hydrometeorological events has increased in recent years, largely because of the effects of global warming. For example:

- Floods in the seven major rivers, including the Yangtze, Yellow, Pearl, and Huai, have increased in frequency compared to the 1960s and 1970s;
- The incidence of typhoons during the 1976–1990 period (174) was 28% higher than the 1951–1970 period (136); and
- The total area of farmland affected annually by drought increased from around 10 million ha in the 1950s to 25 million–30 million ha in recent years (annual grain losses due to drought generally account for more than 50% of total grain losses due to all natural disasters).[24]

The overextraction of water resources is exacerbating the ecological limitations in many places. The Yellow River and one of its most important tributaries, the Qinhe River, are examples of the human systems overriding natural ones. Since 1970, the average runoff depth of the Qinhe has declined by 85 mm. Changing rainfall patterns and other climate variations are responsible for about 46% of this change, while the balance is attributable to human factors: coal mining, rainwater harvesting, industrial and agricultural water use, and groundwater extraction. The story of the Yellow River is the same, evidenced by frequent flow disruption in the lower reaches and a gradual decline of water flowing into the sea (Box 3). Reducing the adverse impacts from human factors could offset climate factors. The water savings that demand management

20 Y.Y. Li. 2010. *Water Resources Situation and Water Demand Analysis in the People's Republic of China*. General Institute of Water Resources and Hydropower Planning, Ministry of Water Resources. Presentation given to ADB, Manila, Philippines, 47 pp.

21 The northern catchments, because they are so susceptible to water shortages, are also highly regulated. Storage capacity in the 3-H basins is equivalent to more than 90% of average annual runoff. The average for the PRC as a whole is less than 20%.

22 C.A. Sullivan and C. Huntingford. 2009. *Water Resources, Climate Change and Human Vulnerability*, 18th World IMACS/MODSIM Congress. Cairns, Australia. 13–17 July. Available at: http://mssanz.org.au/modsim09.

23 Economics of Climate Adaptation (ECA). 2009. *Shaping Climate-Resilient Development—A Framework for Decision-Making*. A Report of the Economics of Climate Adaptation Working Group. Beijing.

24 S. Yafeng. 1996. Trend of Natural Disasters under the Influence of Global Warming. *Journal of Natural Disasters*. 5 (2).

Box 3 Water Allocation Management in the Yellow River Basin: Potential for Water Trading

The Yellow River, at 5,464 kilometers (km), is the fifth longest river in the world, traversing nine provinces and regions of the vast territory of the People's Republic of China (PRC). It arises from glacial springs on the Qinghai–Tibetan Plateau and drops 5,000 meters in its eastward course through a serious of gorges, bringing much-needed water to the arid north.

Management of the Yellow River Basin is critical for PRC's agricultural production and socioeconomic development. The cultivated area in the basin is about 13% of the total cultivated area in the PRC, but the basin holds only 3% of the country's water resources. At the same time, the basin provides water to an estimated 150 million people—both inside and outside the basin area—and rapidly growing industries in the downstream area and, more recently, the midstream area, where mining and industries are expanding. As a result, the basin faces severe water shortages.

In the 1990s, the Yellow River dried up, 750 km from its mouth in the Bohai Sea in 1997, triggering significant concern both within and beyond the PRC. To address years of river-flow cutoffs, the government, including the Ministry of Water Resources (MWR) and the Yellow River Conservancy Commission (YRCC), enforced the cross-provincial, quota-based Water Allocation Agreement of 1987 through the Unified Water Flow Regulation (UWFR) in 1999. According to the water-simulation model of the YRCC, annual water consumption under the UWFR is lower—by 11% (34.5 billion cubic meters compared with 38.3 billion cubic meters, under the scenario without regulation). At the same time, the basin-wide gross domestic product (GDP)—at CNY1,247 billion ($195 billion) under the UWFR scenario—is 10% higher than the scenario without regulation (at CNY1,123 billion or $176 billion). In the last decade, the YRCC has also implemented an integrated operation of reservoirs along 3,000 km of the river, to regulate river flow and boost storage capacity. With these combined measures, the river has flowed again during the past years, and it constitutes a remarkable achievement with significant ecological and other benefits. In 2010, the YRCC was awarded the Lee Kuan Yew Water Prize, a prestigious award that recognizes outstanding contributions toward solving global water problems by either applying technologies or implementing policies and programs which benefit humanity.

However, it was argued that the UWFR did not take into account the value of water in various uses, and water users who were forced to give up their water resources—primarily irrigators in the upstream and midstream provinces—were not compensated. A water trading scheme will be an effective instrument for recognizing the value of water and their services, and further increase the water allocation efficiency of the 1987 cross-provincial Water Allocation Agreement. According to the estimation, with the water trading scheme adopted, the annual water consumption could be slightly lower at 33.8 billion cubic meters than the annual water consumption under the UWFR allocation scenario while total GDP is higher at CNY1,270 billion ($199 billion) in the former scenario. As expected, water users upstream use less water under the water-trading scenario compared to the UWFR scenario (a decline of about 3.27 billion cubic meters), while midstream and downstream users use more (2.55 billion cubic meters). Thus, upstream users tend to sell water to gain revenue, while downstream users buy water for greater water-use benefits.

Ongoing intra-provincial irrigation-to-agriculture transfers provide important inputs for the potential development of inter-provincial water trading, which can improve the net benefits of water users in the basin as well as the overall basin water use efficiency. This instrument has been discussed for several years by both policy makers and water allocation managers at the MWR and the YRCC. If adopted, water trading has the potential to further mitigate growing water shortages in the Yellow River Basin.

Sources:

1. X. Cai, Y.-C. E. Yang, J. Zhao, and C. Ringler. 2010. Water Allocation Management in the Yellow River Basin: Potential for Water Trading. *Yellow River Basin: Living with Water Scarcity*. July.
2. D. Pietz and M. Giordano. 2009. Managing the Yellow River: Continuity and Change. In F. Molle and P. Wester. *River Basin Trajectories: Societies, Environments and Development*. Wallingford, UK: CAB International.
3. J. Ma. 2004. *[People's Republic of] China's Water Crisis*. Norwalk, CT: EastBridge.

produce through structurally reliable ways can create reserves that the ecosystem needs to mend and fend off the rising severity of droughts.

Responding to Risks, Not Just Disasters

In 2010, ADB released the results of a study on drought management practices in the PRC. The consultants concluded that while the country has a finely tuned and sometimes stunningly agile disaster response system, a corresponding system of risk reduction and management does not exist. In effect, the country does not prepare for droughts; it only reacts to them. An agency to manage the risks associated with various disasters does not exist, and there is no national policy requiring local governments to establish or implement drought risk reduction strategies.

Drought is currently managed as part of an emergency and disaster relief process, which is primarily designed for floods. The disaster response system has been good at coping with short-term emergency needs, but it is less suitable for managing a multi-year, widespread drought or drought as a natural and common climatic event. The ADB-supported National Flood Management Strategy came to similar conclusions as the drought study—greater risk assessment, monitoring, and an early warning system would greatly reduce response times and costs incurred from unnecessary losses, damages, and rebuilding. Box 4 discusses the value of disaster insurance and the study of its application for drought insurance in the PRC.

The PRC is caught in a reactive mode to droughts and needs to focus policy and resources earlier in the disaster cycle. The country's focus on disaster management should be expanded to

Xinhua/Shi Xinrong

A firefighter carries water for an elder in Qianxinan Buyi and Miao Autonomous Prefecture, in the southwest province of Guizhou, 26 August 2011. A severe and persistent drought in the province created a drinking water shortage affecting more than 5.47 million people.

Box 4 Drought Insurance—A Risk Management Tool

This case study demonstrates how drought insurance in the United States may have lessons for the People's Republic of China (PRC).

Drought Insurance for Cattle Ranchers in the United States

Prior to 2005, when drought struck, many ranchers in the United States had to sell their livestock because it simply did not make sense to have them, as there was little that could be done for them. To help the ranchers mitigate the risks from drought, which many states suffered from in the 1990s, the United States Department of Agriculture began piloting in 2006 drought insurance products in nine states. A pair of possibilities—a rainfall index and a vegetative index—was developed. Six out of the nine states offer just the rainfall index.

The rainfall index is based on the National Oceanic and Atmospheric Administration (NOAA) information dating back to 1948. Using a grid system, which breaks down land into 12-mile by 12-mile patches, and applying NOAA's moisture records, the average rainfall for each 12-mile patch can be determined over a span of nearly 60 years. Ranchers who sign up for coverage may determine how much of their land they want insured as well as when they want it covered. Coverage is offered in 2-month intervals.

For example, a rancher may choose to insure 75% of the average rainfall spread across six 2-month periods. If the rancher receives 1 inch of rain during a time when the average rainfall is 4 inches, the rancher would receive an indemnity equal to 66% of the coverage available for that 2-month period. This is because 1 inch represents one-third of the guaranteed rainfall.

According to the assessment, the payments from the insurance program are often enough for ranchers to pay for supplemental feed and these claim payments increase with the severity of the drought.

When the drought insurance product was introduced, expectations were that roughly 10% of those in eligible areas throughout the nation would sign up, and they have generally been met. Many states have viewed the drought insurance product as an effective risk management tool.

Drought Insurance in the PRC—Opportunities and Challenges

PRC's agricultural production is highly exposed to natural disasters and the potential impact of climate change. Traditionally, Chinese farmers turn to a variety of ad hoc coping strategies, from diversifying their crops to, more commonly, borrowing money from friends and relatives or relying on remittances.

Since the 1990s, the central and provincial governments have supported farmers through premium subsidies for a national multi-peril crop insurance (MPCI) program, which covers a variety of crops for risks including rainstorms, flooding, waterlogging (oversaturation), strong winds, hail, frost, disease, pests, and rodents. However, drought, as one of the main weather risks, was not covered, and the time-consuming as well as inaccurate loss adjustment procedures have become its key challenges.

A joint index (weather) insurance pilot targeting drought incidence was launched in 2008 by the World Food Programme (WFP), the International Fund for Agricultural Development (IFAD), and PRC's agriculture ministry. Yanhu Village in Changfeng County of Anhui Province, one of the 592 national poverty counties, was selected as a pilot for the drought insurance product. Guoyuan Agricultural Insurance Company (GAIC) was selected to join the project. Apart from underwriting the risk and subsidizing the pilot product, it participated in the product design and is responsible for marketing. After the approval of the drought index insurance by the China Insurance Regulatory Commission (CIRC), the insurer GAIC sold a group insurance policy to Yanhu Village, which bought it as a complement to MPCI, as the latter does not cover drought risk. According to the approved weather index, if the cumulative rainfall from 15 May to 31 August is less than 230 millimeters (mm) or the cumulative rainfall from 1 September to 15 September less than 15 mm, the payout is triggered and farmers will receive the payment from GAIC.

continued on next page

Box 4 *(continued)*

Despite its early stage, the pilot has garnered some significant results. A total of 482 farmers purchased policies, and the strong commitment from the government and insurer has been encouraging for the future of the drought insurance program. IFAD's recent assessment also suggested that client understanding and trust, sustainability of financial subsidies, weather data availability and structure, and capacity building of local stakeholders will be the key factors affecting the success of future drought insurance in the PRC.

Insurance itself does not reduce damage and consequent financial losses, but by providing a previously agreed level of compensation in response to premium payments, it delivers cash quickly to fund recovery when it is most needed. Insurance relieves governments of pressures for relief money at such time, and also hastens an otherwise slow and frustrating recovery process because of bureaucratic procedures.

Sources:
1. International Fund for Agricultural Development and World Food Programme. 2010. *The Potential for Scale and Sustainability in Weather Index Insurance for Agriculture and Rural Livelihoods*. Rome.
2. D. Austin. 2007. Drought Insurance. *The Cattleman*. February.

risk management. Local governments need to understand the factors making them particularly vulnerable to droughts and how they can improve their resilience by addressing the risk factors.

The difference between drought risk management and drought disaster management is the management timeframe and actions taken.

- *Risk management is a proactive approach* focused on the design of measures that will be put in place in advance of a drought to prevent or mitigate the level of risk exposure and, hence, vulnerability to impacts. This approach seeks to build resilience in the systems through structural and nonstructural measures on an ongoing basis.

- *Disaster management is a reactive approach* based on the implementation of measures and actions after a drought disaster is recognized. This approach applies to emergency situations and is likely to produce inefficient technical and economic solutions since actions are taken under stress without the time to adequately evaluate options. This tends to support dependence on emergency relief measures rather than resilience.

Figure 2 outlines the difference between a reactive and a proactive approach for drought management. The proactive approach is more complicated but supports a longer term outcome compared to the reactive approach. It leads to improved resilience, better planning, and more timely actions.

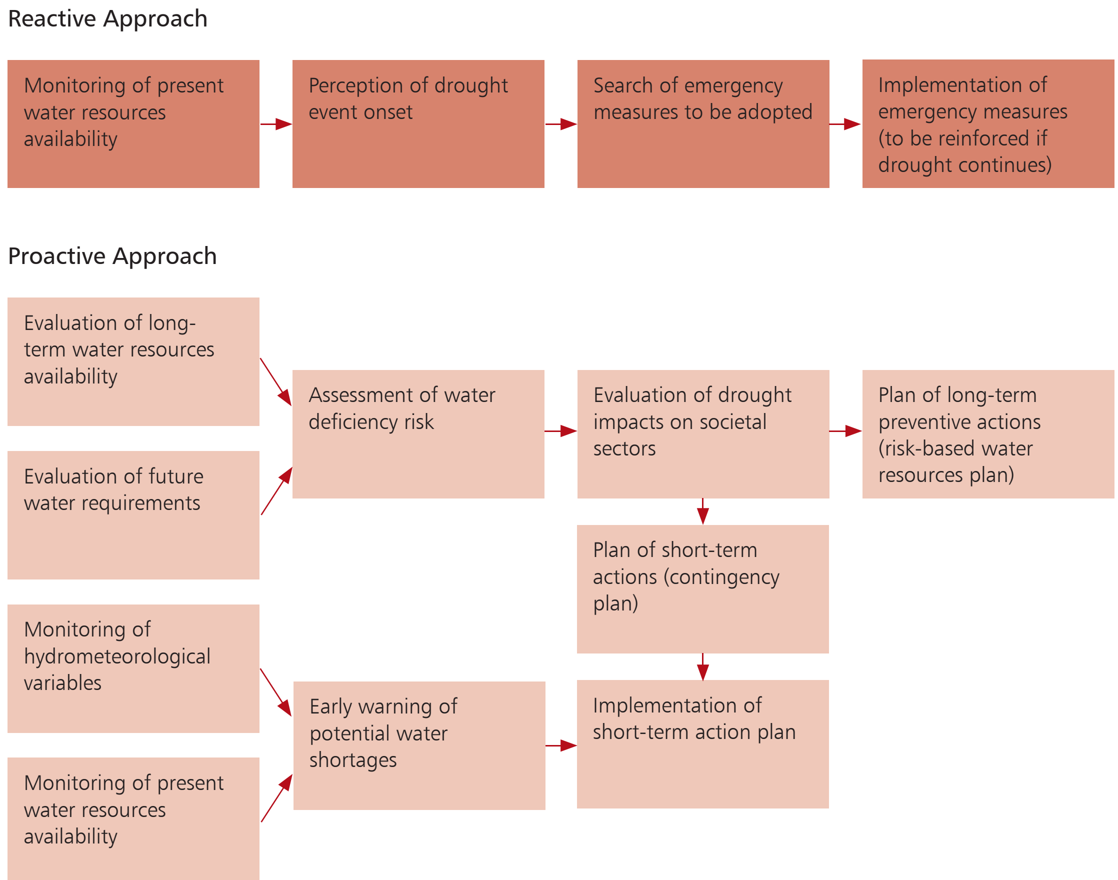
Steps to Greater Risk Management

There is no way to prevent a drought, but there are ways to mitigate its impacts on and reduce losses by those who are affected. A drought plan is a comprehensive risk assessment of all water uses. Water conservation (demand management or water savings) is a central theme of risk management strategies and drought plans.

Drought risk management is based on the following steps and actions:

1. Monitor and forecast for early warning;
2. Assess risks of water shortfall;
3. Mitigate risks by balancing supply and demand;
4. Reduce and manage demand;
5. Enhance drought supply;
6. Mitigate impacts and respond to emergencies;
7. Recover, evaluate, and plan contingencies; and

Figure 2 **Comparison of Reactive and Proactive Approaches to Drought Issues**



Source: ADB. 2010. *Strengthening of Water Resources Management in Guiyang (IWRM towards Demand Management)*. Consultant's report. Manila (TA 4912-PRC).

8. Involve stakeholders and educate the public.

This approach has been developed and tested internationally and applied to different national contexts.

Costs and Benefits of Risk Management

Risk management begins with a comprehensive risk assessment of all water uses so as to plan measures to be taken in accordance with the steps enumerated above. In this section, we demonstrate some costs and benefits of risk management in Guiyang. But demand management will be highlighted in this publication as it is an integral part of any drought risk management planning, particularly when a critical imbalance between supply and demand exists (Box 5).

Over the past 10 years, average annual disaster losses increased by about 30%, from CNY194 billion ($30 billion) in 2001 to CNY252 billion ($40 billion) in 2009.[25] In an

[25] L. Jiang, J. Wang, and L. Liu. 2008. *Providing Emergency Response to Wenchuan Earthquake: ADB TA 7081-PRC*. Report prepared for ADB, Manila, 195 pp.

Chinese villagers lay water pipes during a drought in Aoxi town, Yuqing County, Zunyi City, Guizhou Province in southwest PRC, on 1 September 2011. A lingering drought has left more than 12.6 million people short of drinking water and huge tracts of farmland parched in the PRC's southwestern regions. The State Flood Control and Drought Relief Headquarters said that a total of 6.24 million hectares of farmland nationwide has been affected by the drought. It has also caused water shortages for 14.54 million people nationwide.

average year over the 2001–2009 period, natural disasters affected 379 million people and killed 11,986 people (2,368 if the Wenchuan earthquake of 2008 is excluded), collapsed 2.8 million houses (1.8 million if Wenchuan is excluded), and incurred economic losses of CNY315 billion ($49 billion) (CNY207 billion or $32 billion if Wenchuan is excluded).[26]

The losses and damages suffered by the PRC from droughts are significant, averaging $8 billion annually in direct economic losses between 2004 and 2007.[27] Over the past 10 years, 66 million tons of grain were lost every year because of drought conditions. This is 7% of annual production and valued at CNY33 billion ($5 billion). Annual industrial losses from drought conditions are over CNY230 billion ($36 billion). Since 1990, direct economic losses from drought account for more than 1% of annual GDP. The scale of recurring losses with every new drought is an indication of opportunities for savings.

Costs. The costs of a risk management strategy are the costs of measures taken to reduce drought impacts and losses, and demand management is a significant risk mitigation measure. For example, the cost of better models to forecast drought and inform stakeholders in advance would be a cost of risk management. Farmers may invest in drought-resistant seeds, which, if more expensive than normal seeds, will be a risk management cost. The cost of water conservation measures to save water for use before and during a drought may involve the cost of new fixtures, appliances, technologies, and public awareness campaigns for domestic, public, commercial, industrial, and agricultural users. Reduction in water losses of

26 Ministry of Civil Affairs. 2010. *Civil Affairs Development Statistics Report of Year 2009*.

27 Economics of Climate Adaptation (ECA). 2009. *Shaping Climate-Resilient Development—A Framework for Decision-Making*. A Report of the Economics of Climate Adaptation Working Group. Beijing.

Box 5 **Rational for Demand Management as a Resilience Strategy**

Demand management is an important and economically, technologically reliable option for improving supply levels as a means for raising resilience to water-related disasters and for sustainable water resources management. This is because demand management

- can be implemented more quickly than new infrastructure.
- increases water levels in existing reservoirs before a drought hits, carrying over more water than would have been available into successive dry years.
- is cost-effective compared to new supplies.
- provides solutions to generalized water shortage.
- does not require new treatment or discharge facilities.
- can be implemented in phases and in response to conditions.
- reduces energy use when hydropower production declines during a drought.
- leaves more water for wetlands and habitats.
- requires less displacement of people.

Source: ADB. 2011. *Planning Ahead: The Economic Basis for Drought Risk Management. The Case of Guiyang Municipality.* Consultant's report. Manila (TA 7261-PRC).

water companies due to leakages will require new equipment for the detection, location, and repair of leaks.

Benefits. The benefits of risk management are defined as the avoided losses or costs that would have occurred in the absence of risk management measures. For example, if early warning of drought causes a farmer to switch to drought-resistant seeds, the avoided loss in income is a benefit of risk management. If actions are taken before a drought that reduces subsequent costs of relief and recovery, the savings in public funds are also counted as a benefit. All of the reductions in damages or costs that would have occurred without risk management are counted as benefits of this approach.

By providing more water in time of drought, conservation reduces the losses and damages from it. In addition to these avoided losses, water conservation can provide water at a lower cost than traditional sources. These cost savings are also counted as a benefit. Conservation extends the existing community water supply. It is real water. No longer needed by one segment of the community, it makes that water available for someone else to use. In effect, it is no different than the next increment of a new water supply. The difference between conserved water and "new" water development is that developing new water involves the costs of land, construction, materials and equipment, as well as the costs of treatment and safe wastewater disposal. There may also be costs of resettlement and environmental mitigation. On the other hand, these facilities have already been constructed and are operating to take care of a conserved water supply. All of these costs are "avoided costs" (benefits) of conservation.

Ecological risks of naturally-induced disasters, overextraction, degradation, and climate fluctuations can be neutralized through demand management for more sustainable water reserves, which allow the human and natural systems to respond to stress over time.

Case in Point: Guiyang

The drought that occurred in Guiyang in 2009–2010 was part of a widespread drought across the southwest provinces. Reservoirs

AFP Photo

A team of workers starts preparing to dig a new water well amid a drought in the village of Qujing, Yunnan Province, on 28 March 2010. Millions of people face drinking water shortages in southwestern PRC because of a once-a-century drought that has dried up rivers and threatens vast farmlands in the huge areas of Guizhou, Yunnan, and Sichuan provinces, as well as the Guangxi region, and the megacity of Chongqing.

were reduced to dry cracked earth with intakes abandoned. Isolated villages suffered from a lack of basic drinking water as streams, springs, and wells went dry. Crops were lost, crop yields and industrial production fell, livestock suffered, and fisheries and forests were badly affected. Control and prevention of infectious diseases became a concern.

A drought of this nature has been uncommon for Guiyang and this region. As the impacts of the disaster became apparent, those responsible for disaster relief, from the Central Committee and the State Council, to officials and volunteers at all levels, organized to minimize the losses, provide relief to those affected, and encourage recovery. Drought relief actions taken during and after the disaster included efforts to improve local information, deliver local drinking water, develop wells or transfer water supplies, provide financial assistance, and bring demonstrations of new drought-hardened seed and techniques to farmers and villages in the hope of improving results for the next spring planting. In the aftermath of the drought, the government replanted drought-affected forestland and repaired damages in the reservoirs that had been exposed by low water levels.

All of these actions came with a cost, although the costs of these relief efforts are less well known than the direct economic losses. Based on government figures, they include hardship allowances (CNY20.8 million or $3.3 million), relief money donated by Chinese citizens (CNY21.5 million or $3.4 million), and costs to stabilize food production and prices (CNY3.1 million or $0.5 million). However, the full cost of government disaster relief efforts include the costs of developing new water sources or delivering drinking water to about 135,000 people and also for livestock; government-purchased equipment; reduced hydropower production; revenue losses to utilities and government; and the tens of thousands of person-days committed. There are also costs associated with the loss of habitat and increased flooding, indirect downstream costs, and the longer-term effects on families. The true costs of the drought are never fully known.

Guiyang did have some contingency plans for droughts, but the local government had to wait until the central government had declared the drought an official disaster before it could access emergency funds and implement contingency plans. By that time, people in the rural areas were without drinking water. The rural population suffered most—1.28 million people were affected, and 725,000 were without enough water to meet basic daily needs. The worst affected areas lost entire seasons of crops and 170,000 people needed grain rations to survive.

The Guiyang government identified its own shortcomings, which include: (i) near-term actions to assist areas still affected by drought; (ii) medium-term actions in expediting infrastructure construction, investing in meteorological disaster forecasting, and better disaster contingency planning; and (iii) actions that build long-term resilience, such as water conservation and environmental protection.

Until the Southwest drought, Guiyang Municipality had not implemented a strategic demand management program.

Human and Ecological Drivers

Despite the experiences and lessons of the drought, experts doubt that Guiyang's response would fare significantly better if another drought occurred soon. The government's emphasis on the lack of infrastructure as a "root" cause of their chronic water shortages and vulnerability to drought is similar to the approach taken elsewhere in the PRC: an overreliance on engineering, which is discussed more in the next section. Guiyang's investments in infrastructure can be undermined by even stronger human and ecological factors at work.

Natural landscape. Guiyang, like nearly the entire Southwest region, faces a unique and fragile ecosystem, making it more sensitive to impacts from climatic conditions than realized by planners. The Southwest forms the world's largest terrain of karst limestone formations—600,000 square kilometers across eastern Yunnan, most of Guizhou and Guangxi, and into Chongqing, Sichuan, Hunan, and Heibei. The stretch of topography forms a giant slope, declining from the Northwest to the Southeast. Karst is naturally predisposed to stone desertification, poorer water quality due to higher erosion rates, surface collapse, and inaccessible water storage in deep aqueducts. The connection between Guizhou's poverty and landscape is textbook: the poorer an area, the higher the dependency of people on the environment and natural resources. The poorest people also tend to live where the environment's life cycles and ability to rehabilitate are low, and the environmental damage is most severe. The cross factor of poverty and difficult terrain for water capture and storage exposes Guiyang to even higher risks of impact. With the optimal infrastructure and risk reduction approach, its vulnerability to water shortages and droughts decreases.

Pollution. On top of the precarious water supply, the high pollution loads in Guiyang's rivers are further limiting its usable amount of water and creating the need for costly treatment systems. Two reservoirs that supply Guiyang's drinking water (the Baihua and Hongfeng) have a Class IV pollution rating (Class V being the most polluted). The Nanming River, which runs through the heart of Guiyang's urban areas, is of poor quality (Class III) as it enters the downtown area and deteriorates to Class V quality as it passes through the city. The downstream waters are unusable and untreatable by conventional methods.

Two pollution sources are to blame: the combined storm and wastewater drainage, and the extremely high industrial pollution loads. With an average of 120 days of heavy rain every year, storm water and wastewater regularly overflow and pollute rivers. Industrial waste, even when treated to standards, has extremely high pollution loads. Naturally, the dirtier the water, the costlier pollution is in terms of both economic losses and treatments costs. Other cities in the country have estimated that the water they have lost to pollution is equivalent to an annual economic loss of 2% of GDP.

Climate change. Guiyang's karst landscape makes it especially sensitive to higher temperatures. It is prone to stone desertification, high evaporation losses, and runoff without the benefit of capturing water. Annual rainfalls average about 1,000–1,300 mm. Changes in rainfall patterns would create an even higher volatility in an area that already sees stark distribution in rainfall. About 80% of rain falls between April and September. The yearly variations can also be significant, from a high of 1,273 mm to a low of 765 mm. Annual rainfall data shows there can be consecutive periods of low rainfall, and rainfall well below the mean can occur for a period of 9 years.

Opportunities for Risk Management

While water sensitivity may register higher in places like Guiyang, the systems to reduce exposure to risk and to better prepare for droughts are simply not in place. First, monitoring systems are not in place to detect when a prolonged dry season or drought may be on the horizon and just how far away. Second, even if officials in Guiyang did recognize a potentially dangerous dry season, the system does not allow them to respond until an emergency has been declared by the central government, which releases the relief aid. This is often too late to spare people the hardship from the onset and early months of the drought.

The reactive approach of the PRC to drought management relied more on drought relief instead of on proactive risk avoidance and management. Although there is prior organization and planning efforts on how to alleviate the impacts of drought, they focus on what to do after a drought emergency has been declared. In the interim, before the impacts become dramatic, there will have been great losses, some of which could be prevented had an early forecast and warning been issued and adaptation measures taken.

Actions planned after the drought, such as the construction of new facilities, are intended as preventive actions for a subsequent drought. This reserve of water, certain to be reduced by less precipitation during a drought, is often fully utilized for a wholly new population occupying new urban development, creating an even larger population vulnerable in terms of their water needs when the next drought occurs.

As an element of risk management, Guiyang does not attempt to manage demand through any aggressive water-saving measures or tariff increases. The master plan for Guiyang does recognize the need for demand management, although its solutions favor supply-side development. However, the plan

- recognizes that supply problems are caused not by the absolute shortage of water, but rather by the timing and location of rainfall and the inefficient use of water;
- recognizes the need for environmental and ecological water flows;
- identifies the benefits of water savings;
- pursues wastewater treatment and recycling to prevent pollution;
- prioritizes drinking water while aiming to reliably meet the needs of other users;[28]
- proposes measures to improve irrigation efficiency and raise farm incomes; and
- identifies ways to make industries more efficient with their use of water.

To see that these major tasks are pursued, Guiyang has established a project leading group. It has initiated its own "Water Saving Society Program"

[28] Local conditions and preferences need to be carefully considered before implementing responses to drought. For example, prioritizing water for critical services and industries, while ensuring at least a few hours of drinking water per day, may be necessary to avoid risk of unemployment as a result of drought.

as a bid to become one of PRC's next pilot cities, and has also enforced a licensing system for water abstraction. A comprehensive water demand management program, based on international best practices, would include three major components: water-saving technologies discussed in the previous chapter, regulatory methods such as pricing, and improved management.

The ADB-financed Guiyang Integrated Water Resources Management Project will strengthen Guiyang's water management capacity with a variety of nonstructural demand management and risk management measures, which are not covered in the master plan for Guiyang. Policy, institutional, and IWRM-based reforms will coincide with the design and construction of the infrastructure subprojects. In addition to the wastewater treatment plant, surface water quality in Guiyang will be improved through reforms and new processes and systems for discharge control, non-point source pollution control, reservoir catchment pollution protection, and soil conservation.

These reforms will promote stakeholder participation and cooperation, sustainable operations and maintenance of new infrastructure, resolution of water conflicts, and water conservation. Like the rest of the PRC, Guiyang needs an aggressive and comprehensive demand management strategy to reduce its vulnerability to droughts. Demand management is the single most effective early adaptation or risk management measure for droughts.

Benefits of Demand Management in a Drought Scenario

In the aftermath of the Southwest drought, the direct economic losses of Guiyang Municipality were estimated to reach CNY1.35 billion ($212 million). Industrial losses were the highest at CNY732 million ($115 million), followed by agriculture at CNY540 million ($85 million).

Guiyang could have had 20% more water during the Southwest drought had it been implementing effective demand management.

The next chapter discusses a cost–benefit analysis of various demand management programs for urban domestic users, industry, and leakage prevention. The analysis found that Guiyang could have had 20% more water during the Southwest drought had it been implementing effective demand management in these sectors.

The highest economic losses during the Southwest drought in Guiyang came from industry; hence, finding ways to become more efficient in industrial water use is critical. If lack of water during the drought accounted for the direct economic losses, then making more water available through conservation and recycling during a drought will avoid some or all of the losses during the next drought.[29] A comparison and indicative analysis of similar industries and demand management programs in Silicon Valley in California show that the cost of implementing a similar demand management program in Guiyang, and reducing industry's risk to drought, would have been a fraction of the losses. Although such a program for Guiyang's industry would come with an investment cost of approximately CNY137 million ($21.5 million), this compares favorably with the industrial losses of CNY732 million ($115 million) incurred from the drought.

More importantly, these efficiency changes would remain in place for future water shortages and drought at no additional investment. In effect, the risk to droughts is managed once a company implements water efficiencies. If it does not, however, and another drought occurs, the losses suffered before will be repeated because the risk has remained the same.

[29] Not enough is known about the specific industrial plants and their practices or the cost of applying water-saving and recycling technologies in the PRC. Each case should be analyzed for the specific monetary costs and benefits.

Track 2: Optimal Infrastructure

Reservoirs, dams, and diversions will still be needed to a limited degree, but would be more optimal if combined with investments in demand-side structural and nonstructural technical measures. Water-saving fixtures, leakage protection, and efficiencies for irrigation and industry offer the reliability planners look for, but at a fraction of the cost of new water source development.

A common response to the widening gap between supply and demand, especially in the aftermath of a drought, is to seek out more infrastructure solutions for the capture, storage, treatment, and delivery of water. These solutions are expensive and carry even higher costs associated with the expansion and operation of wastewater treatment facilities. They also may not be completed before the next drought occurs or, if completed, may still not be enough to meet the increasing demand of an ever-growing population. However, from the perspective of water planners, infrastructure carries an element of certainty: a structure has been built that will store a certain amount of water to be delivered.

The PRC has a long history of supply-side management. With its natural imbalance between prime agricultural soil in the North and overly abundant water resources in the South, the PRC has depended for more than a millennium on its expert technocrats, engineering prowess, and abundance of labor. The Grand Canal, completed in the early 7th century, is still the world's longest artificial waterway. And while the Romans were limited to the waterwheel for grinding grain and mining, the Chinese scaled it up and put it to industrial use, first in making silk. It has always been a "hydraulic civilization."[30]

Nonstructural technical solutions are under-estimated as second-best options. Planners typically consider conservation or demand management an additional way that the population can "help," but conservation is not perceived as a real supply option with real water quantities that can be reliably evaluated and compared for cost.

A comprehensive survey of provincial officials for the Office of State Flood Control and Drought Relief Headquarters in 2009 ascertained the extent to which provinces carry out drought risk management measures. The survey focused primarily on *nonstructural* technical measures such as forecasting and early warning systems, policies, regulations and contingency plans, and efficiency and conservation measures (see Appendix 1 for a list of nonstructural demand management/risk management measures). They also included *nontraditional structural* measures that would diversify the sources of water available, beyond traditional dams, in case of a drought. In each province, it was found that a number of measures were used some of the time. What was less apparent was a systematic approach demonstrating an understanding of the interconnection and economic value of these different measures and how to assess their relative value. Yet, these nonstructural and

[30] S. Solomon. 2010. *Water*. New York: HarperCollins.

nontraditional structural measures can be as economical or more so than traditional structural responses. However, they would augment existing or planned traditional structural investments.

The Optimal Mix

A strategy of optimal infrastructure investments would explore both structural and nonstructural technical measures for increasing supply and making reserves more possible through increased efficiency and productivity, such as (i) rehabilitation of damaged irrigation and drainage facilities; (ii) extension of small-scale irrigation schemes; (iii) multipurpose reservoirs, dams, and water-impounding systems; and (iv) reclamation of used water and water-saving fixtures. These types of infrastructure solutions also support other environmental and agricultural outcomes.

Similarly, the 2030 Water Resources Group identified three approaches for balancing supply and demand in the PRC: increase supply, increase productivity of water use, and reduce demand by changing how water is used.[31] The first two approaches are expected to be the first taken up by governments, but the third—reducing demand and through technical means—requires investment choices that are more unusual. The 2030 Water Resources Group charted 55 optimal measures to close the 201 bcm gap it projected for the PRC in 2030—the majority of them are nonstructural technical measures. The total cost of this solutions mix is negative: net annual savings were estimated at $21.7 billion, including annualized capital and net operating expenditures, mostly from raising industrial efficiency.

Traditional water supply infrastructure will continue to be an important means of filling the supply–demand gap, by as much as 35%.[32] The Minister of Water Resources has said that construction of new water sources will supply 40 bcm of water. The largest of such water supply infrastructure will be the South–North Water Diversion Project. But other means that would help supply more water will be sea water desalinization, recycled water, and rainwater storage.[33] These new water sources, however, are not likely to reduce vulnerability to drought impacts on their own. Typically, new water sources get reallocated to growing and new populations and sectors, rather than saved for dry times or allocated to the environment for ecological services and sustainability. In this scenario, storage does not equal savings, which is what is needed to increase supply and mitigate the impacts of drought and other climate change effects. Other nontraditional structural and technical levers on both the supply and demand sides will be required to close the gap.

Opportunities for Demand Management

Agriculture, industry, and cities have already shown a capacity to be more conservative yet productive in their use of water. PRC's economic development is driven by industrial growth and urbanization, which are also where the greatest opportunities are for increased efficiencies. Agriculture continues to be the biggest water consumer, but in a decreasing trend (see Figure 1 in previous chapter).

Urban domestic water. Urban residential consumption was about 131 liters per capita per day in 2008, which is a significant improvement from 230 liters per capita per day in 1997. The government has been vigorously promoting water savings to urban consumers, increasing water metering and investing in improvements to urban water supply systems to reduce leakage. Presumably the reduced per capita consumption reflects the combined effect of these efforts (although it may also partly be due to better water accounting).

[31] 2030 Water Resources Group. 2009. *Charting Our Water Future: Economic frameworks to inform decision-making*. Washington, DC: World Bank.

[32] Ibid.

[33] L. Chen. 2011. Enhance Water Security and Adapt to Global Climate Change. Speech at the High-Level Roundtable on Strategy of Extreme Climate Adaptation in the People's Republic of China. Beijing. 22 April.

Xinhua/Zhou Ke

A boat is seen on the bank of the Nanchang section of the Ganjiang River in PRC's eastern Jiangxi Province on 18 September 2011. The water level of the Ganjiang River, one of the major branches of the Yangtze River, the country's longest river, continuously dropped due to the lack of rainfall.

Agricultural water. The most remarkable trend over the 2000–2008 period in terms of sectoral consumption occurred in agriculture, where absolute consumption decreased by about 3%. During this period, irrigation was greatly expanding in the country and the total value of agricultural output (irrigated and non-irrigated) increased by about 230%. The government is promoting water-saving irrigation technology, alternative management, and cultivation techniques, along with changes in cropping patterns, particularly in northern PRC, in response to increasing water prices and changing patterns of demand for agricultural outputs.

The 12th Five-Year Plan (2011–2015) envisions major expansion of irrigation systems. According to the Minister of Water Resources, 70% of large irrigation systems and 50% of backbone schemes will be rehabilitated by 2015—affecting 2.6 million ha.[34] New highly efficient irrigation systems will cover another 3.3 million ha.

In addition to irrigation water, the 12th Five-Year Plan will introduce cellars, ponds, dams, pumps, and canals for rural drinking water.

Industrial water. Total industrial demand has increased by about 23%. Industrial water consumption, in aggregate, has increased steadily over the last 20 years; although, industrial water use efficiency improved by a factor of 10, a reflection of the substantial structural change that has occurred in PRC's industry sector over the period.

Most industry on the East Coast of the country uses less than 50 m^3 per CNY10,000, but the

[34] Ibid.

rate can vary widely—sometimes by 300%—in different areas of the country.[35] The 12th Five-Year Plan aims for a national average of 140 m^3 per CNY10,000 of GDP and 80 m^3 per CNY10,000 of industrial output.[36]

In Conclusion

The national trends in water conservation are not progressing at a rate that would close the projected supply–demand gap in 2030. More must be done to curb actual water usage. Box 6 compares how the PRC expects to improve water savings versus savings actually accomplished in Australia.

There are challenges to be hurdled when implementing the various measures called for in the cost curve analysis. The "hidden costs" of overcoming institutional barriers and influencing sociocultural understanding could undermine the effectiveness of technical options if they are not included in the development of a sustainable water future. Additional qualitative, nontechnical costs such as education and training are also to be expected.

To focus more public and private investments on demand-side structural measures, the most powerful tool is often the assurance of a timely payback and recurring savings. When convinced of this, users are more likely to adopt the

Box 6 Sydney Achievements Compared to Expectations in the People's Republic of China

Comparing water savings targets within the People's Republic of China (PRC) to rates of achievement outside the country indicates that PRC planners are likely underestimating the gains from structural and nonstructural demand management measures.

For the more developed East Coast provinces of the PRC, it is estimated that about 33% of losses could be avoided through (i) demand management, (ii) water pricing, and (iii) system rehabilitation.

In more mature water management systems, such as that of Sydney, Australia, the achievement rate was nearly double but far more dispersed between the types of levers and by sector. Sydney reduced consumption by 60%. The achievements came from demand management in the following sectors and at the following rates:

- Residential housing, 20%;
- Industrial recycling and water saving, 13%; and
- Business water saving, 27%.

Regulation, including tariff increases, reduced consumption of water by more than 6%. Network management and leak reduction saved 34% more water.

These impressive reductions in Sydney took 11 years to implement and may not have been achieved had there not been an extreme drought to convince users of the changes required. Water pricing in Sydney was not a significant source of reducing consumption because the city has a long history of adequately priced water; the opposite is true for many places in the PRC, making price increases a powerful control lever.

Source: ADB. 2010. *Strengthening of Water Resources Management in Guiyang (IWRM towards Demand Management).* Consultant's report. Manila (TA 4912-PRC).

[35] ADB. 2010. *Strengthening Water Resources Management for IWRM Institutional Reforms*. Consultant's report. Manila (TA 4912-PRC).

[36] L. Chen. 2011. Enhanced Water Security and Adapt to Global Climate Change. Speech for the High-Level Roundtable on Strategy of Extreme Climate Adaptation in the People's Republic of China. Beijing. 22 April.

conservation measures. A tool to determine the "payback curve" compares measures according to their capital requirements and the number of years it will take for investors to recover their capital. For the PRC, 74% of the supply–demand gap could be closed by measures that return investments in less than 5 years. It is irrational to not invest in measures that reduce consumption while maintaining productivity.

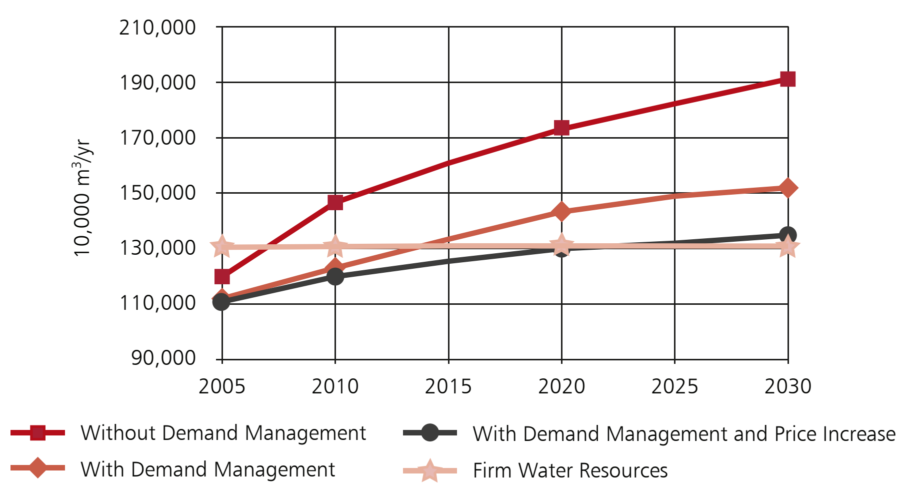
Case in Point: Guiyang

In 2007, the Guiyang Hydrology Bureau completed its most thorough IWRM study it had done for the municipality. The study showed a wedge opening in the water supply–demand gap as early as 2009. If water demand remains unconstrained, the study found that it will have nearly doubled to 1.9 bcm annually by 2030 (Figure 3). The sustainable supply limit for Guiyang is only 1.3 bcm annually. The ADB study in Guiyang analyzed the effects of three degrees of demand management: water-saving techniques (structural and nonstructural) in all sectors, reduction of network losses, and price increases. Various degrees of demand management would bring demand more in line with supply.

Guiyang's per capita water use is high by any standard, but especially for a municipality with low per capita income and low levels of commerce and industrial output, which usually correlates with lower consumption. In 2010, per capita water use in Guiyang was expected to be 180 liters per person—i.e., 30%–40% higher than usage rates in Beijing, Shanghai, Singapore, and cities in the United Kingdom, France, and Germany; some of these countries have average annual per capita incomes of $34,000–$40,000. The unusually high consumption rate is an indicator of tariff rates that do not reflect the value of the resources, high inefficiency in processes and infrastructure, leakage, and unproductive usage.

To address the real-time and greater pending shortages, the Guiyang Integrated Water Resources Master Plan (2006–2020) encompasses all forms of water use, both urban and rural, including initiatives to (i) develop new water sources, (ii) improve irrigation facilities and forego investments in uneconomic irrigation, (iii) manage

Figure 3 **Demand and Supply Scenarios for Guiyang, 2005–2030**



m^3/yr = cubic meter per year.

Source: ADB. 2010. *Strengthening of Water Resources Management in Guiyang (IWRM towards Demand Management)*. Consultant's report. Manila (TA 4912-PRC).

demand by conserving water, (iv) exercise pollution control and protect existing water resources, (v) reform institutions, and (vi) introduce market-based measures to save water. However, while the master plan contains a large listing of structural interventions, not much attention is given to resolving institutional constraints and developing nonstructural interventions and practices in keeping with the IWRM principles. This situation is understandable given the traditional emphasis to supply-side water resources planning in the PRC, and the relatively recent consideration given to demand-side solutions. However, the master plan correctly identifies the priorities, which are to provide water to unserviced or underprovided areas, and recognizes that these priorities require predominantly structural solutions, albeit with greater stakeholder involvement in their design and implementation.

ADB is providing a $150 million loan to finance a portion of the master plan. The ADB-financed Guiyang Integrated Water Resources Management Project is PRC's first large IWRM-based project at the municipality level. Following an optimal infrastructure approach, covering both supply- and demand-side structural measures, the project augments the masters plan's heavy supply-side strategy with investments in demand-side structural and nonstructural measures. The types of infrastructure financed by the project will improve urban water supply, rural water supply, and irrigation, as well as control soil erosion. The project components are summarized in Table 1.

While the project will help alleviate water stress in Guiyang, it will by no means resolve it. The creation of new water sources, such as reservoirs, is limited because of the unique ecological features of the area. By 2015, despite the project interventions, Guiyang will still face water shortage of about 5.6 million cubic meters (mcm), which will increase annually to 11.5 mcm in 2020 and to 19 mcm in 2030. To fill this widening gap, construction would have to start by 2020 of water diversion tunnels from neighboring river basins and of wastewater treatment plants to reclaim water. These are capital-intensive options. Other less-explored structural, technical, hardware-based options exist and can be considerably less expensive and environmentally beneficial.

The ADB-supported study of IWRM and demand management in Guiyang focused more on the effects of nonstructural options of tariff reforms and other institutional improvements to address demand management. It also looked at potential savings from a general implementation of demand management. Further to this work, ADB commissioned a follow-up cost–benefit analysis of various demand management options in Guiyang, which focuses only on structural measures for reducing demand.[37] The study analyzed cost effectiveness in three areas: savings in urban domestic water use, savings from repairing leaking networks, and savings from more efficient industrial water use versus creating a new water source. The demand management study and the indicative cost–benefit analysis illustrate the economic savings of demand management and particular advantage of water savings in a drought.

Urban Domestic Water Use Savings

Demand for urban domestic usage is expected to grow the fastest as the services sector overtakes the growth of the industry sector in Guiyang. The present urban population of Guiyang is 2.35 million, which is expected to grow to 3.85 million by the year 2030. While total annual population growth in Guiyang has been averaging 1.7% in recent years, urban population growth rates have exceeded 2.5% since 2000. The suburbs are only growing at about 1.2%. In real numbers, this accounts for about 50,000–60,000 people moving every

[37] The cost–benefit study is not a complete analysis of the situation in Guiyang or a comprehensive economic analysis of drought risk management. Through the analysis rendered, the economic rationale for risk management provided is that prevention of a disaster is less expensive than disaster response.

Table 1 Core Subprojects and Benefits of the ADB-Supported Guiyang Integrated Water Resources Management Project

Core Subproject Name	Features	Benefits	Estimated Cost ($ million)
Urban Water Supply	The establishment of one medium-sized reservoir and two small reservoirs, including the construction of dams, water conveyance tunnels, transmission pipes, one water treatment plant, and the extension of the municipal water distribution networks.	Increase in urban water supply (about 40 mcm/year)	67.6
Rural Water Supply	The construction of up to 43 small reservoirs, including about 3 for county water supply, 20 for water supply and irrigation at the township level, and 20 for human and livestock water supply and small irrigation systems. Many of these include investments in water conveyance systems, small township water treatment facilities, and irrigation systems.	Increase in rural water supply (more than 70 mcm/year)	168.9
Irrigation Rehabilitation	Rehabilitation and upgrading of up to nine irrigation systems covering 13,030 ha, including installation or repair of intake structures, canals, and aqueducts.	New irrigation area (about 2,000 ha)	44.4
Soil and Water Conservation	Farmland restructuring, conversion of sloping farmland to terrace and tree or grass planting, and fruit tree planting, to protect the upper catchments of the water sources (about 800 km^2) from soil and water losses.	Rehabilitation of land at risk of erosion (about 800 km^2)	41.4
Small Water Storage Structures	The provision of up to 105,100 small water storage tanks in rural areas to catch spring water for human consumption, and rainwater for irrigation and livestock consumption.	Increased storage capacity (about 3.4 mcm) and new irrigation area (about 9,000 ha)	56.1
IWRM and Capacity Building	Support institutional reform for implementing IWRM, improve coordination and awareness among relevant agencies, facilitate water tariff adjustments, and enhance staff skills in water management.	Reformed institutions to comply with IWRM principals and 50 water user associations for subprojects that include irrigation development or rehabilitation activities	11.6

IWRM = integrated water resource management, ha = hectare, km^2 = square kilometer, mcm = million cubic meter.

Source: ADB. 2009. *Report and Recommendation of the President to the Board of Directors: Proposed Loan to the People's Republic of China for the Guiyang Integrated Water Resources Management (Sector) Project.* Manila.

The first benefit of demand management, or conservation, is the avoided cost of having to construct an alternative water supply.

5 years from the suburbs to the urban districts. Agricultural areas have been less productive than at any other time, with more households seeking registrations to move to the city. As a result of migration from both rural and suburban areas, the urban population grew from 48% in 2000 to 60.5% in 2009. By 2030, 78% of Guiyang's population will be living in the urban districts.

Savings. The first benefit of demand management, or conservation, is the avoided cost of having to construct an alternative water supply.[38] For projects which are already under preparation, the value of conserved water should be compared to the next water supply project, which typically would be more expensive.

To determine the potential for water savings from this sector, the cost–benefit analysis studied the various effects of installing water-saving fixtures (toilets, faucets, showers, and washing machines) in all apartments. Savings are based on the difference in water flow rate for each fixture multiplied by the number of times each fixture is used per person per day. Based on the analysis, the per capita consumption rate of 2.34 million people for toilet, drinking, washing, cooking, and bathing could be reduced from 170 liters per capita per day (lcd) to 130 lcd, and up to 101 lcd in times of drought.[39]

The savings of 40 lcd would have produced 34.3 mcm more water in 2010, when the country was suffering from the Southwest drought. This exceeds the volume of water that will be made available by a medium-sized reservoir, such as the ADB-financed Yudongxia Dam and Reservoir, and would provide enough water for an additional 720,000 new residents. At projected population growth rates, these savings defer the need for another reservoir by about 8 years.

After 30 years, if existing apartments were retrofitted with water-saving fixtures, the cumulative amount of water that would have been conserved for other uses (1.12 bcm) would be the same as that delivered by the three new reservoirs being developed for the Guiyang urban population (1.02 bcm) over the same period of time.

Costs. The cost of any hardware, appliances and labor, and educational materials needed to achieve the water savings were factored into the analysis. A preliminary analysis of the prices of Chinese manufacturers shows these costs could be as high as CNY4.16 ($0.65) per cubic meter of the water saved.

Benefits. The net benefit (avoided costs) of these conservation measures compared to the development of new reservoirs translates into CNY63 billion ($10 billion) annually, if the existing population installed these water-saving devices.

Future savings, costs, and benefits. New water source development can be avoided by continuing the installation of water-saving devices in new construction for future populations.

Future savings. Per capita consumption is projected to increase from 170 lcd to 200 lcd in 2020 and to 240 lcd in 2030 (the population is projected to grow to 3.18 million in 2020 and

[38] Costs include new water source design and development, land acquisition, construction, transmission, pumping, and water treatment, and environmental mitigation costs, such as in-stream flow reduction and social resettlement costs. Although excluded from the analysis here, the avoided cost to safely dispose additional wastewater should also be considered, such as the costs of expanded wastewater plant capacity, treatment, energy, and chemicals.

[39] The analysis uses 130 lcd, rather than 101 lcd, as the optimal demand level for non-drought conditions because conservation programs should leave room for additional savings during a drought. If people have already reduced their use to a safe minimum, then conserving more— without hardship—when drought conditions prevail will be difficult. Also, saved water is usually just reallocated to new residents instead of constructing new facilities to serve them, not to creating reserves for drought conditions or ecosystem use and rehabilitation.

3.85 million in 2030).[40, 41] This would increase total domestic water use from 145.8 mcm to 337.1 mcm per year. However, with the conservation measures described in place, as new development occurs, water use will only increase to 182.6 mcm per year in 2030. This ultimately will produce a savings of 154.5 mcm per year—a 54% savings with demand management.

Future costs. The average incremental economic cost of saved water per cubic meter will be CNY2.61 ($0.41) in (constant currency) compared to CNY6 ($0.94) for alternative water sources if the current population installed water-saving devices. The total cumulative water savings from domestic use over the 30-year period will be 2.99 bcm, approximately 1.96 bcm of which would otherwise have to be produced from new water sources.

Future benefits. The net avoided costs (the net benefit) of not having to develop new water sources as a result of domestic demand management in Guiyang would be about CNY6.6 billion ($1.0 billion). It is clear that these measures alone produce benefits that exceed the costs. Unlike large structures built with excess capacity, water conservation measures are employed only as they are needed and benefits are returned in the same year as the expenditure. The cost of conservation will drop as the population increases if new apartments are built with plumbing codes requiring water-saving fixtures in place, as retrofitting old buildings or equipment with new

The net avoided costs of not having to develop new water sources as a result of domestic demand management in Guiyang would be CNY6.6 billion ($1.0 billion).

Water savings based entirely on changing household "hardware" and not on people's habits offer a high level of reliability.

equipment is always more expensive than doing something correctly the first time.

Because the water savings are based entirely on changes built into a household's "hardware" and not on changing people's habits, this level of conservation has a high level of reliability. Achieving greater reductions would require continuous education and is more dependent on changing personal habits. This would occur during a drought to bring water use down to an additional 25% or more, if needed.

Industrial Water Use Savings

Industrial water use makes up about 53% of present urban use in Guiyang, or about 602 mcm of water per year. Guiyang has major water-using industries—steel, chemicals, non-ferrous metals, electronics and machinery, building materials, national defense, and food processing. Advertisements for companies producing chemicals and aluminum boast of Guiyang's richness in water resources as an advantage for these industries.

The industry sector in Guiyang uses three times the national industrial average for water consumption. Most industry on the East Coast of the country uses less than 50 m^3 per CNY10,000 of industrial output, whereas Guiyang uses about 150 m^3 per CNY10,000 of industrial output.

The major uses of water in industry are cooling, processing, boiler feed, and sanitation. On-site costs associated with water use include the raw

40 ADB. 2010. *Strengthening Water Resources Management for IWRM Institutional Reforms*. Consultant's report. Manila (TA 4912-PRC). This forecast does not figure in any factor of demand management.

41 IWRM Report, page 25 for baseline per capita use in these years. Project costs and benefits are projected for 30 years as the economic project life from start of operations.


Guiyang Municipality

The industry sector in Guiyang uses three times the national industrial average for water consumption.

cost of water, chemical treatment, pumping, heating or cooling towers, and wastewater discharge. In fact, there can be significant avoided costs from energy use since about 15% of the industrial plants use water to generate energy. In a drought, when hydropower production will be decreased, the lower water and energy needs have a dual benefit both to the watershed and to the cost structure of the company. The primary methods used to reduce water use include adjusting the flow rate, modifying or replacing equipment, supplying new water and sanitation fixtures, water recycling and reuse, and changing to a waterless process.

Water use in industrial production differs significantly even within the same industry, depending on the level and type of production and the number of employees. For this reason, the cost–benefit analysis considered the outcomes of demand management in industries in California's Silicon Valley that are similar to the industries found in Guiyang. In all cases, the company's financial savings exceeded the cost of reducing water use. Many industries, including steel mills, have found it possible to reach zero discharge by creative methods of conservation and recycling. The scale of industries in Guiyang may exceed the examples from Silicon Valley, which would only lower the investment cost per cubic meter saved.

The benefits of industrial water conservation measures also exceed the costs to implement them. In a survey of industrial plants and commercial and institutional sectors in California's Silicon Valley, the Santa Clara Valley Water District found that industrial plants, including electronics, food processing, packaging, metal, and building materials showed an average water use reduction of 41% and that the annual cost savings exceeded the total project cost (Table 2).[42] The payback on investment was less than 1 year. The source of greatest savings came from the industry sector and its process modifications and wastewater recycling. The average overall industrial savings was 35%.

Savings. If industries in Guiyang could also cut their current total water use of 602 mcm per year by 35%, this would translate to an annual savings of 211 mcm. The techniques applied would require changing existing equipment and practices. Future industries could save on costs

Table 2 **Sample of Water Savings Rates for Various Companies and Industries**

Company/Industry Sector	Water Savings Rate[a]
Potash (fertilizer)	52%
Intel (computer chips)	61%
Sandia National Labs (defense)	30%
Shijiazhuang Iron & Steel	Zero discharge
Los Alamos National Lab (defense)	44%
Delta Airlines	>60%[b]
Office building and apartments	50%
Food processing	27%
Building materials	57%
Building control products	82%

[a] Calculated as: water savings = average annual water savings/average project cost.
[b] "Drought and Demand-Side Water Conservation," Water Efficiency: May–June 2008.

Source: ADB. 2011. *Planning Ahead: The Economic Basis for Drought Risk Management*. The Case of Guiyang Municipality. Consultant's report. Manila (TA 7261-PRC).

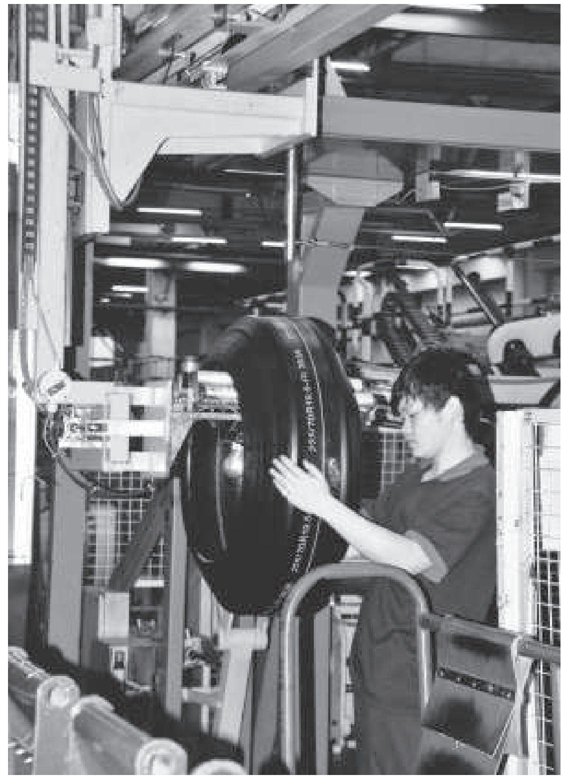
[42] Santa Clara Valley Water District. 2004. *Commercial, Industrial and Institutional Water Use Survey Program: Final Report*. San Jose, CA.

by incorporating water-efficient practices rather than modifying existing ones.

Costs. Achieving these annual savings for the whole sector would require a significant investment. In the Santa Clara Valley Water District study, the average water savings per dollar (CNY6.33) invested was 0.5 m^3, and all projects were cost-effective. Further analysis needs to determine the costs and size of a program in Guiyang. If, in the worst case, the costs in Guiyang were as high as in the United States, the program to reduce industrial use by 35% would be CNY137 million ($21.5 million).

Benefits. Even if an industrial water efficiency program in Guiyang cost as much as it did in Silicon Valley, a CNY137 million ($21.5 million) program would still be considerably cheaper than the CNY732 million ($115 million) that Guiyang's industry lost during the Southwest drought. More importantly, these changes would remain in place for future water shortages and droughts at no additional investment.

Industry can also expect to improve efficiency rates as technologies and ideas improve. New skyscrapers are being constructed that will reduce water use in half, along with harvesting storm water, each saving 1 mcm a year.[43] The types of solutions and level of savings vary greatly. Droughts, or other severe water cutbacks, have typically been the incentive to seek these changes. Although an individual company may make its own decision based on company costs and revenues, it is clear that the avoided cost to society far exceeds the savings calculated by an individual company. Fewer water supply projects need to be developed. On-site reuse of recycled wastewater cuts the capacity and treatment costs of wastewater treatment plants. There are significant benefits for in-stream flows and water quality, requiring fewer government expenditures to repair.



Guiyang Municipality

Even if an industrial water efficiency program in Guiyang cost as much as it did in Silicon Valley, the investment cost in such a program would still be considerably cheaper than the direct economic losses that Guiyang's industry incurred during the Southwest drought.

Physical Water Losses Recovered

Reducing physical losses is an important way for a water utility to preserve more water in the event of a drought.

Savings. Guiyang Municipality loses about 35% of the water it produces, or about 39 mcm. If leaks account for just one half of total water losses, cutting these losses by 50% will save 10 mcm per year.[44] These water savings could meet other needs or be reserved for dry periods. As with residential savings, water savings from leaks are derived from water that has already been developed and the treatment already paid for.

[43] *Urban Water Management*. 2009. Urban High-Rise Design Meets Water Conservation Goals. Fall.

[44] Losses that only represent lost revenue because of a lack of metering, poor billing, and collection would not provide savings in a drought because water is still being used. In other words, water is not really lost, but rather the revenues from water use.

The water conveyance of on-farm systems are almost 60% more efficient than the large-scale irrigation schemes.

The ADB-financed irrigation component of the Guiyang project will rehabilitate irrigation systems that service almost 10,733 ha.

Costs. Equipment would be needed for detection and repair. The California State Department of Water Resources estimates that the cost for its own system would be less than $100/1,223 m^3 saved. One half of this is the cost of labor in California. The cost for Guiyang could be safely estimated at CNY0.2/m^3 ($0.03/m^3), or about CNY2 million ($0.3 million) to cut losses by 10 mcm.

Benefits. The economic net benefit in avoided costs would be CNY5.8 million ($0.9 million).

Irrigation Rehabilitation

Although not included in the cost–benefit analysis of water demand management in a drought scenario, a significant opportunity for water savings is in irrigation. Drip irrigation for vegetable and flower farming can use 90% less water than traditional flood irrigation. Canals for paddy farming could be lined to ensure less water loss and more efficient designs can use less water per hectare.

Up to 40% of irrigation in rural Guiyang has been abandoned and almost 29 km of canals are damaged. Yet, irrigation is essential to production in Guiyang—50% of cultivated area that is irrigated produces 70% of Guiyang's agriculture. The water conveyance of on-farm systems are almost 60% more efficient than the large-scale irrigation schemes (99% versus 40%). A secondary impact from this is soil erosion, which affects some 2,600 km^2 in Guiyang as well as the quality of water sources. The ADB-financed irrigation component of the Guiyang project will rehabilitate irrigation systems that service almost 10,733 ha.

In Conclusion

Droughts, or other severe water cutbacks, have typically been the incentive to seek changes, and more imaginative reforms are required than what traditional supply-side structural approaches can offer. Demand-side structural measures can be technically reliable and more cost-effective in improving environmental flows. When water savings are reserved for environmental flows, society's resilience to climate change and extreme weather events, particularly droughts, will be stronger.

Track 3: Ecosystem-Based Management

The long-term returns and gains from managing demand now will be healthier, more productive ecosystems. Watersheds, in particular, integrate the various functions of natural resources and have the inherent ability to regulate climate, reduce risks of impacts, and rehabilitate themselves over time. This is not possible under traditional ecosystem management. A water resource base needs a system of water rights and allocations and innovative approaches to ecosystem protection. These systems need to be strategically managed and in integrated ways. PRC's model for integrated water resource management tries to streamline the typically fragmented roles and responsibilities of a multifaceted sector into a single, consolidated, and reformed Water Affairs Bureau.

The greatest challenge to building resilience to droughts is institutional. Structural and technical solutions exist, are cost-effective, offer the reliability that planners seek, and can be manageable to implement. Nonstructural technical solutions also exist in the forms of monitoring, forecasting, and early warning systems to reduce risks to disasters. What is lacking, however, are the institutional capacity and management systems to implement these measures, and others, effectively. These gains are necessary, but will be hard earned.

Change in Management Approach

Chinese policy clearly supports the global reform paradigm of IWRM, as seen in various revisions of the national water law. Two recent State Council memos directly supported IWRM-based reforms programs, calling it an ideal approach to implement balanced development at the river basin or ecosystem level.[45] The national guideline for implementing IWRM, prepared by the Ministry of Water Resources, is being piloted in several provincial water resources bureaus. Since 2000, about 63% of the higher government levels have begun reforms—about 1,532 administrative units at the province, prefecture, municipality, and county levels.

Rational. In contrast to traditional water management, an IWRM system is as much interested in water demand and conservation as it is in water supply. Rather than always striving to stretch supplies to meet current demand levels (without consideration for downstream needs or trends into the future), water can be supplied in such a way that affects demand positively, such as through the quality, availability, and cost of water.

45 ADB. 2010. *Strengthening Water Resources Management for IWRM Institutional Reforms*. Consultant's report. Manila (TA 4912-PRC).

The Global Water Partnership, an intergovernmental policy coordination group advocating IWRM policy and implementation, defines IWRM as

> *"a process which promotes the coordinated development and management of water, land, and related resources in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems."*[46]

To accomplish this, IWRM works at bringing together the natural and human systems—the availability and quality of natural resources and the human decisions that govern how resources are used, by whom, and how much, as well as how waste should be disposed, where, and in what condition. Examples of technical areas that relate to each other but are often mistakenly managed separately are

- land and water development and use,
- surface and groundwater,
- water quantity and quality, and
- the needs throughout a basin.

In accordance with IWRM principle, reform is more likely with three kinds of major changes. The first change comes in the form of combining the management of urban and rural water resources and systems. Second is the added emphasis on water quality in the new management systems put into place. Third is streamlining the business and management of all the various agencies, bureaus, and units involved in some aspect of the water sector (as many as a dozen at some levels of government) into one agency.

IWRM model for the PRC. In the PRC, the newly streamlined agency is typically called a "water affairs bureau." This model of management usually consolidates the water-related roles of the water resources bureau, urban construction bureau, and urban management bureau. It has been adopted by many cities, including Beijing, Changchun, Chengdu, Harbin, Shanghai, Shenzhen, Shijiazhuang, and Tianjin.

Creating a water affairs bureau entails the brave task of consolidating power and responsibilities over any and all aspects of water in a particular place. A water affairs bureau, acting as an apex body, is supposed to resolve the majority of water resource concerns, including drought and flood management and disaster response (Box 6). This is not easily or quickly done. It is as much a political process as it is an administrative and logistical one. Achieving this, though, indicates a reform process that is firmly established and well on its way to correcting past resource degradation, addressing present issues, and preparing for future demand.

Box 6 **Main Functions of a Water Affairs Bureau**

- Develop strategy and planning
- Manage water resources
- Determine and manage water use permits
- Monitor water quality
- Monitor water saving
- Organize water construction projects
- Water and soil conservation
- Levy water fee charges and manage funds
- Organize flood and drought control
- Develop and implement local water laws
- Address rural water issues
- Fishing license
- Hydropower
- Reservoir design and resettlement
- Wastewater treatment
- Sea and/or island management and protection

Source: ADB. 2010. *Strengthening of Water Resources Management in Guiyang (IWRM towards Demand Management).* Consultant's report. Manila (TA 4912-PRC).

[46] Ibid.

One of the key departments in the Water Affairs Bureau will be a demand management department. This department will assess short-, medium-, and long-term demand and continuously monitor the supply–demand balance. It will also have an early warning system for impending droughts and will establish a triggering system that interrupts or reduces water supply to ensure the most important demands are always met.

Ecosystem as a Water User

The PRC is increasingly recognizing the importance of appropriate flows—including volumes and timing—to maintain downstream aquatic ecosystems and provide services to dependent communities. A critical function of the IWRM is to also ensure water is allocated to ecosystems, which are legitimate users of water. Water savings that are created from demand management should be reserved for emergency supplies as well as for ecosystem rehabilitation to build long-term resilience.

Creating these reserves and allocating a proportion of them to ecosystems require an understanding and valuing of the services that ecosystems provide.

The types of ecosystem services that relate to water management and require adequate water flows are

- watershed protection for providing the quantity and quality of water required for development and ecosystem health,
- biodiversity and wetland protection for regulating climate and protecting watersheds, and
- forest carbon sequestration for mitigating greenhouse gasses, promoting nutrient cycles, and protecting from soil erosion.

In many river basins, serious impacts of excessive exploitation of water resources have led to rivers ceasing to flow, lakes shrinking or drying out, land subsidence, and other problems.

Ecosystems being allocated a certain right to water as a legitimate user is a growing concept. Ecological water rights (EWRs) refer to the quality, quantity, and timing of water flows required to maintain the components, functions, processes, and resilience of aquatic ecosystems that provide goods and services to people. EWRs are really about the equitable distribution of water to aquatic ecosystems and the promotion of clean water and services provided by them.

EWRs have received higher priority in several water allocation schemes:

- Yellow River: Water required for flushing sediment through the lower river reaches was deducted before allocating remaining water to administrative regions.
- Hai River: Water requirements for the inland seas of the east and west Luyan lakes were made explicit in water allocation, and they receive a share of water resources that depends upon the quantities that are seasonally available.
- Daling River in Liaoning Province: A minimum discharge into the ocean is given highest priority as a measure to provide required water for the eco-environment.
- Shiyang River Basin in Gansu Province: Groundwater levels in Minqin County were chosen as a control mechanism to sustain the eco-environment there.

More uniform and widespread application of EWRs is likely to happen with ongoing reforms. The Ministry of Water Resources said the fundamental right of the square kilometer as a *user* of water resources will be enshrined in water allocation schemes. And in a clear shift to decentralized water resources management, the river basin and watershed committees will be responsible for allocating those rights.

Watershed Eco-Compensation as Conservation Tool

Eco-compensation, or payment for ecosystem services, is a payment and incentive system that supports sustainable ecosystems and provides stable financing for conservation. Watershed eco-compensation is emerging as a key tool for providing financial and economic incentives for IWRM. It can also serve as a valuable platform for engagement and negotiation between the key stakeholders of watershed protection, helping to highlight and address the underlying issues of rights and responsibilities, equity, and effectiveness.

Watershed eco-compensation programs in the PRC fall into two general groups: those developing ways to better coordinate watershed management across jurisdictional boundaries, and those directly targeting better management in the upper watersheds of reservoirs and river systems that are important sources of drinking water. Programs in the first group involve the creation of cross-jurisdictional management frameworks that map out responsibilities, rights, and targets. They include a range of different financial transfer mechanisms. An example of this is Fujian's eco-compensation programs to manage the Jiulong, Min, and Jin river watersheds by using cost-sharing arrangements and lower-to-upper watershed financial transfers to improve funding for managing the quality of upper watershed water.

Programs in the second group, which are also cross-jurisdictional in a number of cases, generally involve some form of direct compensation from downstream beneficiaries (water users and local governments) to upstream ecosystem services providers (local governments, communities, and households), with compensation linked to the implementation of upper watershed zoning restrictions and land-use requirements. One classic example is the program to protect the upper watershed of the Miyun Reservoir (Beijing's main water supply), which involves direct payments from Beijing Municipality to upstream counties in Hebei Province (where per capita incomes are only half of Beijing residents) to restrict development that compromises the watershed.

Ecosystem-Based Basin Management

IWRM, the rights of ecosystems to minimum flow levels, and eco-compensation programs are essential tools in watershed management. They build a better water resource base. What grows from that base, though, also needs to be considered in planning. For this, a broader management system would look at water and the environment together.

A more advanced management system, but less practiced in the PRC, is the ecosystem-based integrated river basin management (IRBM). It manages both water resources and the environment. It is more specific in its scale and scope. Its scale and geographic unit to manage is an entire basin; its scope is the whole ecosystem—the resources depending on the health of the river. IRBM covers water, land, biodiversity and environmental issues of a river basin.

The ecosystem-based IRBM principles include

- understanding the ecosystem first before designing management systems,
- using resources according to what the ecosystem can naturally support ("carrying capacity"), and
- adapting land use functions based on the natural system and not vice versa.

Experts also advocate this approach for the PRC because environmental problems are spreading across entire basins, and are no longer confined to a specific watershed or reaches of a river. To address the environmental factors that are exacerbating climate change in the form of more severe droughts and floods, more than just water resources will need to be managed in integrated ways. The relationship between resources and the interdependency of their services must be understood and managed.

Case in Point: Guiyang

Guiyang has been shifting away from a purely administrative approach to water resource management over the past 30 years, to a more operational approach characterized by watershed monitoring and soil conservation. The municipal government has indicated a clear commitment to IWRM in its master plan and in its partnership with ADB for the Guiyang Integrated Water Resources Management Project, which is accompanied by a technical assistance grant for institutional reforms.[47]

The single greatest impediment to a more water secure and drought resilient future in Guiyang is its current management regime (see Box 7 for how this affects flood and drought recovery). Few places in the PRC need IWRM more than Guiyang. Compared to elsewhere in the country where IWRM reforms have also not yet been implemented, the division of responsibilities for water management in Guiyang is unusually scattered and complicated vertically among levels of government and horizontally across line agencies. Forty-two bureaus and offices have some degree of influence over how water resources are managed, and eight of them are directly involved in planning and supervising of water resources.

Current distribution of roles and responsibilities. There is no management structure for the water sector in Guiyang. Instead, three main government stakeholders and various agencies under them are organized in the following way:

- Rural water management, including irrigation, water saving in irrigation, flood control, rural water supply, and river maintenance, is the responsibility of the individual counties and Guiyang Water Resources Bureau;
- Urban water management, including flood control, river bank management, water supply for urban residents, drainage, and wastewater collection and treatment, is managed by the Urban Construction Bureau of the city or in the individual counties, while water supply is managed by a water supply enterprise; and
- Water pollution control is managed by individual counties or the City Environmental Protection Bureau.

Water projects (whether rural or urban) are financed and implemented independently by the bureau or department. Although the implementing agency must submit plans to the municipal government and all bureaus and departments may comment, opposition to plans are unusual. As a result, projects usually achieve suboptimal returns.

Shifting to IWRM. Guiyang recognizes the need for moving toward IWRM and has prepared the Guiyang Integrated Water Resources Master Plan. The primary goal of the master plan is to increase water supply, but it covers all other forms of water use: improve irrigation facilities, manage demand and conserve water, control pollution and protect water resources, reform institutions, and introduce market-based measures to save water. Each of these comes with targets to extend rural water supplies to non-serviced areas, increase irrigation coverage, and address soil erosion. Most of the plan's investments focus on structural interventions. Attention to institutional constraints is inadequate, and nonstructural interventions are far less developed.

The ADB-supported study of Guiyang's water management practices identified eight priority steps that are both management and operational in nature and also support measures required for drought risk management. Table 3 compares the steps and/or measures recommended for establishing a comprehensive IWRM system and a drought risk management.

[47] ADB. 2010. *Strengthening Water Resources Management for IWRM Institutional Reforms.* Consultant's report. Manila (TA 4912-PRC).

Box 7 Faulty Drought Administration Protects Borders, Not People

The administration of water allocations during the current drought and the flood management in Guiyang illustrate the gaps created by fragmented and uncoordinated management.

When dry conditions persist, drinking water for users in all local jurisdictions should be prioritized over all other uses, yet this typically does not happen, nor could it happen very easily given the fragmented way water is managed. Each jurisdiction allocates water according to its users. So one jurisdiction may indeed prioritize drinking water, yet it still allocates water to other sectors regardless of whether that will create a drinking water shortage in a neighboring or downstream community. Droughts do not follow political boundaries, though. So if one county decides (as many have in the past) to continue to allocate all of its water (leaving none to spare), this may keep its own factories producing while neighboring farmers starve and lose entire seasons of crops.

The same scenario is true for flood management. In Guiyang, people may even be more vulnerable to floods than what they would be naturally because of inconsistent methods of managing riverbanks. The urban construction bureaus design and manage riverbanks in the urban districts, while the various county water resources bureaus are responsible for design, construction, and management of flood protection measures on rural banks. Like droughts, rivers do not necessarily follow political boundaries. They flow between counties and through both urban and rural areas. Their management must keep the varying topography and development of the entire river course in mind. Otherwise, protection for one area may actually cause floods for another area.

These two entities—the urban construction bureaus and the county water resources bureaus (along with the bureaus of agriculture)—are also responsible for soil conservation, but again, only within their jurisdictions. Their different methods of soil conservation are evidently not working: sediment flows, silt, and riverbeds are all rising.

Source: ADB. 2010. *Strategy for Drought Management in the People's Republic of China.* Consultant's report. Manila (TA 7261-PRC).

Table 3 IWRM and Demand Management Process Steps

Step	IWRM Reform Process	Drought Management Planning Process
1	Create "watershed management stations" in each basin to implement plans at grassroots levels	Invest in early warning, monitoring, and forecasting technologies and systems
2	Monitor water abstraction in each watershed	Conduct comprehensive risk assessment
3	Monitor water quality in each watershed	Implement risk mitigation measures identified in the assessment
4	Create short-term forecasts for water demand based on data collected by the new watershed stations	Implement demand management program
5	Consolidate all water-related responsibilities into one "water affairs bureau"	Manage water savings from demand management to ensure reserves for enhanced drought supply
6	Manage demand by using forecasts, water saving measures, and incentives for all sectors, and tariff increases	Prepare plans for mitigating drought impacts and emergency response
7	Protect watersheds by limiting pollution loads through stricter standards, monitoring, and penalties	Prepare plans for recovering and evaluating drought incident and further contingency
8	Prepare risk reduction strategies in addition to emergency strategies for droughts.	Implement stakeholder participation and public education and awareness measures

IWRM = integrated water resources management.

Sources: ADB. 2011. *Strategy for Drought Management in the People's Republic of China*. Consultant's report. Manila (TA 7261-PRC); ADB. 2010. *Strengthening of Water Resources Management in Guiyang (IWRM towards Demand Management)*. Consultant's report. Manila (TA 4912-PRC).

The eight steps effectively form a change agenda. The consolidation of roles and responsibilities into a single Water Affairs Bureau is a major milestone. The Guiyang municipal government has begun shifting toward a more coordinated management of water resources.

First, it is developing a watershed committee for one of its three major river systems, the Nanming. IWRM is a bottom–up approach, where watershed is the bottom. Supply of water resources has a chance of being more equitably and strategically managed when the needs of users within the entire watershed are considered.

Second, the Water Resources Bureau has developed from performing purely administrative work to doing more practical and operational tasks of water management. By requiring abstraction permits now, the bureau is measuring water abstraction, managing municipal water resources, and studying environmental conditions.

Third, and most importantly, about 40 water-monitoring stations are obtaining data to study short-term availability, demand, and water quality. The monitoring stations are also developing plans for water resources, including any opportunities from groundwater. The stations are also analyzing total wastewater discharge loads in their jurisdictions and controlling sewage discharge.

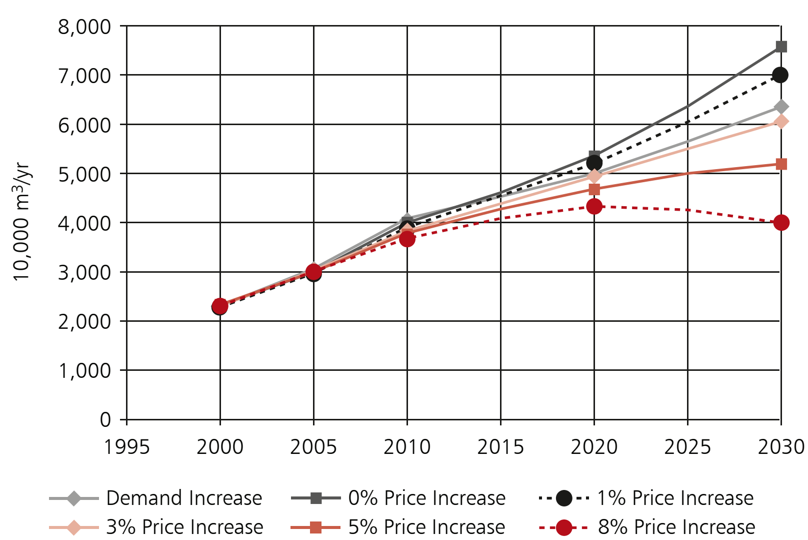
Pricing Water to Save Water

Regulatory methods, such as changes to water tariff levels and structure, can be a powerful way of introducing demand management. For example, a 5% price increase in water tariff would begin to level off demand, and an 8% increase will level off demand completely (Figure 4). However, price increases must be implemented carefully because they can cause negative financial issues for utilities. The more people will conserve to control their water bills, the less revenues will there be for utilities to recover their fixed costs.

Demonstrating the Will to Change

Within Greater Guiyang, pioneering efforts are already under way in individual cities and counties. Qingzhen City and Xifeng County are

Figure 4 Water Price Effects on the Demand Forecast of Yunyan District, Guiyang



m^3/yr = cubic meter per year.

Source: ADB. 2010. *Strengthening of Water Resources Management in Guiyang (IWRM towards Demand Management)*. Consultant's report. Manila (TA 4912-PRC).

demonstrating what needs to begin happening for the entire Guiyang Municipality.

Following the national reform trend, Qingzhen City has replaced its water resources bureau with a water affairs bureau and expanded its mandate to include urban and industrial water management, recommending changes to the tariff, flood protection measures, water-saving activities, and recycling equipment. The standard "water resource stations" at the lower government levels have been retained, but given the new title of "water affairs stations."

Xifeng County in Guiyang has accomplished nearly the same reforms as Qingzhen City, but without changing the name of its water resources bureau to reflect its expanded role. The only function left for the bureau to fully take over is wastewater management; it is in the process of taking over management of the local treatment plant, all sewers, and drainage in the townships.

An IWRM system and a consolidated Water Affairs Bureau would support improved outcomes of a host of initiatives Guiyang has been pursuing, such as the "ecological city" and "circular economy" approaches, and more recently a low-carbon growth strategy. An IWRM system is also needed to aggressively facilitate ecological restoration and conservation, which will support long-term resilience.

In its most progressive step yet, Guiyang has initiated three types of eco-compensation schemes. Each scheme is new and at different phases of implementation.

Programmatic within Guiyang. The Financial Bureau administers two categories of eco-compensation scheme: earmarks (used on a project basis that bureaus can apply for) and financial transfers. The Guiyang municipal government transfers a total of 7% of the previous year's growth: 3.5% to urban areas, 2.5% to suburban areas, and 1% to rural areas. In addition to existing sources for conservation, Guiyang has allocated an additional CNY10 million ($1.6 million) from the municipal budget and 3% of government land sales to fund conservation projects and financial transfers to districts for the environmental services they provide. The districts must spend the transfers evenly on drinking water source protection, forest coverage, and air quality management. The rural districts received CNY12 million ($1.9 million) each, and the two urban districts of Guiyang and Nanming received CNY1.5 million ($0.2 million) each, only because they are the largest users of ecosystem services.

Cross-jurisdiction scheme with upstream county. To improve the water quality in Hongfeng Reservoir, Guiyang agreed to pay 50% of the construction costs of a wastewater treatment plant in Pingba County, which is located upstream of the reservoir. It also agreed to pay the county annually CNY1.5 million ($0.2 million), with annual increases of CNY100,000 ($16,000), for treating its wastewater and protecting downstream waters.

Yudonxia Reservoir project. ADB has agreed to finance the construction of a fourth reservoir

Guiyang Municipality

ADB has agreed to finance the construction of a fourth reservoir in Toupu Village along the Yudong River. If managed properly, increased storage would help address water scarcity and drought.

in Toupu Village along the Yudong River, which originates in Longli County and runs about 19 km before reaching the proposed reservoir site. All but one village in Longli County is located inside the catchment. With both agriculture and industry growing at 7%, they are major sources of pollution, as wastewater from either source are currently treated properly. To protect the river and the proposed downstream reservoir, an eco-compensation scheme is being prepared with technical assistance by ADB. Four options are being proposed for the agreement. To protect its drinking water reservoir, Guiyang would pay Longli a portion of the amount to

- install household biogas systems to treat animal manure,
- convert sloping farmland into forest land,
- prevent soil erosion, and
- abate point-source pollution, such as through industrial biogas digesters at large livestock farms and wastewater treatment for other industrial effluents.

The cost of these mitigation measures is estimated at CNY2 million ($0.3 million) in initial capital costs with annual payments to Longli ranging from CNY892,000 ($140,000) to CNY1.7 million ($0.3 million). Guiyang is planning to raise the money for the eco-compensation scheme through tariffs, based partly on results from willingness-to-pay surveys.

Conclusion

The pressure of development on natural resources and general ecosystems in the PRC has been more evident in the recent successive years of severe drought and a growing scarcity of available freshwater resources. Demand management would help address the constant water shortage in some areas, while creating reserves for droughts and supporting the ecological flows necessary for the rehabilitation and conservation of water resources.

This publication explored three tracks to greater demand management and resilience to drought: risk management, optimal infrastructure, and ecosystem-based management.

Key Message 1: Natural droughts may be a new normal for the PRC, but unnatural water shortages are making matters worse. Regions of the PRC have a natural proclivity to dry conditions and droughts, but water shortages caused by economic development and unconstrained water consumption are exacerbating the effects of dry periods and droughts. The PRC has committed extraordinary financing to complete what it considers to be essential water infrastructure. A more cost-effective and environmentally sustainable approach would involve three tracks:

- First, prioritize risk assessment and reduction plans, of which demand management is essential.
- Second, make optimal use of infrastructure by including nonstructural technical options and nontraditional infrastructure to bring demand levels down to sustainable levels.
- Third, reform water management at the local level in order to achieve the healthy ecosystems—the long-term benefit of demand management.

Key Message 2: A risk reduction approach to droughts would spare the PRC much of the unnecessary hardships currently experienced. Droughts cannot be prevented, but the severity of their effects can be reduced through better systems and demand management. The PRC has the national systems for monitoring and forecasting droughts, but its early warning system must be further developed so that subnational governments can respond early and quickly. Provinces and cities should assess the risks associated with current water resource extraction rates and demand levels. Unsustainable consumption rates put populations, industries, and economies at greater risk during a drought. This is unnecessary risk. More conservative consumption in normal times can create water savings in reservoirs and natural ecosystems, which will be useful in droughts and for long-term ecosystem rehabilitation. Billions of dollars have been repeatedly lost in damages and relief efforts from droughts, which can be saved with better monitoring, forecasting, and early warning systems.

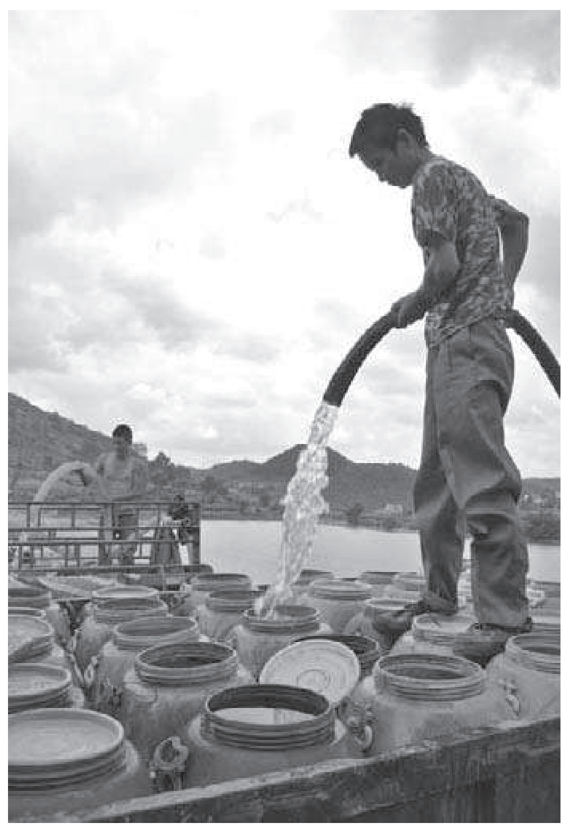
Key Message 3: Use an optimal mix of infrastructure for saving water instead of just spending it. The current infrastructure path in the PRC is still navigating toward increasing water supply when opportunities for saving water are vastly underexplored. Provinces, cities, and industries can invest in technologies and systems that can increase supply by saving water and with greater cost effectiveness than building storage. Water-saving fixtures and appliances for domestic users, increased water productivity systems in industry, and more efficient irrigation offer the same reliability that planners are counting on when they build reservoirs and diversions.

Key Message 4: Demand management offers short-term gains in increased supply and long-term gains in more productive ecosystems. Strategic management is the key to achieving specific results, whether they are near-term results (such as water savings) or long-term results (healthier and more productive ecosystems). The traditional way of managing water resources is a large part of the problem—too many agencies are managing a shared, crucial resources and sometimes with contradictory interests. Water resources need a reliable system of user rights and allocations that consider the needs throughout a watershed despite jurisdictional boundaries. These systems need focused management, and PRC's reform trend toward a single "water affairs bureau" is on the right track. Cities need greater national support in their reform and capacity building efforts to ensure water resources are managed for results—balanced water supply and demand, water savings, and ecosystem protection.

The particular needs of a risk management approach require more forward thinking and (short- and longer-term) actions than disaster response. A proactive approach encompasses early warning, monitoring, forecasting, risk assessment, risk mapping, and drought risk management plans that can better address drought for the more vulnerable groups. This highlights the need for a different funding mechanism to address water security needs in vulnerable areas and different operating and management arrangements from the Office of State Flood Control and Drought Relief Headquarters and the Ministry of Water Resources to support better preparedness for drought. Ultimately, this approach can save considerable money in relief and averted losses and damages from droughts.

An entirely new system is not needed to adopt a risk reduction and management approach. Many of the elements necessary to implement this approach nationally already exist within the government's effective administrative system for disaster response. The PRC has an existing institutional structure, policy and regulatory framework, and an emergency response network in place.

Demand management has been proven as a pathway that can propel the country to greater resilience. Embodied in demand management is the sound monitoring of flows and the allocation system. It significantly contributes to closing the supply–demand gap, which cannot be done by new infrastructure alone. It has direct positive impacts on the environment, returning or maintaining water that the environment demands for its own ecosystem functions and



Eyepress News

Farmers collect water in a truck in Guiyang, western Guizhou Province, on 31 July 2011. About 187,000 people in Guizhou Province are short of drinking water amid an ongoing dry spell, according to provincial drought relief authorities.

services. Demand management is also essential in managing the risks associated with droughts.

Given the national challenges, which were illustrated at the local level through a case study in Guiyang, demand management is a technical and economically rational and reliable option for addressing constant water shortages and drought situations. The country's growing water deficit as a result of human demands has rendered the engineering, supply-side paradigm as increasingly inadequate. A disaster response system is also insufficient and misses opportunities to reduce the costs and personal impacts of droughts. An integrated water resources management and a balance between supply and demand are necessary.

All things considered then, local governments must be deliberate in their reforms and in balancing their water ledgers. Studies are validating water conservation as a viable investment and technically reliable option for closing the supply–demand gap and "de-stressing" the water resources that ecosystems, economies, and people have always and will always depend upon—not just for their survival, but also for their prosperity.

Appendix

Nonstructural Demand Management/ Risk Management Measures

The following is a comprehensive outline of the nonstructural measures that would contribute to a more effective drought management in the People's Republic of China. Some of these are already being implemented in isolated locations or conditions, but not as part of a concerted risk management approach. Of course, not all of the measures are appropriate for all areas (e.g., urban or agriculture). Also, the best way to adopt measures for successful implementation depends on the physical, social, cultural, and economic characteristics of a specific place.

I. Policies, regulations, legal requirements
   a. Drought preparedness planning
   b. Water conservation requirements/water waste restrictions
   c. Water rights allocation laws and permits
   d. Plumbing/building regulations for water savings
   e. Water metering requirements
   f. Water conservation pricing
   g. Land use development and water supply requirements
   h. Authority for regulatory enforcement
   i. Process and authority for declaring drought emergency
   j. Emergency assistance program
   k. Interprovincial and interregional coordination systems
   l. Water rights conflict resolution framework

II. Planning for drought
   a. Water reliability planning (long-term supply and demand)
   b. Data analysis for dry-year water supply and demand
   c. Urban water management plans
   d. Agricultural and pasture water management plans
   e. Drought preparedness plans (pre-drought risk management)
      i. Urban plan
      ii. Agriculture plan
      iii. Range and pasture plan
      iv. Defined "trigger" mechanisms (e.g. reservoir levels)
      v. Detailed action program based on triggers
         1. Drought impact mitigation plan (relief services)
         2. Water transfer agreements and mechanisms
         3. Detailed plans for voluntary and mandatory reductions

III. Drought forecasting system, organization, and processes
   a. Drought forecasting system (onset of wet season)
      i. Definition and criteria for drought

- ii. Criteria and methodology: data collection and analysis
- iii. System of precipitation monitoring stations
  1. Snow pack and water content measurement
  2. Precipitation projections
  3. River flow projections
  4. Soil moisture measurement
  5. Reservoir levels
- iv. Incorporation of climate change models

- b. Data exchange system: national, regional, and local agencies
- c. Up-to-date coordination mechanisms
- d. Establishment of drought task force: operations center
- e. Water bank for water transfers and exchanges
- f. Early dry-year warning notification system (during wet season)
  - i. For water supply companies and stakeholders
- g. Public workshops and media
- h. Continuous data monitoring and forecast modification
- i. Continuous update in criteria, data, and models
- j. Technical assistance to local areas for drought forecasting

IV. Nonstructural water savings measures and practices

- a. Water supplier and utility operations
  - i. Water savings program implementation
  - ii. Water conservation coordinator
  - iii. Water system loss reduction
  - iv. On-site water audits and assistance to customers
  - v. Internal building water saving measures
  - vi. Customer water saver incentive programs
  - vii. Enforcement of water waste prohibitions
  - viii. Review of new building design and permit approval
  - ix. Monitoring and reporting of results of measures
- b. Residential water-saving measures
  - i. Ultra-low flush toilets: existing, new housing
  - ii. Low flow faucets and showerheads: existing, new housing
  - iii. High efficiency washing machines: existing, new housing
  - iv. Restrictions on potable water for plants, gardens, and pools
  - v. Water meters for each apartment and house
  - vi. Meter testing, repair, and replacement program
  - vii. Volumetric water pricing
  - viii. Water bills paid by households (not by enterprises)
  - ix. Public information campaigns
  - x. School education programs
  - xi. Customer leak detection and repair
  - xii. Water-efficient design requirements for new buildings
  - xiii. Non-potable water for landscaping (gray water, recycled)
  - xiv. Replacement of water-cooled air conditioning for apartment buildings
  - xv. Special assistance for poor and rural communities

c. Commercial, industrial, and institutional water-saving measures
    i. Industrial process water reduction
    ii. Water-efficient commercial dishwashers
    iii. On-site recycling systems
    iv. High efficiency toilets and urinals
    v. Water-efficient commercial clothes washers
    vi. Cooling tower controllers
    vii. Spray nozzles
    viii. Steamers for medical equipment
    ix. Dry vacuum pumps
    x. High-rise building treatment and recycling systems
    xi. Rooftop storm water collection and filtration
    xii. Water use offset regulations for new buildings
    xiii. Workshops for commercial, industrial, and public sectors
d. Agricultural measures
    i. Delay planting of new permanent crops
    ii. Irrigation management information system
    iii. On-farm assistance to improve irrigation practices, uniform distribution, scheduling, and crop
    iv. Selection and soil monitoring
    v. Financial assistance and incentives
    vi. Crop insurance program
    vii. Land removed from production
    viii. Crop shifting
    ix. Efficient irrigation technologies
    x. Deficit irrigation
    xi. Irrigation recycling and reuse
    xii. Irrigation ditch and seepage reduction improvements
    xiii. Evaluating crop evapo-transpiration rates
    xiv. Workshops for farmers
e. Rangeland and pasture measures
    i. Pre-drought management to protect range condition
        1. Methods to balance livestock with forage
        2. Measures to prevent overgrazing
    ii. Drought management plan
        1. Rainfall predictions and vegetation condition
        2. Monitoring forage production
            a. Changes in forage production and scheduling
        3. Plans and timing for relocation or reduction of herd
            b. Criteria for herd reduction
            c. Emergency feed and water
    iii. Drought vegetation recovery plan of action
    iv. On-site assistance for herders

V. Impact monitoring and mitigation plan

a. Method for monitoring and measuring drought-related impacts

b. Programs for loss mitigation and compensation
    i. Coordinated response framework
    ii. Criteria for technical and financial assistance
        1. Crop losses
        2. Emergency drinking water supplies
        3. Livestock needs
        4. Public health
        5. Conservation assistance
        6. Income, employment, and housing
        7. Food, clothing, health, and schools
        8. Assistance to poor communities

VI. Drought recovery and contingency plan
a. Post-drought evaluation
    i. Updated assessment of damages and losses
b. Replenishment of water supplies
c. Compensation and assistance for social, economic, and resource recovery
d. Planning for another dry year
    i. Lessons learned
    ii. Continued forecasting
    iii. Improved methods
    iv. Increased conservation and efficiency
    v. Diversification of water supplies
        1. Water reuse
        2. Rain/storm water catchments
        3. Groundwater banking
        4. Desalination
        5. Local ponds and storage
    vi. Improved flexibility
        1. Integrated regional management agreements
        2. Increased reservoir operational efficiency
        3. Conjunctive use of ground and surface water

Drying Up
What to do about droughts in the People's Republic of China

Climate change is one of a few major factors that ensure the country will continue to struggle to supply its cities and industries and fields with enough water, particularly in the North, as well as face more frequent and longer droughts. The country has shown a stunningly agile disaster response system, but its system for disaster prevention and management is far less developed. The road to greater drought management and sustainable water supplies is demand management. How to achieve this in a historically hydraulic-engineering society is explored through the case study of Guiyang Municipality in Guizhou Province.

About the Asian Development Bank

ADB's vision is an Asia and Pacific region free of poverty. Its mission is to help its developing member countries reduce poverty and improve the quality of life of their people. Despite the region's many successes, it remains home to two-thirds of the world's poor: 1.8 billion people who live on less than $2 a day, with 903 million struggling on less than $1.25 a day. ADB is committed to reducing poverty through inclusive economic growth, environmentally sustainable growth, and regional integration.

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ISBN 978-92-9092-447-0

Printed on recycled paper

Printed in the Philippines